"BEHAVIOUR STEREOTYPY
AND
TIMING BEHAVIOUR"

by

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CHAPTER I

INTRODUCTION :

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INTRODUCTION

THE RESEARCH PROBLEM

"Just as the problem of action at a distance created conceptual difficulties in philosophical analyses of causation, action delayed over time remains with us to create conceptual difficulties.......In other modalities, such as vision, the question of whether behavior mediates simple discriminations such as the discrimination of intensity does not arise. It is not felt that such sensory processes must have the same dimensions as behavior . In temporal discriminations, however, the temporal gap is there to be bridged, and the analysis of mediating or timing behavior may be regarded as a kind of search for the temporal receptor". (Catania, 1970, p.36).

The research reported in this thesis arose from a review of the literature on timing behaviours in organisms. This revealed that while many experimenters have described behaviour, produced by both animals and humans, where responses have been spaced accurately in time, the empirical results are open to equivocal explanations.

One aspect of timing behaviour which has received little experimental attention is the function, if any, of the stereotyped behaviours which often occur collaterally with accurately spaced responding in time. These stereotyped collateral behaviours have sometimes been termed mediating behaviours because several researchers claim that they mediate accurately spaced responding in time (Kramer and Rilling, 1970, p.234 ff.). A detailed functional analysis of these "mediating" behaviours has not appeared in the literature. This is possibly because the initial appearance of such behaviours is out-

:with the experimenters control and, furthermore, these behaviours are normally peculiar to the individual and therefore difficult to measure quantitively.

The present investigation used a technique which made it likely that a certain behaviour would occur as the stereotyped collateral behaviour, and allowed a degree of quantitive measurement of this behaviour.

It was hoped that investigation of stereotyped collateral behaviours would throw some light on the wider question of how organisms space responses accurately in time.

OPERANT CONDITIONING

Operant, or instrumental, conditioning is the name applied to one of "the basic procedures and techniques that are the essential features of modern behaviorism". (Rachlin, 1970, p.60).

As a technique, operant conditioning implies the control exercised by an experimenter over the occurrence of an operant, or class of behaviour, when contingencies are set up between instances of that operant and the occurrence of reinforcers (or rewards).

Reinforcement may be either positive, usually delivery of food or water to an animal appropriately deprived, or negative, which involves the removal of aversive events, such as an electric shock. Whether or not an event is a reinforcer is a purely empirical question, to be determined by making the occurrence of a supposed reinforcing event contingent on the emission of a response (an instance of the operant). If the response increases in probability as a result of this procedure then the event, or stimulus, can be deemed a reinforcer for that response.

Typically operant conditioning experiments are characterized by a fairly high degree of environmental control. The use of automated equipment increases this control. Experimental sessions are normally run within a small experimental space (Skinner box) in which noise, light and temperature levels are controlled. The manipulanda upon which the subject responds vary according to species. The two most common are a small lever which rats can depress with their fore feet, or a circular disk or key which pigeons can peck. Responses are normally reinforced by delivery of a food pellet for rats, or several seconds access to a grain hopper for pigeons.

Within operant conditioning there are several types of procedure characterized by the degree of constraint imposed, by the experimenter, on the occurrence of a response. The procedure in use throughout this investigation can be described as a free operant procedure.

The manipulandum, a lever, was available to the subjects (rats) throughout each session. The response consisted of a downward pressure on the lever equal to, or greater than, a specified amount. In fact the response required little effort and was usually of very short duration with none of the complications of refractory periods associated with some responses. In effect, the rats could respond at any time and at a wide range of rates for long periods of time. This was of course an advantage, since the experiments involved the temporal spacing of responses.

With other types of operant conditioning procedures responding cannot be free in this sense. For example, runway procedures in which the experimenter has to remove the subject from the apparatus after each (extended) response would not have been suitable for the experiments reported in this thesis.

The spacing of free operant responses in time, so that the intervals between responses conform to some criterion, can be readily achieved using the differential reinforcement of low rates (DRL) schedule. Under DRL schedules a response is reinforced only if a specified time has elapsed since the preceding response. Like reinforced responses, premature responses reset the timer which times the specified interval, otherwise they are ineffective. Under appropriate conditions most species exposed to this schedule of reinforcement space their responses in a regular way to meet the temporal requirements of the schedule. Characteristically, stereotyped behaviours occur collaterally with the spaced responding required by the DRL schedule.

"TIME" IN EXPERIMENTAL PSYCHOLOGY

This investigation looked at two "timing behaviours". These were:- (a) rat lever press responses which were so spaced in time that they frequently fulfilled the requirements of the DRL schedule in operation, and (b) stereotyped collateral behaviours which have been observed to occur between instances of such spaced responding. To call (a) "timing behaviour" is to describe it. To call (b) "timing behaviour" is to explain it's function. While descriptions of behaviour occur frequently in experimental analyses of behaviour, explanations occur less frequently.

Explanations of the timing behaviour described in (a) have been presented by several reviewers. Catania (1970) stated that, "the DRL schedule (is) a schedule in which temporal discriminations may develop based on the time since the preceding response" (p.6). This represents a theoretical position taken by many of the reviewers of timing behaviour (Harzem, 1969, p.300; Staddon, 1972, p.217). These reviewers of timing behaviour in animals imply that some form of discrimination of temporal variables is involved in successful animal timing behaviour. There is a "retreat into the organism" where some judgement is made, similar in kind to a sensory discrimination. Why is this view so widely held and is it the most parsimonious explanation of the available data?

To answer these questions it is necessary to look briefly at the status of the term "time", in both experimental psychology in general and the experimental analysis of behaviour in particular.

Ornstein (1969) summarised the four modes of time experience which experimental (human) psychology has studied:

"1. The present, short term time.
    (a) The 'perception' of short intervals.
    (b) Rythm or timing.
2. Duration, the past, long-term memory.
3. Temporal perspective - philosophical, social, cultural constructions of the world and their effects on the interpretation of time experience. 'Becoming', the future.
4. Simultaneity and succession" (p.23).

Categories 1 and 4 are the fields of cognitive psychologists interested in short term memory (Neisser, 1967) and of psychologists interested in the aspects of perception relating to rythm (Fraisse, 1956; Loehlin, 1959;) or causality (Bergson, 1920 Michotte 1963). The third category encompasses the cross-cultural studies of Nakamura (1966) and the large eclectic surveys of time research (Frazer, 1966; Doob, 1971).

The second category is the one which concerned Ornstein and to which his research was directed. He concludes that research into the experience of duration has relied for its methodology almost entirely on the psychophysical approach, assuming that there is either a "biological clock" which regulates experience or an "organ" of time which discriminates some hypothesised "real" time.

"In linking particular theoretical approaches with modes of time experience we found that (a) major reason for the confusion in time experience was that time had been considered as if it were a sensory process such as hearing. This type of analysis would presuppose external time stimuli, existing independently of ourselves as do sound waves, which would be apprehended by an organ of sensation, like the ear. Many have looked for such a 'time base' in an internal organ of time experience........Almost everything possible has been considered as the 'clock' or 'chronometer', the heart, the cerebellum, pacemakers in the brain, the respiration cycle, the Weber fraction for taste, cellular metabolic rate, etc. If all these could be the 'clock' then the concept of the 'clock' could have no meaning. There is no consistent identification of the 'clock' in any one of these processes, and no real way that an 'inner clock' would relate to time experience" (Ornstein, 1969, pp. 102 - 103).

In a series of elegant studies, Ornstein (1969) has shown that the concept of "storage size" is a useful analogy in explanations of duration experience. The storage size refers to the "space" that information "consciously" received during an interval occupies in some hypothesised "input register". He demonstrated that human experience of duration lengthened as a function of the stimulus complexity and number of stimuli "in storage" during an interval. The interested reader is referred to Ornstein's book for greater detail. Even this brief precis of Ornstein's results illustrates the cognitive nature of his explanation of human time experience. Unfortunately, the type of experiment he conducted is not possible with non-human subjects, but perhaps his conclusions on the methodology of previous experiments in this field should be noted when explanations for animal timing behaviour are being discussed.

Just as it has been assumed that the methodology appropriate to the psychophysical studies of the human senses is also appropriate to the study of human temporal experience, so psychophysical methods have long been employed in studies of animal timing behaviour (Behar, 1963;

Cowles and Finan, 1941; Heron, 1949; Reynolds and Catania, 1962; Stubbs, 1968; Woodrow, 1928). Catania (1970) has said:- "The development of a technology that allows psychophysical studies to be conducted with animals has demanded that the contingencies involved in psychophysical judgements be made explicit (Blough, 1958). This advantage of animal psychophysical procedures may be expected to hold for the psychophysics of time as it has for the psychophysics of sensory modalities". (p.27).

However, there are big differences between animal psychophysical experiments (Stebbins, 1970), and human psychophysical experiments. Human subjects are given brief verbal instructions and normally this is sufficient to produce the required topographical response. "It is not at all clear whether animals can behave in such a way and even less clear is the kind of training procedure that might be equivalent to the brief verbal instructions given to the human observer. The latter's competence may depend on a long history of various kinds of training and getting an animal to display a similar type of behaviour may require a similar extended training procedure." (Boakes, 1969, p.358).

Boakes' remarks preface a discussion on response continuity in animal psychophysical experiments. Unlike the human situation, the animal does not produce a newly acquired behaviour in an unfamiliar test environment over at most a few sessions. The animal has to be trained, and, in exposing the desired response to the contingencies of reinforcement, other, non-recorded, behaviours are similarly exposed. When successful "discrimination" is demonstrated these established non-recorded behaviours are rarely mentioned and if they are they are dismissed as being irrelevant. This view is most clearly illustrated by Catania (1970):-

"In all cases of temporal discrimination, it is possible to appeal to mediation by discrimination of response properties or of environmental events. The demonstration or analysis of such mediation, however, is concerned with the mechanisms that may underlie a particular temporal discrimination and should not be substituted for an analysis of the properties of the temporal discrimination itself. The relationship is analogous to that in the study of sensory discriminations: for example, an analysis of the physiology of vision may clarify some aspects of visual discrimination, but the physiological mechanisms do not replace behavioral data that demonstrate the properties of visual discrimination" (p. 7).

It will be noticed in the above extract that the latter argument-by-analogy depends crucially on the premise that the appeal in all cases of temporal discrimination can be "mediation by discrimination of response properties or of environmental events". Catania's statement presupposes that the process involved in timing behaviour is temporal discrimination.

Catania's introduction could be rephrased in a less hypothetical manner:- "the appeal in all cases of timing behaviour can be to mediation by response properties or environmental events". When phrased like this, the case for analysing the function of such "mediational" variables is strengthened.

The acceptance of the definition of time, "as a single property of a stimulus, comparable with intensity, wavelength, etc....."(Skinner, 1938, p.269) has a long history, both within human experimental psychology, and the experimental analysis of behaviour. Recent research has questioned it's usefulness in human experimental psychology. This investigation of stereotyped collateral behaviour arose from the idea that possibly the "discrimination" explanation for timing behaviour is not necessarily the only one, and that other, alternative, explanations might fit the available data.

SUMMARY

This introductory chapter is primarily intended to outline the direction of the research. The research problem was identified as an investigation of the stereotyped collateral behaviour which often occurs with accurately spaced responding in time. Some advantages of using a free operant as the basic behavioural datum in investigating the spacing of responses in time were emphasised in a discussion of operant conditioning as an experimental technique.

Finally some of the ways the term "time" has been used in experimental psychology were reviewed. In particular the reader's attention was drawn to the consistency with which time is conceptualised as a property of a stimulus, (similar in kind to intensity or wavelength) which can be "discriminated" by organisms. It was concluded that particularly for non-human subjects, there might be alternative explanations of timing behaviour which would equally well accommodate the available data.

CHAPTER II

LITERATURE REVIEW :

CHAPTER II

LITERATURE REVIEW

INTRODUCTION

The following literature review is divided into two sections. The first section is a selective review of the literature on the differential reinforcement of low rates (DRL) schedule of reinforcement. Each subsection deals with either a characteristic of the typical behaviour reported under this schedule, or with the effect of some experimental manipulation upon that behaviour. The first section concludes with a review of the theoretical interpretations of the development and maintenance of DRL schedule performance which have appeared in the literature.

The second section is a selective review of the literature on the stereotyped collateral behaviours which, it has been suggested, mediate correctly spaced responding on the DRL schedule. The second section concludes with a review of the explanations for the occurrence of these stereotyped collateral behaviours.

DRL Schedule of Reinforcement: DEFINITION

In it's simplest form, the DRL schedule of reinforcement requires that reinforcement be contingent upon responses which occur "t" seconds or more after the previous response. The time between these two responses is called the interresponse time (IRT). Responses which occur less than "t" seconds after the previous response are not reinforced. All responses reset the timing equipment which times the duration of the IRT.

BASIC CHARACTERISTICS OF DRL SCHEDULE PERFORMANCE

Response Rate and Efficiency: Species Differences

The first experimenter to describe the differential reinforcement of low rates was Skinner (1938), who added a DRL contingency to a fixed interval (FI)* 7 minute schedule. Using the stable behaviour of a rat on this schedule as a baseline he introduced the contingency that no response would be reinforced unless it had occured at least 15 sec. after the preceding response. The result was a decline in response rate from approximately 12 responses per minute (averaged across the interval) to about 1 response per minute, after 75 minutes exposure to this contingency (Skinner, 1938, p.161).

The first published report of performance on a simple DRL schedule of reinforcement was given by Wilson and Keller (1953) who established that the rate of responding on a DRL schedule is inversely related to the duration of the minimum interval required between two responses before the second response is reinforced. This interval will be referred to as the criterion IRT. Wilson and Keller exposed rats successively to criterion IRTs of 10, 15, 20, 25 and 30 sec. As the criterion IRT increased, (a) the rate of lever press responding decreased in a linear manner over the range of intervals used, (b) the median time between successive lever press responses increased for each animal, and (c) the number of reinforcements decreased.

That a particular DRL schedule can control rate of responding was demonstrated by Zimmerman and Schuster (1962) in whose experiment two different/

Footnote:- *The schedule terms used in this thesis are defined and explained in the glossary:
See Appendices.

different DRL schedules alternated. Rats were run on a multiple DRL schedule which consisted of one DRL 36 sec. component (that is the criterion IRT was 36 secs.) and one DRL 18 sec. component, with a time out period of 3 minutes preceding each component. During the time out (TO) period lever press responses were not reinforced. Each component was accompanied by a different discriminative stimulus. The subjects developed two, different, stable rates of lever press responding. The higher response rate was associated with the DRL 18 sec component. The experimental procedure was such that equal reinforcements, and equal reinforcement opportunity, were obtained in each DRL component.

In absolute terms, however, there are great differences in rates controlled by a DRL schedule, depending on which species is used as experimental subject. One sensitive measure of DRL performance is the efficiency ratio which is calculated by dividing the number of reinforced responses by the total number of responses in a session. Rats consistently perform efficiently (that is a high efficiency ratio is obtained), whereas pigeons typically produce very inefficient behaviour. The efficiency ratio is normally expressed as a percentage of responses reinforced, typical percentages for rats lie between 55% and 75% (Conrad, Sidman and Herrnstein, 1958; Laties, Weiss, Clark and Reynolds, 1965; Malott and Cumming, 1966; Wilson and Keller, 1953). Primates usually perform better than rats giving percentages ranging from 70% and 90% (Hodos, Ross and Brady, 1962; Weiss, Laties, Segal and Goldstein, 1966). The most efficient performance is seen in humans where very high efficiency can be observed (Bruner and Revusky 1961, Carter and McGrady, 1966; Kapostins, 1963). Most of these experiments use criterion IRT in the range 0 - 60 secs.

Efficiency is much lower in DRL experiments with pigeons as subjects, where the required response is a keypeck. Typical percentages of responding reinforced are 2% or less (Kramer and Rilling, 1969; Holz and Azrin, 1963; Staddon, 1965). Hemmes (1970) has concluded that the pigeons inefficiency on DRL schedules is dependent on the nature of the operant response. Noting that all previous studies with pigeons had employed the key-pecking response Hemmes used a treadle response and reported between 20% and 25% efficiency on DRL 20 sec. schedule. Topping, Pickering and Jackson (1971) reported a similar increase in efficiency when response effort, the minimum force required to operate the key, was increased from 15 gms. to 45 gms. The efficiency of the key peck response increased from under 1% to 20%. Topping et al. conclude that "the present results support Hemmes' (1970) conclusion that DRL performance is a function of the nature of the operant and emphasise the importance of non-temporal factors on spaced responding schedules".

Current theoretical writings (Staddon and Simmelhag, 1971; Staddon, 1972) and research on "autoshaping" (Brown and Jenkins, 1968; Gamzu and Williams, 1971) suggest that there are species specific factors which "predispose" the pigeon to peck salient objects in a situation where food is presented intermittently. One might conclude therefore that as far as DRL research is concerned, the pigeon may be a less than ideal subject. However the high rate of key pecking evidenced by pigeons on DRL schedules gave very interesting results in an experiment by Reynolds (1966). In Reynolds' experiment a peck on one key initiated the interval and a peck on a second key terminated it. If the interval between the two pecks was greater than 18 sec., further responding on the second key was reinforced on a variable interval (VI) 1 minute schedule. Reynolds found that while the interval between pecks on the two keys rarely exceeded 18 secs. the rate of pecking on the second key (under the VI contingency) was an increasing function of the length of the preceding interval. This finding is interesting because the pecking on the second key may reflect a discrimination of the preceding interval. However the 18 sec. delay requirement was rarely met so the amount of reinforcement, the number of times pecking on the second key was reinforced on a VI 1 min. schedule, was small. Explanations of the Reynolds' (1966) results must take into account that while a discrimination appears to have been formed, the absolute number of times reinforcement occurred was small.

An experiment by Richardson (1973) illustrates all the above points. Richardson pointed out that "a low response rate alone is not proof of the effectiveness of the DRL reinforcement contingency. In order to state that the reinforcement contingency of the DRL schedule *per se* produces a low rate of responding it is necessary to compare the response rate maintained by a specific value of the DRL schedule with a second schedule that differs from the DRL schedule only by not specifying the differential reinforcement of IRTs". In Richardson's experiment pigeons and rats were used in a yoke control design that equated the reinforcement distributions of DRL and VI schedules. Both a between subjects design and a within subjects design found response rate higher for the VI schedule than for the DRL schedule, thus demonstrating the effectiveness of the DRL contingency. Furthermore rats had a much higher proportion of their DRL responses reinforced than did the pigeons.

Interresponse-time Distributions

A commonly used method for analysing DRL performance is the relative frequency distribution of interresponse times (IRTs). Typically the distribution is bi-modal with one mode occurring at, or about, the criterion IRT value and the other mode occurring in the very short (0 - 3 secs) IRT range,(Sidman, 1955; Laties, Weiss and Weiss,1969). Sidman (1956) drew attention to the similarity between the distribution round the criterion IRT value, and the normal generalization gradients seen in conventional discrimination training (Sidman, 1956; Guttman and Kalish, 1956) However, the similarity may be only superficial.

In conventional discrimination training the subject is trained to one or two values. During training, discrete values of the stimulus are presented and similarly discrete values are used in testing. DRL training however cannot be viewed in this way. Each IRT is compounded of many smaller "IRTs". In other words,along the only continuum which could be discriminated,that is time or duration, the stimuli presented are not discrete. Furthermore in DRL schedules, unlike discrimination training, the "value" of a stimulus is determined by the subject's behaviour.

For these reasons the analogy between IRT distributions on DRL schedules and the typical generalization curves obtained from discrimination experiments is unclear and consequently of dubious value.

Research on the shape of the distribution of responses round the criterion IRT has been confined to work on the decline in the absolute frequency of IRTs longer than the criterion IRT. Zimmerman (1961) controlled the length of the inter-reinforcement interval to see what effect changes in rate of reinforcement would have on timing behaviour. Using a modified, discrete trial, DRL procedure, as opposed to the free operant DRL procedure, Zimmerman showed that overall rate of reinforcement was an important variable in the control of temporally spaced responding. He recorded the time from onset of trial to lever press response and found a mode in the distribution of such times just above the criterion time. This mode was not as pronounced a mode as that associated with

DRL schedule IRT distributions. However from his results Zimmerman concludes "some factor or factors beside the rate of reinforcement must account for the subject's great tendency to respond shortly after a reinforcement is set up".

Most reports of DRL performance describe relatively high frequencies of short (0 - 3 sec.) IRTs, These usually represent response "bursts" (a sequence of rapid responding). The cause and function of such response "bursts" are still in dispute.

The literature on this subject is comprehensively reviewed by Harzem (1969) and Kramer and Rilling (1970). Since that time further research on this topic has been presented by Lowe and Harzem (1973).

There appears to be a relationship between response "bursts" and the length of the preceding IRT. Kramer and Rilling (1969) using pigeons as subjects, found that frequency of response "bursts" decreased as response rate increased. This supports the findings of Ferraro et al. (1965), using rats as subjects, who support Sidman (1956) in finding that the frequency of "bursts" decreased as the modal IRT, and therefore the response rate, decreased.

In the light of the known differences between DRL responding in rats and pigeons further research as to the function, if any, of response "bursts" should prove rewarding.

One recent report by Lowe and Harzem (1973) suggests that control of response "bursts" may lie in the discriminative effects of reinforcement. This supports the observation by Holz and Azrin (1963) which attributes the source of these short IRTs to the non-reinforced prior IRT.

Studies of the sequential dependencies of IRTs in DRL schedules have highlighted the fact that reinforced IRTs tend to occur after reinforced IRTs (Farmer and Schoenfeld, 1964; Ferraro et al, 1965; Weiss, Laties, Siegal and Goldstein, 1966). This has led researchers to suggest that stimuli occurring as a consequence of reinforcement may come to act as discriminative stimuli for reinforced responding (Farmer and Schoenfeld, 1964; Reynolds, 1964; Carter and Bruno 1968). Lowe and Harzem (1973), using a two value DRL have shown the rigidity of DRL behaviour. Their schedule contingencies were such that following a reinforced response, criterion IRT value (1) was in force. Should the next response fail to meet this criterion, IRT value (2) came into operation. In one interesting condition of their experiment IRT value (2) was half the duration of IRT value (1) (10 sec.and 20 sec.). The optimum strategy in this situation would be to produce a short IRT or "burst" immediately following a reinforced response thus keeping the shorter criterion value in force. However Lowe and Harzem's results showed the complete opposite. Most, if not all "bursts" occurred after unreinforced IRTs and by far the most time was spent in criterion value (1) or the longer contingency. Lowe and Harzem claim this behaviour illustrates the discriminative effect of reinforcement.

EXPERIMENTAL MANIPULATION OF DRL BASELINE

This section of the review deals very briefly with the salient effects of several experimental manipulations. Again, for a more detailed review the interested reader is referred to Harzem (1969) and Kramer and Rilling (1970).

Amount of Deprivation

Using rats and monkeys, Conrad et al (1958) reported: "In all cases the major effect upon performance of manipulating deprivation in the DRL situation was observed to occur only after short deprivation or when the animals were near satiation" (p. 64) Deprivation of food for less than 20 hours produced a lowered response rate but from 20 - 70 hours deprivation appeared to have little effect in altering the normal (23 hrs. deprivation) DRL behaviour .

Similar findings for pigeons were reported by Holz and Azrin (1963) and Reynolds (1964).

Magnitude of Reinforcement

Beer and Trumble (1965) showed that for rats (1) increasing magnitude of reinforcement decreased the mean IRT; (2) the efficiency ratio decreased linearly with increases in magnitude of reinforcement (3) Measures of response variability (not described) indicated that responding was least variable with the largest amount of reinforcement (4 pellets) and most variable with the smallest amount of reinforcement (1 pellet). (4) These effects were clearest when more than one magnitude of reinforcement was presented during each session. Kramer and Rilling (1970) conclude, "the combined results of experiments on deprivation and magnitude of reinforcement suggest that increasing the 'motivation' for food increases the rate of responding. This is quite interesting since increasing rate of responding usually leads to a decrease in frequency of reinforcement on the DRL schedule".

However the Lowe and Harzem (1973) results discussed earlier suggest that a re-appraisal of the Beer and Trumble (1965) results might be in order. Beer and Trumble did not present any IRT distribution data and it could be the case that the greater the magnitude of the reinforcer the greater the probability of a "burst" following a non-reinforced response. This would of necessity decrease the average IRT . The ambiguous nature of the presented data detracts from this study.

Extinction

Extinction refers to the procedure by which previously reinforced responding is no longer reinforced. The data from extinction experiments on behaviour previously maintained by a DRL schedule seem to support the discrimination of reinforcement view. Where the efficiency of responding in terms of total number of responses reinforced is greater than 50% extinction produces a rapid reduction in responding (Ferraro et al.,1965; Carter and Bruno,1968; Laties et al.,1965; Laties et al.,1969) In cases, usually pigeons where the efficiency percentage is much lower than 50%; reduction of responding in extinction is slower. Kramer and Rilling(1970) point out that: "This is reminiscent of the partial reinforcement effect (Deese and Hulse, 1967). These data might suggest that the omission of reinforcement, particularly where the ratio of reinforcements is high, serves as a discriminative cue for not responding. They might also suggest that the omission of reinforcement eliminates the discriminative stimulus for further responding".

Aversive Stimulation

Two experimental manipulations using aversive stimulation are considered here; the first is punishment of DRL behaviour and the second is the effect of an Estes-Skinner (1941) procedure on a DRL baseline.

The normal effect of response contingent aversive stimuli (electric shock, for example) on behaviour maintained by schedules of positive reinforcement is to reduce the probability of the punished response. Holz, Azrin and Ulrich (1963) showed that this held true for DRL behaviour despite the fact that a drop in response rate in normal DRL performance usually means an increase in reinforcement frequency. There is a decline in the number of "bursts", or short IRTs, and an increase in longer IRTs. It might be expected that the facilitatory effect of increased reinforcement frequency would require a higher intensity of shock for DRL than for other positive reinforcement schedules. Holz et al. comment that: "It appears that a given punishment intensity remains equally effective regardless of whether punishment increases or decreases the frequency of reinforcement". As in the case of magnitude of reinforcement this seems to strengthen the view that reinforcement and punishment act on the probability of the response and not on the probability of certain IRTs terminated by these responses.

The effect of the second experimental manipulation, the Estes-Skinner (1941) procedure, on a DRL behaviour baseline is still largely undetermined. In the Estes-Skinner procedure a stimulus terminating in an unavoidable electric shock is superimposed on the schedule behaviour. The effect of this on most schedule behaviour maintained by positive reinforcement is to suppress the response rate while the stimulus is being presented. This has been termed conditioned suppression (Lyon, 1968), or conditioned emotional response (CER: Watson and Raynor 1920; Hunt and Brady, 1951).

As Blackman and Scruton (1973) have pointed out, "when the Estes-Skinner procedure is superimposed on the behaviour maintained by schedules that differentially reinforce low rates of responding (DRL), the results have been equivocal. Leaf and Muller (1964) found that DRL responding was suppressed during a pre-shock stimulus, but Finnochio(1963) and Blackman (1968) reported an acceleration of DRL responding in certain conditions". The results are so contradictory that Blackman and Scruton (1973) have suggested that the factor controlling response suppression or facilitation may be the disruption of the other behaviour, occurring between responses, by the pre-shock stimulus. Their report is discussed in the section of the review concerned with studies of such collateral behaviours.

Effect of the Amphetamine drug group on DRL performance

While there have been comprehensive studies of different drug effects on DRL performance, (Dews and Morse, 1961; Kelleher and Cook, 1959), most research has been directed at the effect of amphetamine on DRL performance.

McKearney (1972) and Wuttke and Innis (1972) have recently summarised the effects of the amphetamines on schedule maintained behaviour. They conclude that the evidence supports the Kelleher and Morse (1968) contention that the baseline rate of responding on a schedule is of overwhelming importance in determining the effect of drugs on that behaviour.

Segal (1962) pointed out that the DRL schedule is of interest as a baseline for drug effect studies for two reasons. The first is that the typical bimodal distribution allows differential drug effects on IRTs of different lengths to be seen clearly, and second, disruption of DRL performance by the drug may give some clue as to the factors controlling DRL behaviour.

The typical effect of amphetamines is to increase the response rate by displacing the whole IRT distribution in the direction of short IRTs (d-amphetamine, Kelleher and Cook 1959; Dews and Morse 1958; dl-amphetamine: Segal, 1962; Schuster and Zimmerman 1961). The reports agree that while the probability of short IRTs increases greatly there is some measure of temporal discrimination (in the sense of a second reduced mode at a point further along the IRT distribution).

Segal (1962) suggests that analysis of this distribution change in terms of interruption of some "mediating" or collateral behaviour are incorrect, "the main effect of the drug was apparantly a motor excitatory one, and not a specific disruption of some internal timing mechanism......

To the extent that overt behavior mediates timing behavior, then amphetamine may be said to disrupt temporal discrimination. But this is a secondary effect, produced not by interference with an internal timing mechanism, but rather by increasing the rate of emission of all overt behavior".

EXPLANATIONS OF THE MAINTENANCE OF DRL PERFORMANCE

In his examination of temporal processes in schedules and in particular DRL schedules Catania (1970) distinguished between three types of behavioural effects. These were the dynamic, the differentiating and the discriminative effects of reinforcement schedules. Between them these three effects cover most of the explanations of DRL responding to date.

Dynamic Effects

While discussing Skinner's (1938) claim that some apparent temporal discriminations are in fact demonstrating a "differential response to time", Morse (1966 P.87) cites two examples of the dynamic processes within schedules. These are the relation between rate of responding and frequency of reinforcement, and the effect of a time delay between a response and the presentation of a reinforcer.

Catania (1970) discusses the effect of the two processes in DRL responding observing that, "in a DRL schedule......reinforcement depends on a minimum spacing of responses in time; as the rate of responding increases beyond a point at which responses are sufficiently spaced, the rate of reinforcement decreases.......The rate of reinforcement may alter the rate of responding, but the rate of responding then alters the rate of reinforcement in turn. The outcome may be a complex equilibrium between theseeffects" (p.4)

He goes on to say that "delayed reinforcement may be examined directly by reinforcing a response after specified period of time. During the delay period no other response of this kind may be emitted (Dews,1960). The DRL schedule, in which the order of the response and the period of delay is reversed, also places constraints on the way in which delayed reinforcement can vary. Responses that are sufficiently spaced in time are immediately reinforced, but the reinforcement cannot have retroactive effects on earlier responses with delays less than the spacing of responses specified by the schedule. Reinforcement can act with shorter delays only on behavior other than the responses for which reinforcement is scheduled". (p.6).

This last point has led Willoughby (1971) to suggest that reinforcement also acts to strengthen the collateral behaviour or the "other behaviour", though at a delay (p.3).

The concept of delay of reinforcement as a dynamic process in reinforcement schedules is in the present author's opinion a description masquerading as an explanation. The analyses of delayed reinforcement by Dews (1962, 1965, 1966a, 1966b) and Jenkins (1970) have led Staddon (1972) in considering the Relative Proximity Principle (Jenkins 1970; Staddon 1972) to conclude: "The later a response occurs within an interval, the better it's proximity to reinforcement relative to responses which occur at other times. It is tempting to try to quantify this idea in the form of a mathematical model, which can then be subjected to experimental tests. However,......there havebeen a number of attempts to do this for relative frequency, and the case is still open. Consequently, the approach being adopted (here) is rather to accept the quantitative nature of the principle, and attempt to derive existing experimental results from it." (p.222).

It may in fact be the case that the term "dynamic effect" is merely a descriptive term under which differentiating and/or discriminative effects of schedules are subsumed, but not explicitly stated because empirical evidence is lacking.

Differentiation Effects

Explanations of DRL responding in terms of differential reinforcement of different length IRTs stem from Morse's (1966) redefinition of the term IRT. He said that in his analyses of schedules in terms of interresponse time, "Anger's (1954; 1956) term, interresponse time (IRT), will be used with the following modification. The elapsed time between the initiation of the response (RN-1) and the next response (RN) will be considered as a measurable property of the response RN and called it's interresponse time. Thus, reinforcement can be made contingent upon a response having an IRT exceeding some given duration, just as reinforcement can be made contingent upon the topography or intensity of a response." (p.67). Morse, therefore, wishes to claim that "the time preceding the emission of a response (it's latency or interresponse time) is a measurable and conditionable aspect of that response" P.67.

In this formulation DRL responding is the result of differential reinforcement of IRTs greater than a criterion length, which, resulting as it does in a low rate of responding, has been misleadingly termed the differential reinforcement of low rates schedule. As noted by Morse (1966 P.93) this may, in certain cases, be a misnomer because it is a feature of some subject's DRL behaviour that the DRL schedule produces "bursts" or periods of high rate responding (see page 93). Morse suggests that: "In view of the complexity of the behavior produced by schedules, it is probably an advantage for schedule names not to designate the expected behavioral results". (P.93) However the term DRL is now firmly entrenched in the literature and altering terminology in the interests of accuracy might cause unwarranted confusion.

Discrimination Effects

In the performance of the DRL schedule Catania (1970) claims that "a temporal discrimination is demonstrated when the probability of a response at one time since the last response is higher than the probability at another time by virtue of the correlation between reinforcement and the time since the last response". (P.12).

However he then goes on to show that as far as DRL performance is concerned, it makes no difference whether the performance is described as temporal discrimination or as temporal differentiation because empirically the two cannot be distinguished in this situation. In making this very important point (P.13) Catania suggests that:"The relationship is discussed as temporal differentiation or as temporal discrimination depending on whether the response properties or the environmental properties are emphasized".

The situation is further complicated by Staddon's (1972) observation that "on spaced responding schedules, temporal control of each response by the preceding response may be inferred - although in this case control (as distinct from mere temporal regularity) is hard to demonstrate, because responses cannot be directly manipulated by the experimenter". (p.213 - 214) Temporal control is a recent theoretical term employed by Staddon to describe the following relationship:- "Event A (a stimulus) occurs at a certain point in time and can be shown to determine the occurrence of Event B (a response) which occurs at a later point in time". It remains to be seen how useful this new term will be. In the first quote from Staddon (1972) he mentions "temporal regularity" but does not explain it's use.

Stereotyped Collateral Behaviour on Schedules of Reinforcement

The two main terms used in the literature to discuss the non-prescribed stereotyped behaviour in DRL performance are "collateral" and "mediating" behaviour.

Mediating behaviour is usually used in the sense defined by Ferster and Skinner (1957). "Behavior occurring between two instances of the response being studied.........which is used by the organism as a controlling stimulus in subsequent behavior " (p.729). The phrase "used by the organism as a controlling stimulus in", is another instance of the discrimination formulation already alluded to in the introduction. The phrase "which controls" could easily be substituted for it, and the objectivity of the whole statement would increase.

The term stereotyped collateral behaviour is a useful term in that there are no causational overtones, it merely describes stereotyped behaviour occurring collaterally with prescribed DRL behaviour.

It is important to note that stereotyped collateral behaviour has been reported with a variety of schedules of reinforcement. Jetter, Lindsley and Wohlwill (1953) describe stereotyped bowing, licking and barking emitted by dogs on a VI 1 min. schedule. Thomas (1971) reported stereotyped collateral gnawing of the floor bars by a rat on a FI 217 sec. schedule. The stereotyped collateral behaviour occurred in post-reinforcement pauses of considerable length (200 + secs.). Both Catania and Cutts (1963) and Laties and Weiss (1963) reported stereotyped collateral behaviours in humans, the first responding on a VI 30 sec. schedule, the second on a FI 100 sec, LH 10 sec. schedule.

There is, of course, a whole body of literature on stereotyped collateral behaviours which have been termed schedule induced or adjunctive behaviours. These have been ably reviewed by Falk (1972) who defined adjunctive behaviours as "behavior maintained at a high probability by stimuli whose reinforcing properties in the situation are derived primarily as a function of schedule parameters governing the availability of another class of reinforcers". (p.172) DRL stereotyped collateral behaviours clearly fall within this definition.

However, Falk (1972) has clearly ruled out the mediational hypothesis as interpreting the function of all adjunctive behaviours (p.169). He is concerned with a more universal interpretation of this behaviour which he has observed "filling-in" periods of non-prescribed responding.

Periods of "non- responding" when the subject is emitting other behaviours have differing effects with different schedules. On FI or VI schedules periods of such "non-responding" have no effect on reinforcement unless they occur after the interval has timed out but before the reinforced response. In this case they would reduce reinforcement frequency. On FR or VR schedules periods of "non-responding" have a detrimental effect on reinforcement frequency. On these schedules any break or slowing down in responding reduces reinforcement frequency. Periods of "non-responding" are of course necessary for reinforcement to occur at all on the DRL schedules of reinforcement.

Periods of "non-responding", when stereotyped collateral behaviours normally occur, have therefore, different consequences depending which schedule of reinforcement is in operation. The possible factors which might maintain collateral behaviour are numerous and may differ between schedules.

For these reasons this study is limited to the stereotyped collateral behaviour occurring on DRL schedules. Relevant reports from the adjunctive behaviour literature will be used in discussion, but the broader topic of this behaviour in other schedules will not be included.

It is the relevance of stereotyped collateral behaviour to timing behaviour which is the subject of this thesis rather than the much larger topic of their development and maintenance in schedules of reinforcement in general.

STEREOTYPED COLLATERAL BEHAVIOURS ON DRL SCHEDULES

In the first study of the DRL schedule requirements Wilson and Keller (1953) noted that their subjects (rats) each developed an individual pattern or "chain" of stereotyped collateral behaviour between bar press responses.

"In the apparatus used, this behavior may be grooming, going to the water bottle, going to the food cup slot in the rear of the cage, or climbing on the back of the cage. If this behavior occupies a temporal span greater than the delay interval necessary for reinforcement, a bar press following this chain is reinforced. This reinforcement serves to strengthen not only bar pressing but also that collateral behavior which preceded the bar press. Thus when bar pressing has been weakened by extinction, the collateral behavior which has preceded prior reinforced bar presses has a slight differential in strength over other possible behaviors and if it occurs and occupies enought time, it will be followed by a reinforced bar press. The strength of this collateral behavior is maintained through conditioned reinforcers provided by the stimulation attending the responses which make up a crude chain of behavior."(p 193).

In this first report of stereotyped collateral behaviour on DRL Wilson and Keller, although lacking quantitive support, are making two important claims. First that the behaviour is necessary for efficient DRL responding and second that the behaviour is chained together using the secondary reinforcer/discriminative stimulus formulation (Kelleher 1966).

The subsequent literature on stereotyped collateral behaviour, including this thesis, is an attempt to answer the questions implied in Wilson and Keller's statements: (1) is collateral behaviour necessary for efficient DRL performance? (2) what is the functional relationship between collateral behaviour and the other behaviour and environmental events involved in the DRL schedule of reinforcement?

There have been many reports confirming Wilson and Keller's original observation of stereotyped collateral behaviour on DRL schedules. The behaviours reported include, excessive drinking (Segal and Holloway 1963), tail nibbling (Laties et al, 1965), wood gnawing (Laties et al, 1969), gnawing grid floor (Meckner and Latranyi, 1963; Blackman, 1968), responding on irrelevant manipulanda within the experimental space (Nevin and Berryman, 1963).

In two reports (Kapostins, 1963; Bruner and Revusky, 1961) stereotyped collateral behaviour is reported in human subjects on a DRL schedule. These reports are interesting because verbal reports after the completion of the experiment indicated that the subjects were not aware of the reinforcement contingencies. In the Bruner and Revusky study, schoolboys were required to press a key on a DRL 8.2 sec. schedule. Three irrelevant keys were also present and each subject developed a characteristic pattern of responses on the three keys. Post experimental interviews ascertained that each subject believed that reinforcement could be obtained only by a pattern of responses on at least one of the other keys prior to pressing the reinforced key.

There are three reports of DRL performance in the literature which specifically mention that stereotyped collateral behaviour was not present (Anger, 1956; Kelleher, Fry and Cook 1959; Belleville, Rohles, Grunzke and Clark, 1963). The Kelleher et al. study is an interesting report. Using rats they studied IRT distributions on DRL 20 sec. and DRL 18 sec. with several values of limited hold (LH). They conclude, "none of the schedules studied in this investigation generated bursts of responding or chains of overt behavior between responses. Thus neither of these phenomena is necessarily related to the development of temporal discriminations" (p.106)

However recent research (Glazer and Singh, 1971; Frank and Staddon, 1974; Richardson and Laughead, 1974) on restraining subjects on the DRL schedule has indicated that fine movements may be sufficient for efficient DRL performance. Richardson and Laughead go further in stating: "in order to have a low response rate and a high reinforcement rate under a DRL schedule ..... some collateral behavior must occur between responses". It is possible, therefore, that in those experiments which reported that stereotyped collateral behaviour was not present, the collateral behaviour involved fine movements which were overlooked. However, as Kramer and Rilling (1970) have said, "our understanding of timing behavior in general might be greatly increased if the statement could be made with some certainty that overt behavioral chains are not necessary for at least some organisms to form a temporal discrimination". (p.239).

MANIPULATIONS OF STEREOTYPED COLLATERAL BEHAVIOUR ON DRL SCHEDULES

Effect of Disrupting Collateral Behaviour

While discussing the genesis and maintenance of the typical FI scallop, Dews (1962) considers in detail the value of the mediating behaviour hypothesis to explain the apparent temporal discrimination which the FI scallop exhibits."To establish a sequence of responses as being chained or as constituting a mediating behavior it is not sufficient to demonstrate that the sequence is consistent and could so function; it must be explicitly demonstrated that changes in the sequence disrupt the chain or prevent mediation."

Several studies have attempted to disrupt collateral behaviour on DRL schedules.

Hodos, Ross and Brady (1962) investigated electroencephalographic correlates of timing and avoidance behaviour in monkeys. During the DRL component of their experiment certain movement artifacts were recorded which appeared to be distributed in time in a stereotyped manner. In one animal these movement artifacts were produced by head movements in another by licking the water bottle holder. In the latter case a variety of physical methods to prevent collateral behaviour were used (e.g. painting the water bottle with Tabasco sauce, erecting a barrier between the water bottle and the experimental chamber). This disruption resulted in a shift of the modal IRT towards the shorter IRT categories. Hodos et al. concluded that this result, plus the result of drug intervention (to be discussed later) confirmed that the stereotyped collateral behaviour mediated the DRL responding.

Laties et al. (1965) observed a rat on a DRL 22 sec-schedule which filled the pauses between responses by "nibbling it's tail" (not breaking the skin). By having an observer depress a hand held switch while the animal's mouth was in contact with it's tail, Laties et al. established the first quantitative data on stereotyped collateral behaviour. Suppression of the mouth-tail contacts was achieved by painting the tail with cyclohexamide, a substance which is used to prevent rats from chewing plastic-coated wires (Weeks,1962). Again as in the Hodos et al. study the IRT distribution was displaced towards shorter IRTs and the DRL behaviour consequently became less efficient.

A more comprehensive study by Laties et al.(1969) studied the effect of several experimental manipulations on stereotyped collateral behaviour emitted by rats on a DRL 18 sec. schedule. In two cases the rats nibbled a wooden support within the experimental apparatus. The amount of wood nibbled was recorded and the behaviour was maintained at increased DRL values of 36 sec. and 48 sec. Laties et al. established a positive correlation between amount of wood nibbled and number of reinforcements obtained. Fewest reinforcements were obtained when no wood was nibbled.

Effect of Amphetamines

Hodos et al.(1962) reported that the effect of a 3 mg./kgm. dose of dl-amphetamine on the monkey producing the highly periodic head movements was to increase the time between head movements, but to shift the peak of the IRT distribution towards the shorter time intervals. More than three quarters of the responses were not reinforced whereas prior to drug injection over half the responses had been reinforced.

Nearly identical results were observed with dl-amphetamine (dose 2.0 mg./kgm.) on the licking behaviour of the other animal. Licking was suppressed and a similar shift in the IRT distribution observed.

Similar suppression of collateral behaviour and IRT distribution shifts were noted by Laties et al.(1965) when their "mouth-tail contact" rat was injected with 0.5 mg/kgm. of d-amphetamine.

Effect of Restraining Subject on DRL Performance

Glazer and Singh (1971) suggested that: "If the development of collateral behavior is critical for temporal discrimination learning, animals unable to engage in overt collateral behavior should not be able to learn the temporal discrimination."

Consequently they subjected four groups of six rats to three conditions of restraint - no restriction, partial restriction, complete restriction, and a fourth control condition, stress control. The rats were placed on a DRL 10 sec.schedule and three groups showed normal DRL behaviour acquisition, the groups that did not being the complete restriction group.

In brief, the method of restriction involved wooden boxes with openings for head, limbs and tail. The degree to which the wooden lid pressed against the body and inhibited movement was the measure of restraint.

In a second experiment Glazer and Singh found that the aquisition of efficient DRL behaviour, by a groups of rats previously completely restrained and then non-restrained, occurred quicker than that of two groups: non-restriction - non restriction, non-restriction - restriction. The DRL behaviour of this last group was adversely affected by restriction. Glazer and Singh suggest that the inability of complete restriction groups to acquire efficient DRL performance reflects the operation of a performance rather than a learning deficit. "It is possible that the completely restricted groups did learn some type of covert timing behavior but that some performance variable such as generalised arousal rendered them incapable of performing appropriately under body restriction conditions." They themselves quote Perhach and Berry (1970) who, using increases in plasma corticosterone as an index of stress, found that bodily restraint in rats does not produce an increase in plasma corticosterone level within 24 hours after restraint. Despite this evidence they wish to appeal to "generalised arousal" of the completely restrained group to account for the lack of performance.

A recent experiment by Frank and Staddon (1974) investigated Glazer and Singh's results in more detail by exploring the effects of changing the degree of restraint after training of a partial restraint groups (which did show timing behaviour in the earlier study) and which Glazer and Singh had failed to do. Using pigeons on a DRL 5 sec. schedule, Frank and Staddon established that, while all subjects acquired efficient DRL behaviour under different degrees of restraint, a change in this variable in either direction (more or less restraint) after the behaviour had stabilised was disruptive.

Effects of Navel stimuli

Willoughby (1971) has pointed out that changes in the stimulus environment produced by manipulating the collateral behaviour introduce an element of novelty which is known to result in an increase of DRL responding - Contrucci, Hothersall and Wickens (1971) introduced navel stimuli into a DRL schedule at two temporal placements in the IRT. An increase was found in the number of lever press responses and this was independent of the placement of the stimuli within the IRT. Similarly Shapiro and Miller (1965) have pointed out the methodological weakness of most studies of disrupting collateral behaviour: "... to manipulate the occurrence of a response class, some environmental aspect must be manipulated also, thereby producing a confounding variable" (p.210).

These criticisms of the intervention and restraint types of experiment can be countered in part by saying that the experimenters took great care to habituate the subjects to all aspects of the disruption procedure prior to introducing the disruptive element. So that, for instance, placebo injections were given in sessions prior to drug trials and stress controls were employed in restriction studies.

Furthermore Contrucci et al. stress that the effects of novel stimuli decreased both within sessions and over test days, an effect which the disruption procedures do not mention.

Effects of Extintion on DRL Collateral Behaviour

The data on the effect of extinction on DRL collateral behaviour is consistent. Laties et al. (1965, 1969) found that the collateral behaviour ceased shortly after introduction of extinction (10.5 min. 1965). In all cases collateral behaviour disappeared before lever pressing but the distribution of IRTs during extinction rapidly lost it's typical bimodal appearance.

Glazer and Singh (1971) noted that differential bodily restriction had no effect on the rate of the response decrement during extinction. This is significant because their design allowed a between animal comparison. A mediational hypothesis would suggest that the more mediating behaviour the more rapid the breakdown of DRL behaviour in extinction. However, Glazer and Singh report no difference between their non restraint and partial restraint groups in DRL efficiency, and this, plus the corresponding factor of reduced reinforcement rate in their complete restraint group, suggest that comparisons of rates in extinction are hardly valid.

Experiments which study analogues of the DRL stereotyped Collateral Behaviour

A major obstacle to research on DRL collateral behaviour has been the idiosyncratic and unpredictable form of such behaviours which creates difficulties in adequately measuring them. Laties et al. (1969) used amount of wood nibbled as a measure and Laties et al. (1965), Stein, Hoffman and Stitt (1971) used the observer recording methods used by ethologists. (The later study is concerned with collateral behaviour on a VI 2 min. schedule).

To get round this problem several experimenters have attempted to establish collateral responding on one manipulandum in a two manipulanda situation. The procedures used are usually variations on a theme. Mechner and Guevrekian (1962) introduced "the counting schedule" (based on a procedure first devised by Ferster 1958). Later developed and described by Migler + BRADY (1964) it involved the subjects, in this case rats, pressing two levers in succession. Their data show that this procedure gives "a very clean measure of timing behaviour, in that the distributions of intervals are unimodal, regular and relatively compact" (Boakes 1969 P.360).

Nevin and Berryman (1962) used a two key DRL procedure. The first peck on key one started the interval and a peck on key two was reinforced provided more than 2 sec. had elapsed between the two pecks. Further responding on key one, after the first response had initiated the interval and switched off the key illumination, had no effect. All subjects (pigeons) continued to respond on key one after the first peck. Durations of these response runs often met the DRL criterion for reinforcement on the second key. Also, the probability of shifting to the second key was an increasing function of the length of response run on the first key. However no manipulations of this collateral behaviour were carried out.

A similar experiment by Boakes (1969) with two DRL values, each with corresponding stimulus, established that pigeons did not produce the different response topography on the first key which would be expected if such responding were mediating pecking on the second. Boakes concluded that adventitiously reinforced responding on the first key did not constitute mediating behaviour. However Boakes' definition of what might constitute different response topography is an arbitrary one and would depend on the method used to observe such a difference. In his case a cumulative record and unstructured observation might not be regarded as a very stringent search for differences.

Zuriff (1969) established responding on a second key during DRL by reinforcing behaviour on that key on a VI schedule, reinforcement being discontinued when the DRL contingency on the other key was introduced. As in the Nevin and Berryman (1962) study Zuriff found that as the DRL requirement was increased, the mean time _per_ run and number of responses _per_ run of collateral responses also increased. However like Boakes (1969), Zuriff could not establish a strong linear relationship between increases in DRL requirements (criterion IRTs) and the collateral behaviour, so concluded that the collateral behaviour did not mediate DRL performance.

Blackman and Scruton (1973) attempted to generate "a DRL like" behaviour using the "counting" schedule procedure. This required that for reinforcement to occur, a minimum number of consecutive responses on one lever, (A) precede a response on another lever (B) In this case the minimum number on the first lever was 20 responses and Blackman et al. state that "Cumulative records of B responding.... display a spaced pattern of responding that closely resembles that produced by a schedule that differentially reinforces low rates of responding". However as there were no explicit temporal contingencies this experiment is difficult to categorise.

Blackman developed this "DRL-like" behaviour to test an earlier suggestion that "the anamolous results obtained from conditioned suppression studies using DRL schedules may also be related in some way to the effects of the procedure on the unspecified patterns of behaviour which sometimes accompany DRL responding". (Blackman, 1968).

Blackman et al. (1973) conclude "the results of this experiment certainly suggest that the effects of a pre-shock stimulus on a specified pattern of behaviour may partially be related to the effects of the procedure on other, mediating, patterns of behaviour".

Segal-Rechtschaffen (1963) described a procedure for gaining control of collateral behaviour on a DRL schedule. Rats were trained on a DRL 16 sec. in a one lever situation, a second lever was introduced. Responding on this lever was reinforced 16 sec. after last response on lever one. The reinforcement on lever two became a discriminative stimulus for responding on lever one. After two sessions the situation became a concurrent one with reinforcement on lever two on a FI 16 sec. Finally food on lever two was replaced by a buzzer (conditioned reinforcer.)

Davis and Wheeler (1967) established a similar behaviour with a slightly more complex training procedure. Having established FR responding on one lever and DRL 10 sec. on the other, reinforcement for the FR concurrent was withdrawn. The results showed that there was no systematic decrease in the number of responses on the FR lever, while reinforcements on the DRL lever were above 3 a minute.

EXPLANATIONS OF THE FUNCTION OR MAINTENANCE OF DRL STEREOTYPED COLLATERAL BEHAVIOURS

There are three types of explanation of the function or maintenance of DRL stereotyped collateral behaviours. The first suggests that such behaviours are non-functional, the other two that these behaviours serve some function in DRL performance. The two types of functional explanations are (1) that stereotyped collateral behaviours directly mediate accurate, spaced responding on DRL schedules; these are the chaining and counting hypotheses, and, (2) that stereotyped collateral behaviour prevent the subject from responding, but that the factors which control the timing of the prescribed response are independent of the factors maintaining the collateral behaviour: these are the response competition, response inhibition, redirected behaviour and displacement activity hypotheses.

Superstitious or Adventitiously Reinforced Behaviour

Stereotyped collateral behaviour has been described as superstitious behaviour (Gilbert and Sutherland, 1969) in as much as it could be maintained by adventitious reinforcement. (Skinner 1948). This formulation supposes that the reinforcer which reinforces the prescribed response also reinforces the behaviour which immediately preceded it. This could relegate stereotyped collateral behaviour to the functionless collateral of the reinforcement contingencies peculiar to DRL schedules. If such behaviour were maintained by adventitious reinforcement, however, one might expect to see, on stable accurate DRL performances some form of post-reinforcement pause and then a scalloped pattern typical of FI schedules. What data there is of this type (Laties et al, 1965) do not support this. Again, disregarding the novelty objection for the reasons stated previously, there appears to be sufficient evidence from the disruption studies to indicate that stereotyped collateral behaviours do serve some function in maintaining DRL performances.

Stereotyped collateral behaviour as behaviour chains

A number of experiments have led some authors to conclude that DRL collateral responding represents behavioural chaining (Kelleher, 1966). In this formulation successive units of either homogeneous or hetergeneous behaviour act as conditioned reinforcers for the last unit and discriminative stimuli for the next. The final unit is the responses which terminates the IRT. There are two major objections to this description.

First virtually all reports of DRL stereotyped collateral behaviour (with the exception of Wilson and Keller, 1953; Mechner and Latranyi, 1963), report homogeneous "chains" of behaviour, where the only apparent difference between two units of the behaviour are their positions within the IRT. The question that has to be answered therefore, is why does the response terminating the IRT occur at one point in the homogeneous chain rather than another?

The second objection rests on the results of extinction experiments on DRL performance and the stereotyped collateral behaviour. Laties et al. (1969) reported that during extinction of DRL 18 sec. lever pressing behaviour with collateral wood gnawing behaviour the "gnawing ceased before lever pressing, confirming the extinction results of the single tail-nibbling rat of Laties et al. (1965) and demonstrating again the status of the collateral behaviour as a member of a heterogeneous chain"

However the literature suggests that Laties et al. (1969) are mistaken in their view that chains extinguish from the initial to the terminal link. The observations of both Miller (1951) and Zimmerman (1959) clearly demonstrated that chains extinguish backwards from the terminal link of the chain. If, therefore, DRL stereotyped collateral behaviour were chained in the accepted sense, the terminal link, or response maintained by reinforcement, should extinguish first and the stereotyped collateral behaviour should occur in shorter and shorter runs until it too finally extinguished. This does not appear to be the case.

"Counting" or Amount of Collateral Stereotyped Behaviour

A number of studies have shown that animals consistently pause after completing a FR run on, or about, the number of responses required for that run (Ferster and Skinner, 1957; Ferster, 1958; Weissman, 1960; Keehn, 1965). This might imply discrimination of amount of behaviour emitted, or, if the rate at which behaviour was emitted had stabilised, it might imply some form of temporal discrimination.

Several studies have shown that both rats and pigeons emit reasonably accurate behaviour on schedules which require the completion of a certain number of responses on one manupulandum before responding on another is reinforced (Ferster, 1958; Mechner and Guevrekian 1962; Millenson, 1966; Edwards, Dubiner and Crow, 1967; Blackman and Scruton 1973). It is the case however, as Willoughby (1971) has pointed out that all these studies confound the effects of number of responses and duration of responding. The experiment by Edwards et al. (1967) attempted to evaluate the "counting" hypothesis by presenting novel stimuli such as shock or change in colour of key light at different points in "counting" sequences being emitted by pigeons. Apart from a slight increase in the median "counting" response run, the "counting" behaviour was not affected by these procedures. If some incremental or sequential dependency was controlling this behaviour the novel stimuli should have disrupted the process.

The "counting" hypothesis as an explanation of the function of DRL collateral stereotyped behaviour requires more experimental attention. However, just what sort of experiment might unravel the confounding effects of amount, and duration of behaviour, is difficult to say.

Competing Behaviour Hypothesis

Schwartz and Williams (1971) presented data for pigeons responding on a DRL 10 sec. As is usual in such experiments, efficiency was poor, only 10% of all key pecks were reinforced. Introduction of a second illuminated key (key 2) with no programme consequences increased efficiency until 75% of all key peck on key (1) responses were reinforced. It was observed that the subjects pecked vigourously at key (2) between key pecks on key (1).

Schwartz and Williams concluded that their results indicate that either "(a) collateral behavior is central to timing or (b) that collateral behavior is essential to the operation of the response constraining contingency on DRL".

Assuming that (a) is not the case, (b) can be interpreted in three ways. The response-constraint procedure can be either (1) accidentally, or adventitiously, maintained by the reinforcement contingencies of the efficient DRL performance.

(2) The result of inhibition of prescribed responding on the DRL schedule.

(3) The result of conflict between two motivational states.

The first interpretation, which may be termed the competing response hypothesis, suggests that the stereotyped collateral behaviour is maintained by adventitious reinforcement, as is superstitious behaviour (Skinner, 1948), but that such collateral behaviour accidentally fulfills the function of competing with, and preventing, the emission of the prescribed response. Such superstitious behaviours are however prone to topographical change (Skinner, 1948) and in the case of the DRL schedule where reinforcement would depend on a reasonably constant topography of competing behaviour, frequent breakdown in DRL performance might be expected. This is not normally the case.

Response Inhibition and DRL Stereotyped Collateral Behaviour

Richelle (1972) has pointed out that the DRL schedule requires that there be no responding within a prescribed interval; this he suggests requires the animal to inhibit responding. Kramer and Rilling (1970) have said: 'Laboratory folklore holds that in a DRL schedule, the animal learns to actively inhibit responding. This interpretation has occasionally been suggested (Hearst, Koresko and Poppen, 1964) but definitive experimental verification has been lacking." (p.228).

Richelle (1972) has stated that: "Compensation for inhibition might possibly be achieved either by an output of responses of the same topography as the operant response, or by any kind of motor behaviour. If so, collateral behaviour (sometimes called mediating behaviour) would have nothing to do with the time measuring proper; it's effects on the quality of temporal regulation would be accounted for by it's aspecific compensatory function." (p.234). An interesting point arises from this statement. If, as appears from DRL IRT distributions, responding is differentially inhibited one might expect to see changes in the collateral behaviour across the interval.

Contrucci, Hothersall and Wickens (1971) have reported the effect of a potentially disinhibiting novel stimulus introduced early or late into a number of DRL 20 sec. intervals in the DRL 20 sec. performance of rats. An increase was observed in the number of lever pressing responses before the end of the specified interval, and this effect was found whether the stimulus was presented "early" or "late" in the interval; there was no significant difference between responses produced by the "early" or the "late" stimuli. The effect decreased after stimulus presentations within and between sessions. Contrucci et al. claim that these results, "while favouring either a chain or an inhibition explanation of stereotyped collateral behaviour, probably lend more support to a traditional interpretation of inhibition and the disinhibition phenomenon rather than a mediating response explanation".

Staddon (1972) has suggested that the two types of activity on DRL, collateral and prescribed responding, or interim and terminal activity are reciprocally inhibitory (p.248). The latest statement of his position is by Frank and Staddon (1974) ".... assume that passage of time itself is, or can be, a discriminative stimulus like any other. Another reasonable assumption is that the animal cannot do "nothing." On these assumptions then perhaps the simplest possibility is that interim ("collateral", in the present case) activities are under the stimulus control of short postresponse times (on DRL)..... because such times are associated with a low or zero probability of food reinforcement for pecking. The terminal response (pecking), on the other hand, is under the control of longer post-response times because these are the times at which pecking is associated with a high probability of reinforcement. If it then be assumed that the two types of activity (interim and terminal: in the present case "collateral" and pecking) are reciprocally inhibitory (cf. Staddon - 1972), then prevention of the interim activities would leave the terminal response as the behavior of next priority in the situation, since it is no longer being inhibited by the interim activities........This account seems consistent with other results in the literature, cited above, and avoids the difficulties associated with 'chaining' or 'behavior as a clock' explanations" (p.129 - 130).

Frank and Staddon's explanation requires a prior explanation of "the control of......post-response times" which detracts from its utility. However it does introduce the concept of response priority which has a bearing on the following, ethological explanations.

Ethological Explanations of DRL Collateral stereotyped Behaviour

The necessity for the subject on a DRL schedule to withold responding at some points in time and to respond at others, has led some authors to hypothesise that the stereotyped collateral behaviour is a conflict behaviour. Hess (1962) categorised conflict behaviour into four groups:- successive ambivalent behaviours, simultaneneous ambivalent behaviours, redirected behaviours and displacement activity. The first two do not appear relevant to stereotyped collateral behaviours as there does not appear to be much ambivalence in these behaviours. However both redirected and displacement behaviours, as defined in the literature (Burghardt, 1973) have features in common with DRL stereotyped collateral behaviours.

Both these classes of behaviour are linked in the ethological literature to conflict between two motivational states. It has been the practice in the experimental analysis of behaviour to avoid appeal to hypothetical motivational variables. Consequently, ethological interpretations of schedule behaviour have not often appeared in the literature (McFarland,1966).

Recently, however, two papers in particular have focused attention on the relevance of ethological data to certain aspects of schedule behaviour. Seligman (1970), using earlier work like Breland and Breland's(1951), challenged what he called "the equivalence of associability" assumption. This assumption, implicit in the writings of Skinner (1956) assumes that:- "In instrumental learning the choice of response and reinforcer is a matter of relative indifference; that is, any emitted response and any reinforcer can be associated with approximately equal facility, and a set of general laws exist which describes acquisition, extinction, discriminative control, generalization, etc., for all responses and reinforcers". (Seligman,1970,p.407)

Breland and Breland (1951) presented evidence that when animals were trained, using operant conditioning,to do some specific act, a number of species characteristic behaviours began to be incorporated into the trained sequence. Seligman argued that certain response patterns have a greater degree of "preparedness" in certain species than in others. (The "autoshaping" of the key peck in pigeons by Brown and Jenkins (1968) is an example of such a behaviour).

Staddon and Simmelhag (1971) looked at the "superstition" phenomenon first described by Skinner (1948). Skinner reported that regular presentation of food to a food deprived pigeon, with no reference to the behaviour of the bird at the time of food presentation, led after a while to peculiar and bizarre repetitive behaviours as being due to accidental correlations between instances of a particular behaviour and reinforcement. Staddon and Simmelhag (1971) re-examined the superstition experiments and concluded, using concepts such as appetitive behaviour, consummatory acts, evolution, displacement behaviour and species - characteristic responding, that the most probable behaviours in the superstition experiment are those which for species - specific reasons are likely in the animal's normal feeding situation.

Staddon (1972) has extended this analysis into theoretical discussions of the value of such concepts (in particular "evolutionary variability") to the experimental analysis of behaviour.

Redirected Behaviour

"Redirected activity occurs when an animal performs the behavior appropriate to the motivational state but directs that behavior toward an inappropriate object in the presence of the proper stimulus" (Burghardt 1973 p. 359).

Examples of this type of behaviour are: male blackheaded gulls, whose tendency to attack their mates is inhibited, may attack other birds (Moynihan, 1955; Bastock, Morris and Moynihan, 1953): herring gulls in an aggressive encounter may redirect pecking onto objects in the environment (Tinbergen, 1959).

Lowe and Harzem (1973) have made reference to the possible aversive properties of the DRL schedule and it is known that certain schedules of positive reinforcement produce "schedule induced aggression" (Azrin, Hutchison and Hake, 1966). It would seem possible therefore that the two "motivational states" to press the lever and to inhibit lever presses might be supposed to result in the stereotyped collateral behaviour.

Displacement Activity

The argument that adjunctive behaviours might be considered as displacement activities has been summarised by Falk (1972, pps 167 - 169) and McFarland (1972). As noted earlier in this review, Falk (1972) has: "set aside those explanations (of adjunctive behaviours) framed in terms of simple, physiological bases, mediating functions or adventitiously reinforced behaviors " (p.169). He does so mainly because no single interpretation of this kind explains the ubiquitous nature of adjunctive behaviours in many different schedules of reinforcement.

Does the displacement activity hypothesis further the understanding of DRL stereotyped collateral behaviour? If Falk's (1972) rephrasing of Tinbergen's (1952) definition of displacement activity is valid, and the present author believes that to be the case, then this definition is: "The 'displaced' behavior can be referred to as a response sequence that is ordinarily a function of variables other than those that presumably dominate the current situation". This irrelevant or incongruous behaviour is, in ethological terms, the result of competing motivational states which are in equilibrium. Additionally, Tinbergen (1947) suggested that displacement activity can occur when an external stimulus, after having activated a drive state, suddenly stops.

The relevance of these concepts to DRL stereotyped collateral behaviours is certainly not clear. It is true that two "motivational states" may be in conflict (to press or not to press) but the durations in which they may be said to be in equilibrium, as judged from a bi-modal IRT relative frequency distributions, must be very small indeed. It might also be concluded that the termination of the reinforcing stimulus (because it has been eaten) results in displacement activity. Such an interpretation is difficult to challenge.

The incongruity of the displacement activity which is a feature of these ethological interpretations is difficult to assess in the present experimental setting. Because the appropriate behaviours are not clearly prescribed (merely their operational outcome), behaviours which might be considered as inappropriate cannot be defined with any accuracy.

Perhaps the most useful statement on the relevance of the displacement activity concept to DRL collateral behaviours was made by McFarland (1970):

"..........it is possible that low rate of reward is "frustrating" for the animal, and this frustration causes a switch in attention, in accordance with recent suggestions concerning disinhibition of displacement activity (McFarland, 1966). The similarity between........

........adjunctive behaviour.......and displacement feeding previously described in doves (McFarland, 1965) is striking in that both are affected by manipulation of relevant causal factors. However there is also the important difference that displacement occurs in thwarting or conflict situations, whereas the adjunctive behaviour in normal feeding and drinking situations occurs in the absence of overt frustration or conflict. It has been suggested (McFarland, 1969) that displacement activities are a special case of the more general phenomenon of disinhibited activity, which can occur in a variety of circumstances" (P. 72).

Ethological interpretations of DRL stereotyped collateral behaviour

While ethological interpretations of DRL stereotyped collateral behaviour have a certain attraction in that they connect this schedule induced behaviour with a large body of "field" data, it is clear that there is at present insufficient data on the former for any useful comparisons with the latter to be made. Even when such data is available care must be exercised when making assumptions about motivational variables in the schedule situation.

SUMMARY

This chapter is intended to provide a selective review of the literature on the differential reinforcement of low rates (DRL) schedule and in particular those experiments which have reported, or were investigations of, the stereotyped collateral behaviours which have been reported as occurring on this schedule of reinforcement. The theoretical interpretations of the results reviewed in each section were discussed at the end of each section.

The main points of the review are summarised below:

1. The differential reinforcement of low rates (DRL)

a) On DRL schedules, reinforcement is dependent upon the spacing of responses so that a minimum time elapses between successive responses.

b) Performances under DRL schedules are characterised by regular spacing of responses in time. The efficiency of such performances varies with species and the topography of the required response.

c) The relative frequency distributions of inter-response times (IRTs) on DRL schedules are typically bi-modal. One mode occurs in the very short IRT category representing the "bursts" of responses characteristic of some DRL performances. The second mode occurs on or about the criterion IRT value.

d) Reports of experimental manipulations such as magnitude of reinforcement, extinction and drug administration on DRL performance are relatively consistent. The exceptions are the contradictory results of the Estes-Skinner procedure on a DRL performance baseline.

e) Explanations of the maintenance of DRL performance are usually couched in terms of the dynamic, differentiating and discriminative effects of reinforcement schedules. While several writers have stressed the role of multiple causation in the DRL schedule, the difficulty of distinguishing empirically between differentiating and discriminative effects has also been commented on.

2. Stereotyped Collateral Behaviours on DRL schedules

a) These stereotyped collateral behaviours have been frequently reported in DRL performance reports although there have been three reports which specifically mention that they did not occur.

b) These behaviours have typically been reported as oral, gnawing or nibbling behaviours. The behaviours are often peculiar in topography to the individual subject.

c) Several writers have described stereotyped collateral behaviours as "mediating" behaviours in that denying the subject opportunity to emit the established DRL collateral behaviour has led to a rapid increase in response rate and a breakdown of accurate timing behaviour.

d) While no detailed functional analysis of stereotyped collateral behaviour occurring on DRL schedules has been undertaken, the effects of experimental manipulations such as drug and novel stimuli intervention tend to confirm that these behaviours, where they occur, are necessary for efficient DRL performance.

e) Explanations of the factors maintaining stereotyped collateral behaviour on DRL schedules have been of three main types:-

i) That these behaviours are non-functional collateral behaviours maintained by adventitious reinforcement.

ii) That these behaviours are responsible for the accurate spacing of responses in time, either by a behaviour chain process, or by some counting method.

iii) That these behaviours permit the subject to withold responding thus preventing premature responses, but that the factors controlling the emission of accurately spaced responding in time are independent of the factors maintaining stereotyped collateral responding. These are the response competition, response inhibition, redirected behaviour and displacement activity hypotheses.

CHAPTER III

EXPERIMENTAL AIMS & GENERAL METHOD

EXPERIMENTAL AIMS AND GENERAL METHOD

Experimental Aims

As a consequence of reviewing the literature on DRL stereotyped collateral behaviour, the following five experimental aims were constructed.

1. To find a highly probable DRL collateral behaviour which required no additional reinforcement contingencies to establish it, other than the existing DRL schedule contingencies.
2. To develop an apparatus which would give reliable quantitive recordings of the collateral behaviour.
3. To establish this behaviour as a DRL collateral behaviour and analyse such behaviour in depth.
4. To experimentally manipulate the collateral behaviour, keeping the DRL contingencies in force, to establish if the collateral behaviour "mediates" efficient DRL responding.
5. To experimentally manipulate the DRL contingencies to establish the factors which might maintain the collateral behaviour.

GENERAL METHOD

Subjects

Most experimental reports which present data on both efficient spaced responding on the DRL schedule, and collateral stereotyped behaviour, have used rats as subjects. Consequently rats were used as subjects in all the experiments reported in this thesis.

The subjects were male P.V.G. Hooded rats. At the beginning of each experiment all rats were not less than 120 days old and not more than 180 days old.

To ensure adequate rates of responding all rats were maintained at 85% of their free feeding body weights. Starting when the rats were at least 120 days old, each animal was weighed over several successive days and an average weight arrived at.

The rats were then deprived of food, each rat being gradually fed less and less food until the animals weight had dropped to the 85% figure. Gradual weight reduction acclimatised the subjects to the deprivation state.

After each experimental session the subject was weighed and if the weight was below the 85% figure, supplementary amounts of food were given to the subject. The weight of the supplementary food equalled the difference between the subject's weight at the end of the experimental session, and the 85% figure for that subject.

Each rat was housed individually in it's home cage. Light/dark cycle, temperature and humidity were all controlled. A 12 hour light/12 hour dark cycle was implemented. Each animal was tested daily, seven days a week, at the same time in the light cycle. Amounts and degree of handling between the home cage and the test environment were kept as consistent as possible; all experiments except one were run by the author. The above mentioned variables were controlled as part of the effort to reduce variability between daily performances, a requirement of the steady states methodology. (see below).

In the home cage there was free access to water but, other than in the experiment where drinking behaviour was being studied, there was no water available in the test environment.

APPARATUS

Programming and Recording

Experiments were programmed on Grason-Stadler relay equipment and recording was accomplished with Gerbrand Cumulative Recorders, Sodeco printouts, and a Data Transfer Unit, designed by the Technical Services of the Department of Psychology, University of Stirling. The Data Transfer Unit, transferred data from the Grason-Stadler relay equipment on to computer paper tape for computer analysis on the University of Stirling, Elliot 4130 computer. (The computer programme used in analysing the data is included in the Appendices).

Test Environment

All rats were tested in a modified Lehigh Valley Rodent test cage (Cat.No.143-22). The cage was housed in a sound-attenuating cubicle (Lehigh Valley Cat. No.132-02) which has a baffled air intake and 60cfm exhaust fan.

The dimensions of the test environment were as follows:-

Height - 26.75cm, width - 30.5cm, depth - 24,0cm.

The floor of the cage was made up of 0.5cm.dia. stainless steel bars spaced 2.0cm. apart and aligned parallel with the intelligence panel.

The manipulanda were two (Cat.No.121-05) Compound Rodent Levers (for position on intelligence panel, see Figure 1). 25gms. depress force

Stimuli: Visual - three (111-01) "Q" lamps over each lever, house light.

Auditory - one (112-01) Sonalert 2.8 kH_z Standard and on 4-ohm speaker (to provide constant masking noise, thus reducing the effect of extraneous noise.

Electrical - shock floor.

Gustatory - one (114-20) pellet feeder delivering 45mg. Noyes

Figure 1

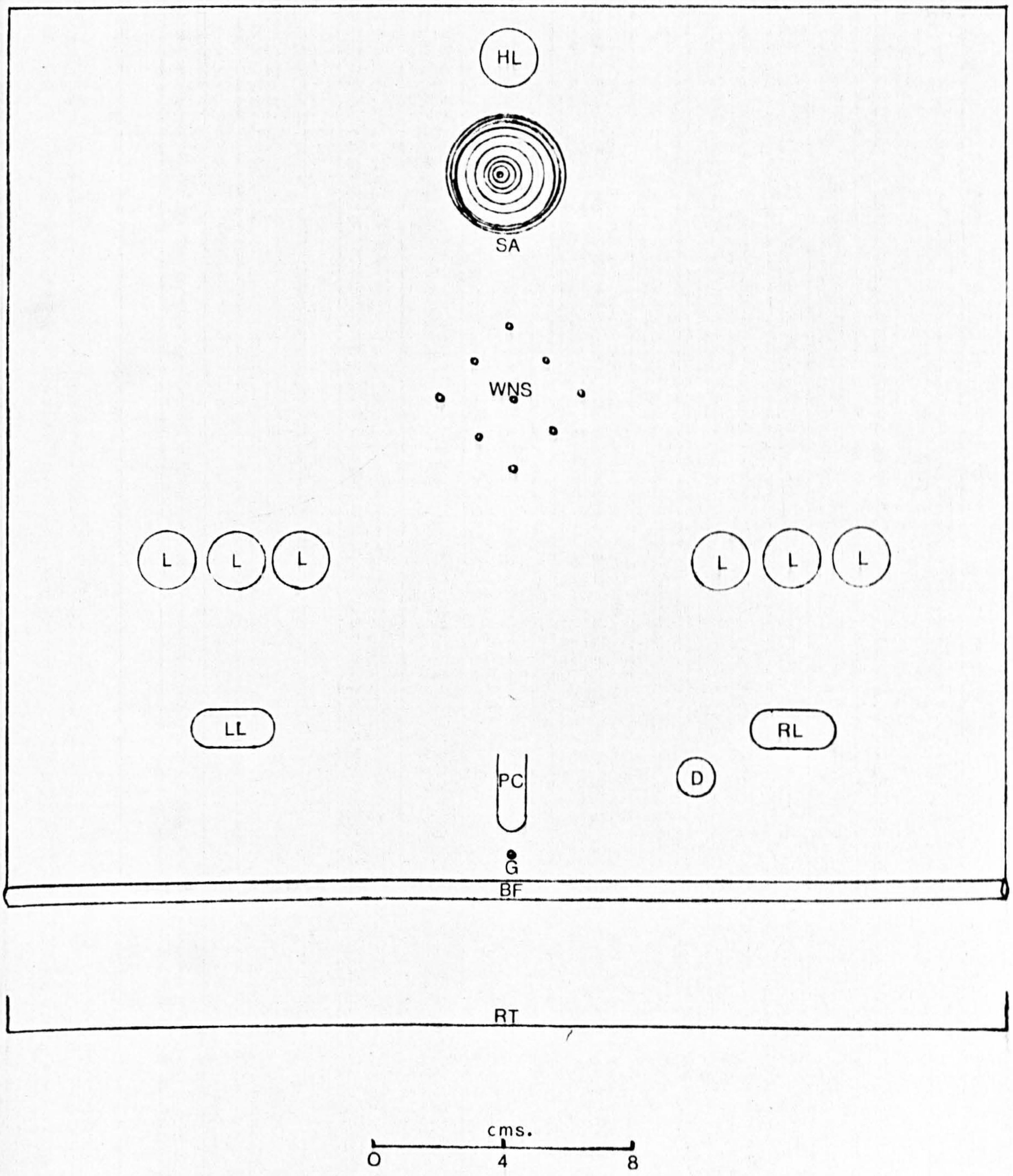
Diagrammatic representation of the test environment intelligence panel.

Figure 1

Test Environment Box

Intelligence Panel

(HL) Houselight
(SA) Sonalert
(WNS) White Noise Speaker
(L) Stimulus Light
(LL) Left Lever
(RL) Right Lever
(D) Drinkometer
(PC) Pellet Chute
(G) "Gnawing" Sensor hole
(BF) Bar Floor
(RT) Refuse Tray


HL
SA
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8

Figures 2a, b

a) View of test environment with subject gnawing wood block.

b) View of the plexiglass mount for the transducer and the sensitivity control box in the foreground.

Fig. 2a

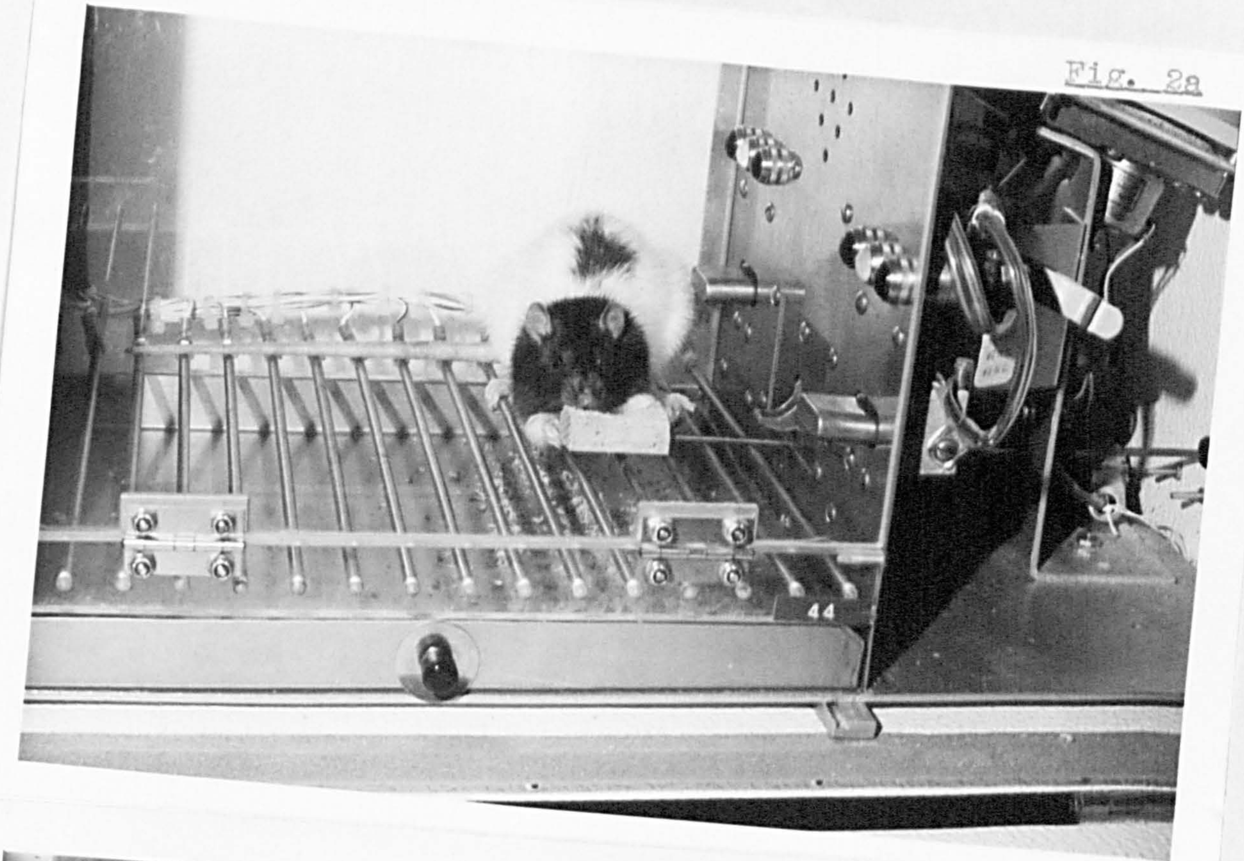


Fig. 2b

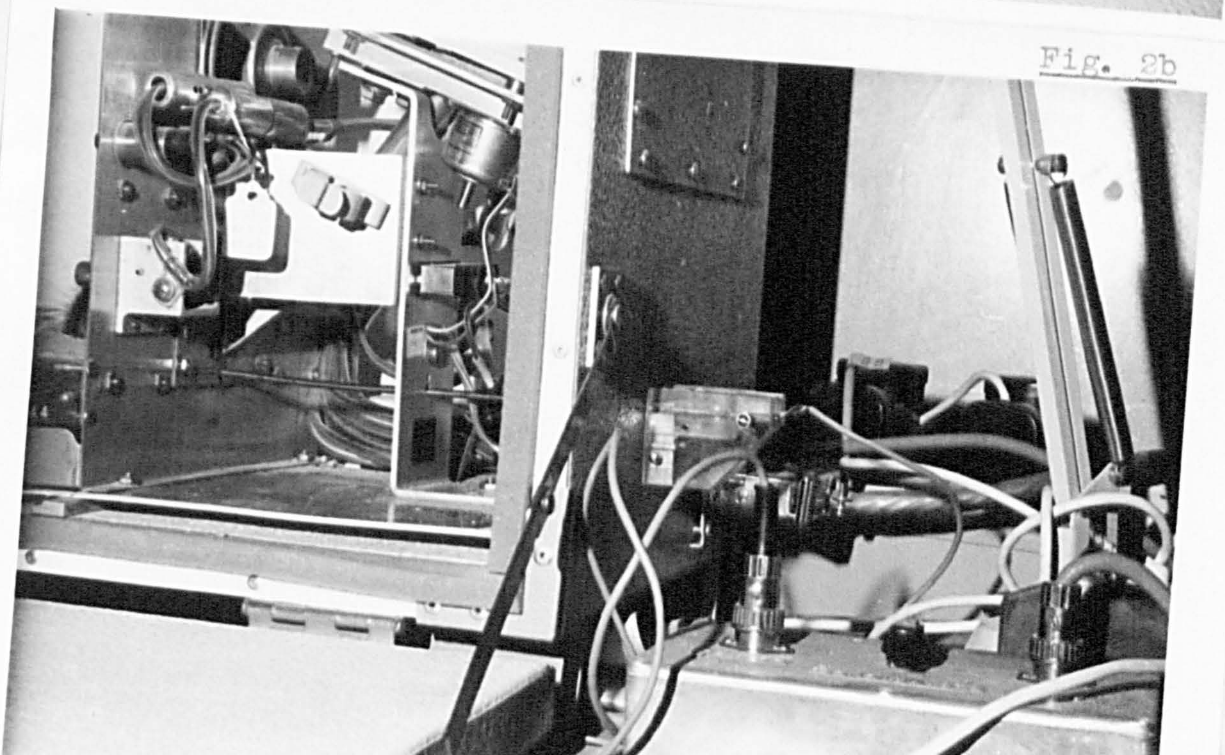
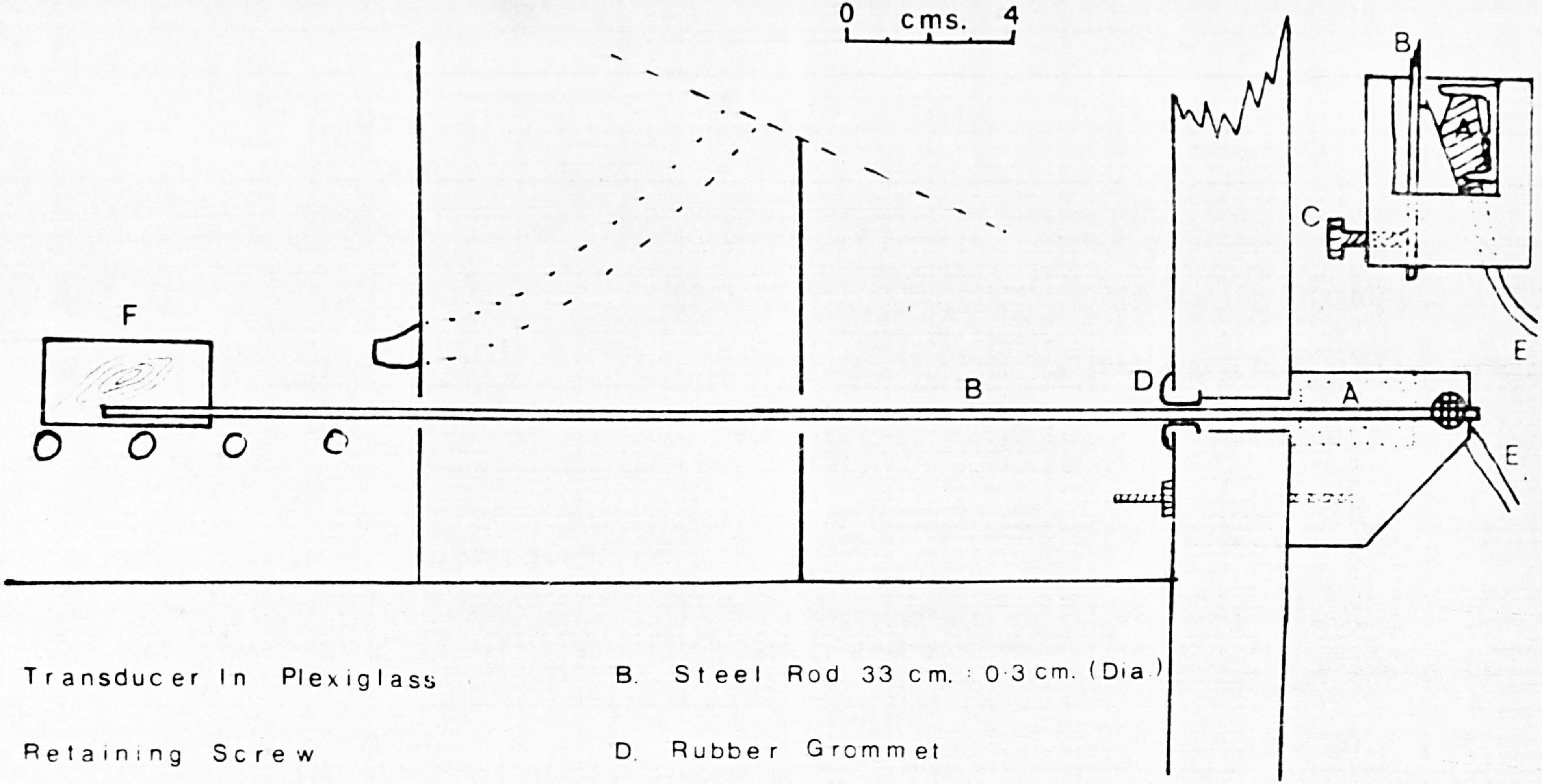


Figure 3

Diagrammatic representation of the wood gnawing sensor.


0 cms. 4
B
A
C
E
F
D
B
A
E
E

A. Transducer In Plexiglass

B. Steel Rod 33 cm. : 0·3 cm. (Dia.)

C. Retaining Screw

D. Rubber Grommet

E. Leads To Sensitivity Control

F. Wood Block 4×2×2·5 cm.

pellets (for pellet formula see Noyes Co. Ltd. literature)

A removable refuse tray was situated 3.8cm. below the bar floor. See figure 1 and Figure 2(a).

The standard test environment was modified in the following way. Two holes were drilled in the intelligence panel (see Fig.1). One 1.5cm. dia. hole was for a water bottle nozzle, used in one of the experiments. Licks on the nozzle could be recorded. The second hole was a 0.7cm. dia. hold situated directly beneath the pellet chute to allow insertion into the experimental space of the gnawing sensor rod (see below).

Gnawing Sensor

The review of the literature suggested that one behaviour, drinking, would be a highly probable collateral stereotyped behaviour, but the literature further suggested that it would only be a post-pellet (post - reinforcement) phenomenon (Falk, 1972; Segal and Holloway, 1963).

Laties, Weiss and Weiss (1969) had reported that four out of their five rat subjects had nibbled wood of one type or another (unspecified, pressed wood:- Masonite, pine block)

Small pilot studies in the home cage established that rats would gnaw wood blocks.

A gnawing sensor for recording movements of a block of wood mounted on a steel rod was developed by the Technical Services of the Department of Psychology, University of Stirling. The device was in three parts:- (1) a steel rod 33.0cm. long, 0.3cm. dia., inserted at one end into a block of untreated beech wood (4x2.5 x 2cm) was passed to the outside of both the environmental space, and the enclosing sound attenuating chamber, leaving the block of wood inside the experimental space (Figs.2(a) and 3) (2) The rod fitted into a plexiglass block mounted on the outside of the sound attenuating base and was held in place by a retaining screw. (Figs.

2(b) and 3). Mounted within the plexiglass holder was a stylus transducer. A Motorola MFC 8040 audio amplifier was used to raise the transducer signal to a suitable level for the operation of the threshold control unit. A pulse former was used to operate the final relay amplifier for 150 msecs from the onset of a disturbance to the transducer. Such disturbances will be labelled "gnaws". In operation, differences between accidental movements of the wood and signals due to gnawing were easily distinguishable. The rate at which signals were received when the subject was gnawing the wood was very high indeed, varying between 2 and 4 a second. While every "gnaw" was recorded on the cumulative recorder and other recording apparatus, because of the high rates involved only every 10th "gnaw" was recorded on the Data Transfer Unit punch tape. Also recorded on this tape were lever press responses (reinforced or non-reinforced) and the time at which any of these three events occured.

The wood chosen for these experiments was beech (Fagus Sylvatica). This wood provided the necessary close grained, short staple length hardwood which prevented large strips of wood being removed from the block thus permitting unrecorded wood gnawing. Villareal (1967) reported that monkeys emitting schedule induced pica of pine wood, chewed strips off a pine block and ingested them. As the wood chips in the present experiment fell through the bar floor onto the refuse tray, it was possible, by carrying out weight comparisons, to conclude that the subjects did not eat the beech wood chips (see Exp.1).

Advantages of the Wood Gnawing Sensor

a) It would record most (see Figure 4) movements of the wood even with the total weight of a rat resting on the wood block, but it would not record extraneous events (i.e. other animal movements, pellet delivery or lever operation)

b) There was minimal extra apparatus inside the experimental space.

c) Minimum alteration to a standard Lehigh Valley test environment cage was required.

d) Gnawing of the type of wood used (beech; Fagus Sylvatica) produced small wood chips, thus preventing eating, and avoiding injury to the rat which might occur if larger splinters were broken off.

e) The wood block and rod were easily removed from the plexiglass holder, thus freeing the experimental test cage for the use of other experimenters.

Disadvantages of Gnawing Sensor

(1) As it was necessary to remove the rod daily after each experimental session, detailed comparisons of wood gnawing between sessions were not possible. Slight differences in placing the rod in the holder made such comparisons doubtful. However, as the rod was clamped tight during each experimental session (i.e. between each rat's daily experimental run), comparison between rats on any day were valid.

(2) In the course of two early experiments with this sensor (not reported in this thesis) 3 subject deaths occurred. These were experiments carried out over a long period (e.g. one experiment lasted 12 months). Pathological examination of the casualties noted "The lung tissue showed evidence of a pneumonia of chronic nature. Most of the reaction was to be seen in the interstitial tissue. Alveolar and bronchiolar exudate was limited. The quite extensive haemorrhages to be seen was probably terminal in nature. Unfortunately, no bacteria of any pathological significance could

be isolated."

Although no wood dust was isolated from the lung tissue it was supposed that extensive and prolonged inhalation of wood chips had led to this non-bacterial pneumonia. For this reason daily sessions were cut from 1 hour to 30 minutes, and attempts were made to reduce the overall length of experiments. Apart from an unwillingness to cause suffering to the animals, changes in behaviour due to deterioration could not be controlled for. After the introduction of 30 mins. sessions and shorter experiments, no animal died of the above lung damage.

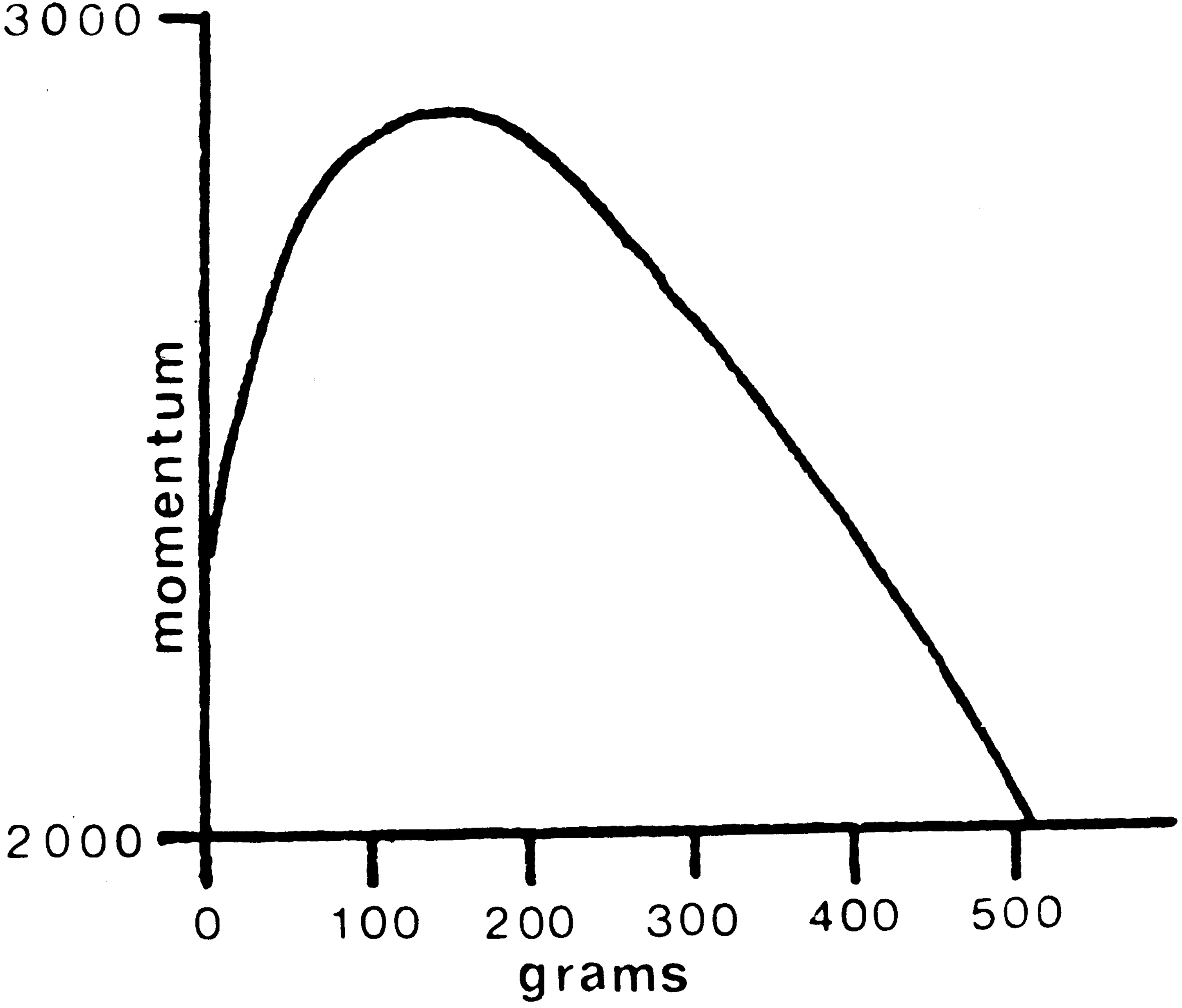
Callibration of Gnawing Sensor

Initially the sensitivity control of the threshold control circuit was set at an arbitrary level. This level was found to give approximately 2.0 'gnaws' per second across the session, and this level was used in subsequent experiments.

At this sensitivity level it was possible to calibrate the device using a procedure based on the one reported by Altman and Hull (1973). Using a pendulum (25cm. long with 0.5gm. mass of putty suspended) the minimum momentum required to operate the device with increasing weight resting on the block was a function represented by the graph, Figure 4. This function was the result of ten tests at each weight-on-block level. In each test ten pendulum swings were made at any selected distance (h) from the block of wood. Providing the sensor operated more than 5 but less than 9 times, this distance (h) was used to calculate the momentum. Momentum = $m \times 2gh$ where $m = 0.5$ gms. and $g =$ gravitational constant (980 cm/sec.^{2}). The rod was removed and replaced after each test and the mean momentum from the ten test momenta was taken as representing the average momentum required to operate the sensor in the experiments which follow.

Figure 4

The minimum momentum required to produce a signal 'gnaw' from the sensor with different weights (representing the subject) resting on the woodblock.


3000
2000
momentum
0
100
200
300
400
500
grams

GENERAL PROCEDURE

Adaptation

In order that the rats should adapt to the novel environment of the experimental space each rat was initially given two 30 min. sessions with only the houselight and white noise operative. As noted previously the white noise, on throughout the sessions, masked extraneous noise. The wood, and attached rod, were not placed in the test environment during adaptation days.

Magazine Training

To accustom the rat to eating from the pellet chute, food pellets were presented to the rat on the third experimental session. Food pellets were delivered singly on a variable time (VT) 30 sec. schedule. This schedule merely delivers food at variable times (mean of 30 sec.) with no response requirement. Apart from accustoming the rat to eat from the pellet chute, it established the stimuli associated with the reinforcer, that is the noises associated with pellet delivery, as discriminative stimuli. No wood was present during magazine training.

"Shaping" the lever press response

In all experiments the rats were trained to press the lever as follows:- During the fourth session for each rat successive approximations to pressing the designated (left) lever were reinforced. The experimenter observed each successive approximation and pressed a key which delivered reinforcers.

Having established the lever press response, each rat was given 50 reinforcements on a c.r.f. (continuous reinforcement) schedule. This schedule reinforced every response. No wood was present.

DRL 18 sec. Schedule

On the fifth, and successive, days the rat was exposed to the contingencies of a DRL 18 sec. schedule. Each response which occured 18 sec. or more after the previous response was reinforced. Responses occurring before 18 sec. had elapsed since the previous response were not reinforced but reset the timer. On this fifth session wood was present for the first time. From a total of over 40 rats trained in such a way only two failed to emit wood gnawing as the DRL collateral, albeit some animals, normally those tested last each day, have produced a-typical behaviour (RAT 12 in Experiment I is an example of this type of gnawing behaviour). This phenomenon will be discussed in the appropriate exper-:imental discussion.

STEADY STATES OF BEHAVIOUR

One of the advantages of operant conditioning mentioned in the introduction is that using this technique stable patterns of behaviour may be studied across many daily sessions. This fact has also led to an experimental methodology, peculiar to the experimental analysis of behaviour, called steady state methodology (Sidman, 1960, Ch. 8).

This methodology is characterised by the use of a small number of subjects, run under a set of experimental variables for a number of sessions until behaviour is stable between sessions. The criteria for stability vary: "The criterion may be determined by convenience, or by visual inspection of curves or by elaborate mathematical procedures, depending upon the precision demanded by the problems under consideration" (Ibid, Ch. 9).

The first two methods of assessing stability are closely linked. Experience with a certain set of experimental variables leads the experimenter to set a limit on the number of experimental sessions prior to the test day. Experience will have shown that round about that time an asymptotic level of behavioural change is reached. Similarly the experimenter, by experience, learns to recognise the level of stability by visual inspection of the cumulative records and other daily session data.

The third method of assessing stability mentioned by Sidman is the mathematical criterion which is established prior to stability. Again this rule is arrived at by experience, but it is a useful method for the experimenter dealing with unfamiliar behaviour. One example of such a mathematical criterion is that proposed by Schoenfeld, Cumming and Hearst (1956) and reprinted by Sidman (1960, p.260).

Most experiments reported in this investigation involve behaviour on a DRL schedule of reinforcement and with one particular value of that schedule. The experimenter's experience with this behaviour prior to the experiments reported here was extensive, so that, except where circumstances dictated use of another criterion, the method of visual inspection of the data to establish stability was employed. Evidence of this stability will be furnished in the case of each subject.

The considerable environmental control exercised by the experimenter in achieving steady states has the additional advantage that few subjects need be used in each experiment. When the behaviour is stable between and within sessions and each subject is emitting similar behaviour, then inferential statistics are not normally required to establish the generality of results. Providing sufficient evidence is presented to show that the data are representative of each animal's steady state behaviour, then the experimenter may feel confident that he can generalise from a small number of subjects.

Normally, the time required to achieve the necessary steady state of behaviour precludes large numbers of subjects.

Evidence of stability will be presented for each subject. Efficiency ratios for the 25 days prior to the test day appear as a graph in the data presented for each animal. Kramer and Rilling (1970), commenting about comparisons between DRL schedule studies in which different response and reinforcement rates are compared, say:- "this leads to extreme difficulty in comparison of data across different experiments. The situation would be generally improved if all DRL studies included both the response rates and reinformement rates in either graphic or tabular form. Presumably due to the existing ambiguity, an 'efficiency' ratio has become increasingly popular. This ratio is calculated by dividing the number of reinforced responses by the total number of responses. The resulting percentage is an index of the animal's adjustment to the schedule contingencies". (p. 230).

SUMMARY

Following an outline of the experimental aims of this investigation, a description was given of the commonalities between the experiments which follow, in terms of the General Method:-

a) Subjects: Rats, maintained at 85% of their previously established free feeding weights. (Their laboratory numbers were used for identification).

b) Apparatus: Standard operant conditioning apparatus with the addition of a drinkometer and a specially designed wood gnawing sensor.

c) Preliminary training procedure: Prior to each experiment the operant lever press response was established by means of some preliminary training.

d) Schedule: Apart from experiments where other schedules were introduced the predominant schedule was the differential reinforcement of low rates (DRL 18 sec).

Finally a description was given of the steady states methodology which was used throughout the following investigation. This methodology is characterised by the use of small numbers of subjects, each exposed to the experimental conditions until it's behaviour is stable both between and within sessions. The criteria for stability were discussed and the stability procedure used in this investigation was outlined.

CHAPTER IV

EXPERIMENT 1

ANALYSIS OF DRL 18 sec. PERFORMANCE WITH COLLATERAL WOODGNAWING

EXPERIMENT 1

Introduction

A survey of the literature on the stereotyped collateral behaviours associated with the DRL schedule found no detailed reports of the pattern of such behaviour between instances of the prescribed response. It might be supposed that data of this kind would be useful in determining the function, if any, of the stereotyped collateral behaviours.

The aim of the first experiment was to obtain, and then analyse, some examples of stable DRL performance with collateral woodgnawing behaviour.

Method

Subjects: Six rats (Laboratory numbers 7, 8, 9, 10, 11 and 12) served as subjects. For other details see the General Method section (Ch. III).

Apparatus: The subjects were run in the experimental space (Skinner box) described in detail in the General Method section.

Prodedure: All subjects were initially pretrained as described in the General Method except that 4 days instead of 2 days of adaptation were given. On the last 2 days of adaptation wood was present in the experimental space. This was done to allow measurement of pre-experimental rates of wood gnawing. Following pretraining, each subject's lever press responding was reinforced on a DRL 18 sec. schedule of food reinforcement for a total of 46 daily experimental sessions. Each individual daily session lasted 30 minutes.

Results:

The cumulative records showing the pre-experimental (or operant) wood gnawing behaviour show that while total amounts of wood gnawing varied considerably between subjects, the "rates"* at which it occurred were similar between subjects. Wood gnawing in this pre-experimental situation appeared to be emitted at between 1.5 and 2.5 "gnaws" per second (Figures 5 - 10 : a) A "gnaw" was said to have occurred each time the recording equipment registerëd a signal from the transducer (see General Method section).

With the exception of Rat 12 the DRL 18 sec. performance of each animal had become stable by the 30th session and subsequently there was little systematic variation. Figures 5-10:b show a measure of this stability in the efficiency ratios for the last 25 sessions prior to the final day.

By the final day there were close similarities between the distributions of behaviours in time for all subjects with the exception of Rat 12. Wood gnawing normally intervened between successive responses (upper cumulative record: Figures 5 - 10: c) Occasionally two or more lever press responses occurred close together in time with no intervening wood gnawing. Roughly 60% of all lever press responses emitted by all the subjects were reinforced (see efficiency ratios: Figures 5 - 10: b)

The cumulative records for Rat 12 on the final day differed from those of the other subjects in showing lower rates of wood gnawing and higher rates of lever press responding. Direct observation of this subject's behaviour showed that wood gnawing was interspaced with a complex pattern of gnawing at other objects. This rat appeared to gnaw the metal rod connecting the wood block to the sensor or, occasionally, to sniff and gnaw the pellet chute. Either of these

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* See P.117

Figures 5 - 10

(a) Shows the operant or pre-experimental rates of wood gnawing for each subject.

(b) Shows the efficiency ratios for each of the last 25 days prior to the final day (Test Day). Efficiency ratios are calculated by dividing the number of reinforced lever press responses in a session by the total number of lever press responses.

(c) The lower of the two cumulative records shows the lever press behaviour of each subject. Each lever press response steps the pen up one step. A downward "hatchmark" indicates that the response has been reinforced.

The upper record shows the wood gnawing behaviour. Each "gnaw" steps the pen up one step. The pen resets after every response. Two consecutive lever press responses without intervening woodgnawing do not show on this upper record but can be seen on the lower record.

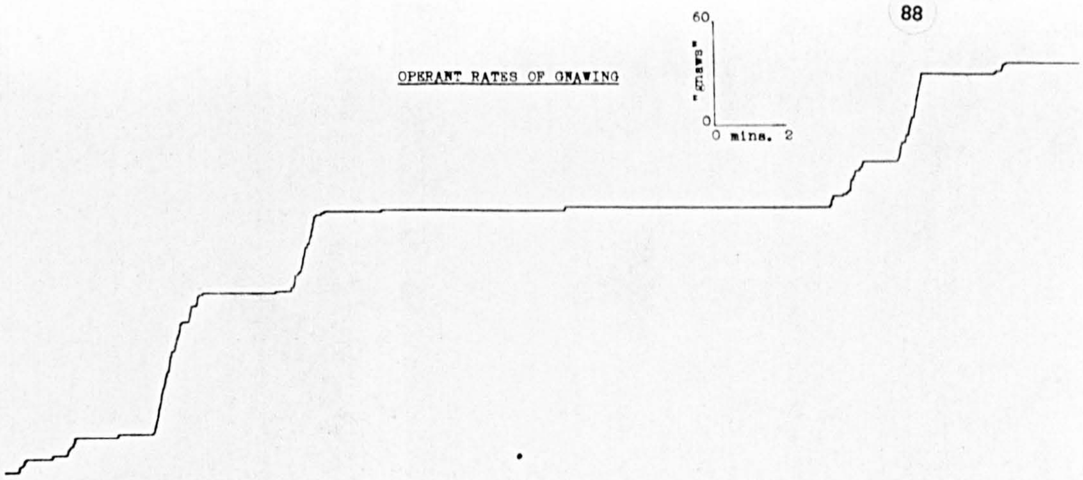
(d) The relative frequency distributions of inter-response times (IRTs) in 3 second categories. IRTs longer than 27 seconds were all placed in the final 27 + sec. category.

(e) The relative frequency distribution of inter response intervals measured by amount of woodgnawing in each IRI. Amount is measured in multiples of ten "gnaws" (decade). The distribution is divided into IRIs which terminate in a reinforced response (solid lines) and IRIs terminated by a non-reinforced response (interrupted lines). Total number of "gnaws" in the session are recorded in the top right hand corner of this figure.

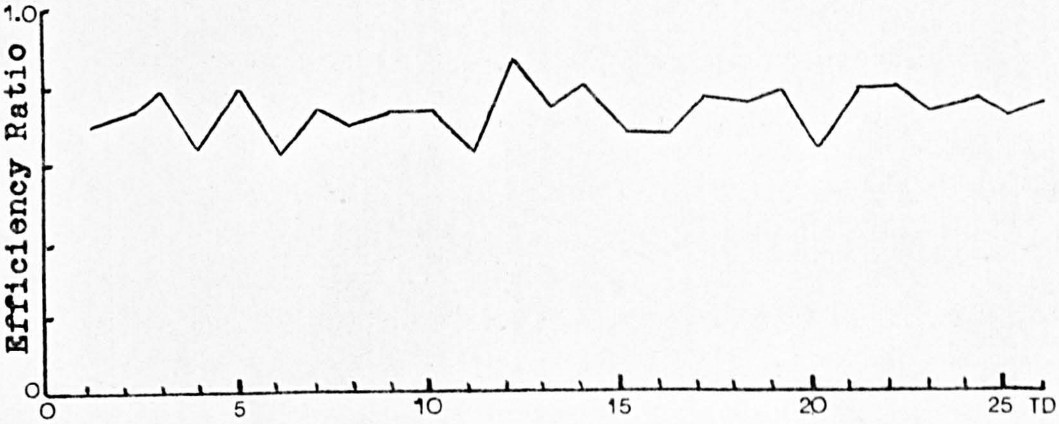
c,d,e illustrate Final Day Performance

Expt. 1 Rat 7 **Figure 5**

(a)

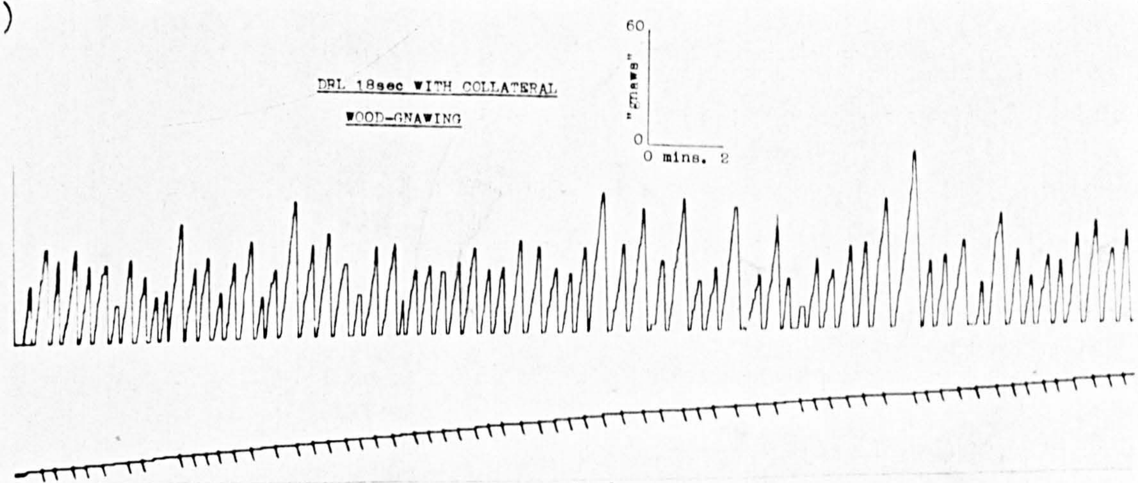


(b)

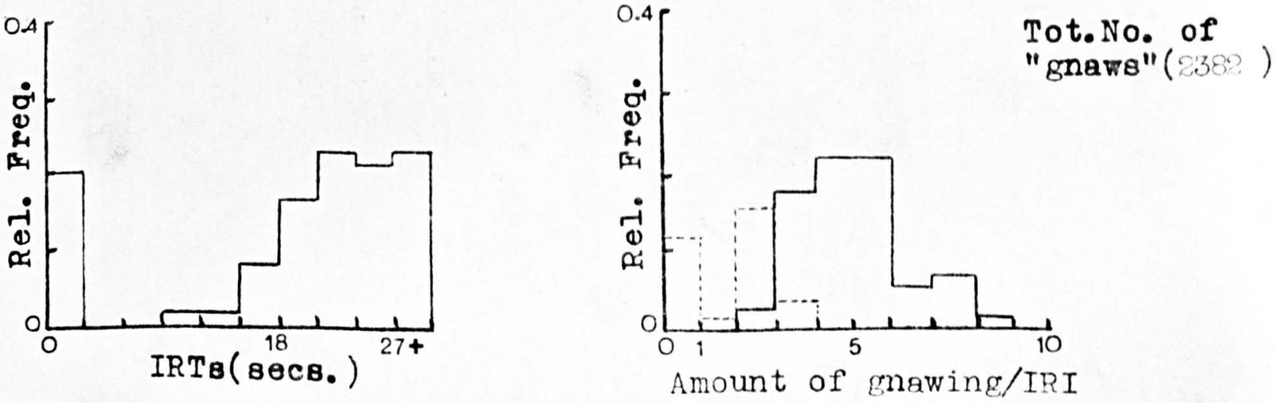


Stability of DRL behaviour, last 25 days before Test Day (TD)

(c)

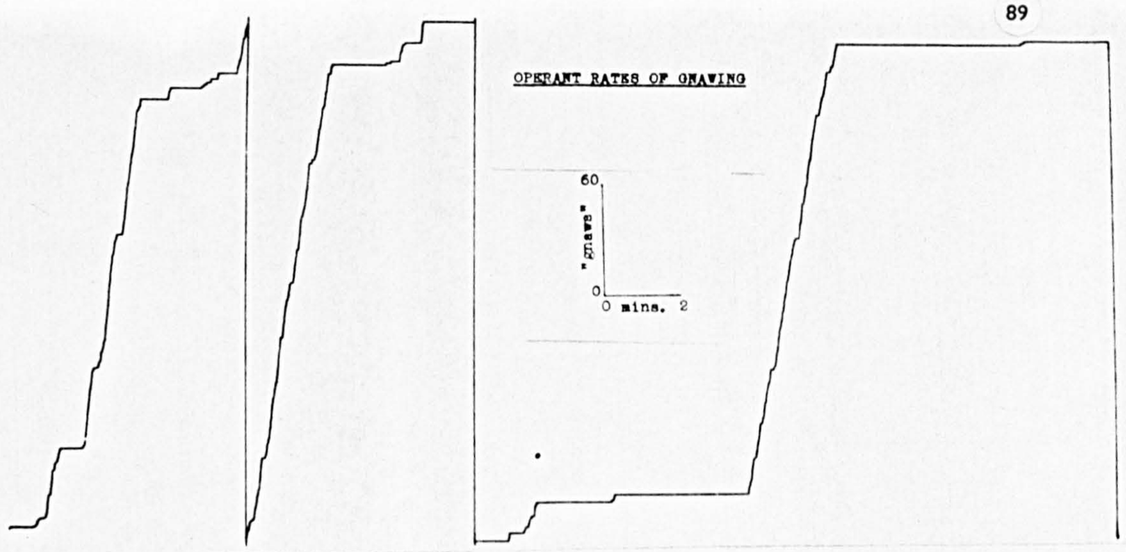


(d) (e)

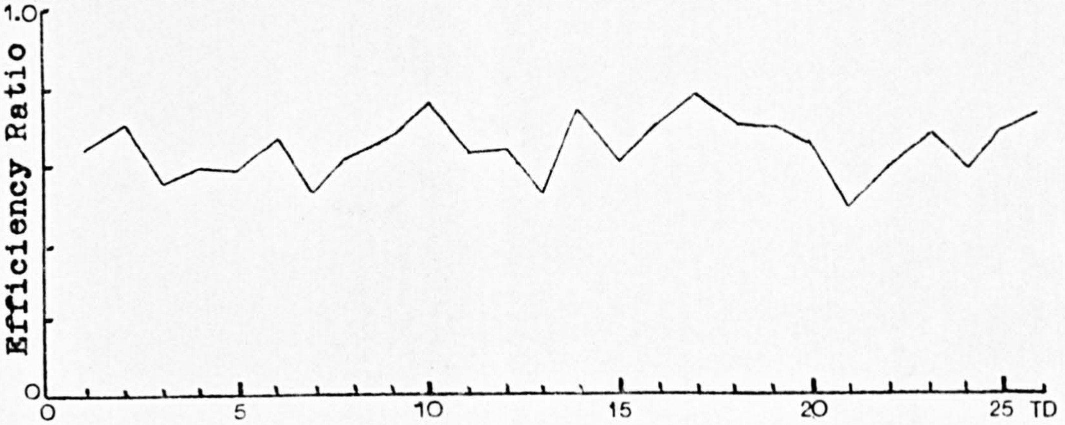


Expt. 1 Rat 8 **Figure 6**

(a)

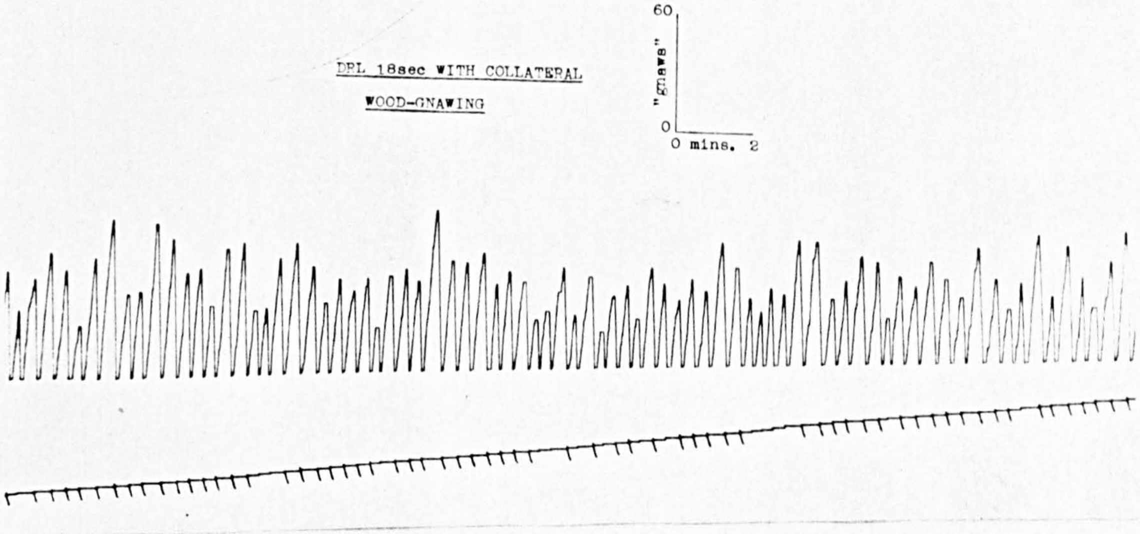


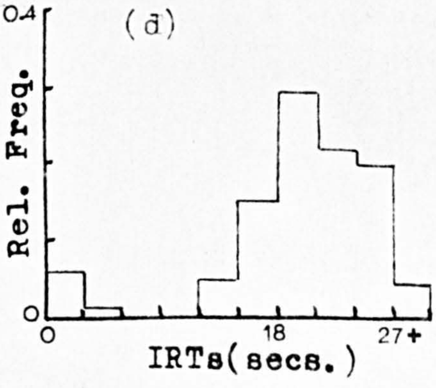
(b)

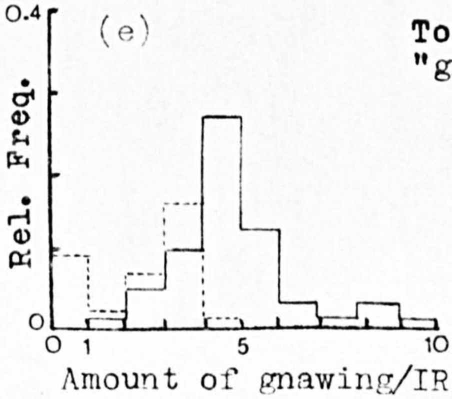


Stability of DRL behaviour, last 25 days before Test Day (TD)

(c)

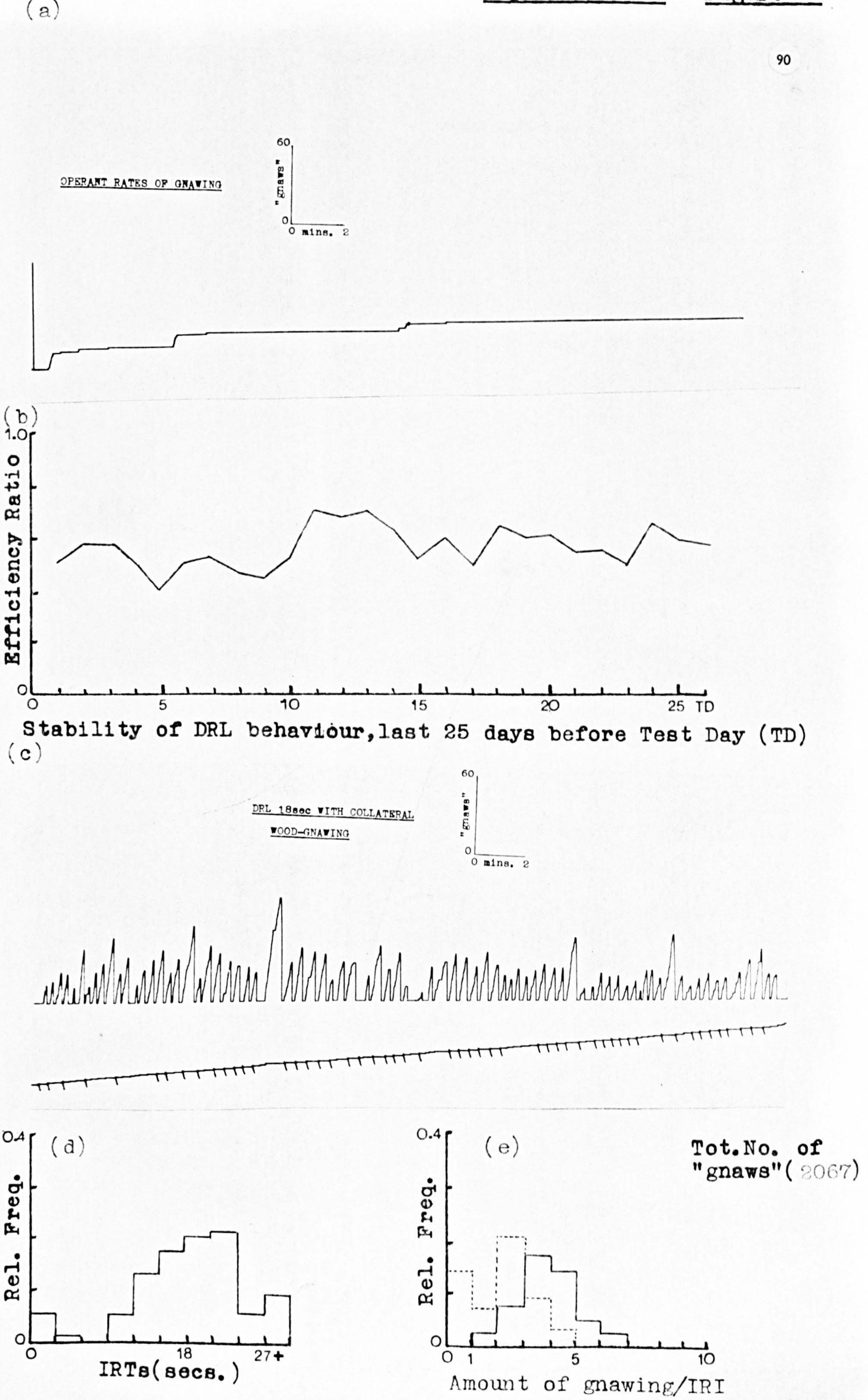




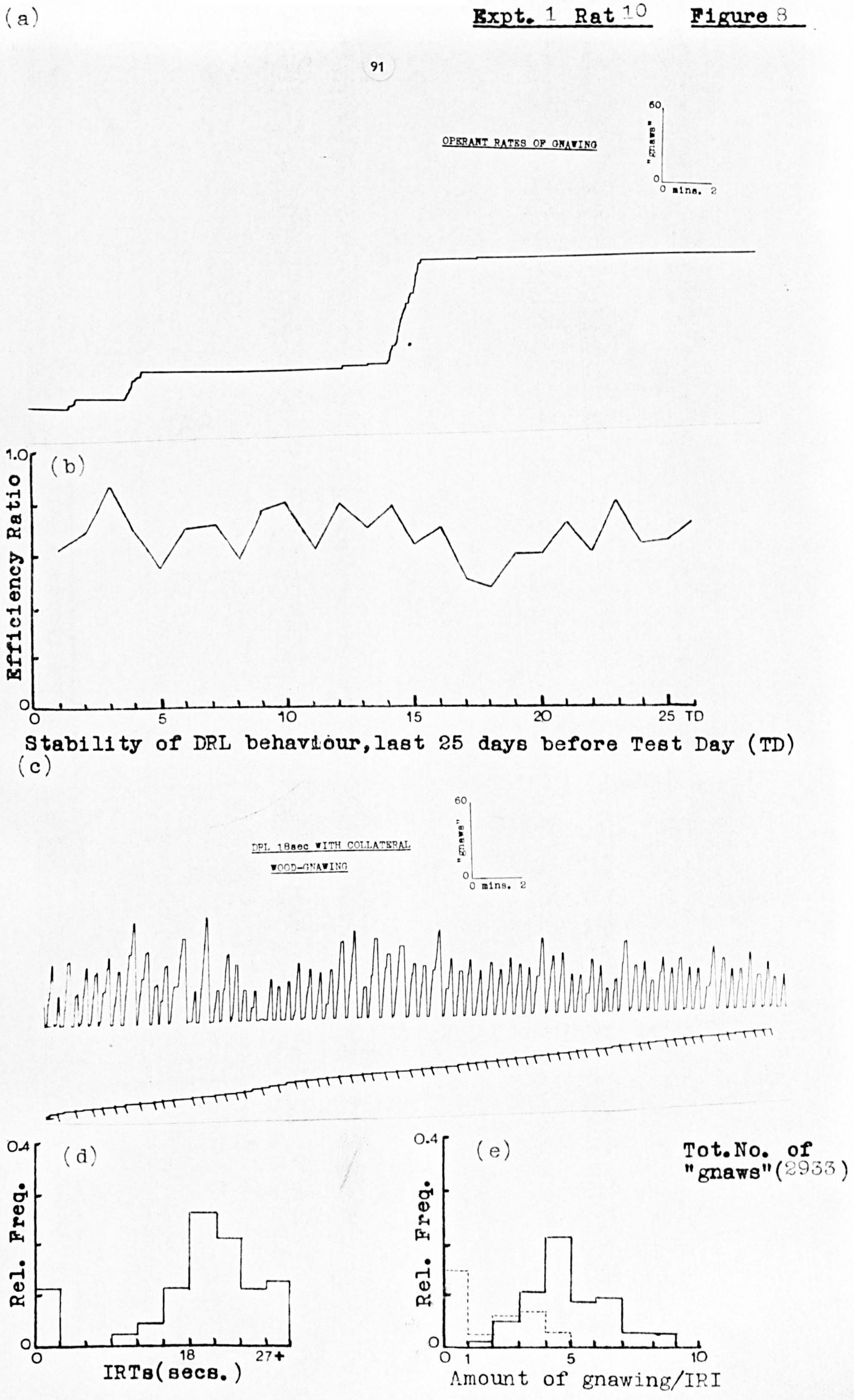


Tot.No. of "gnaws"(3723)

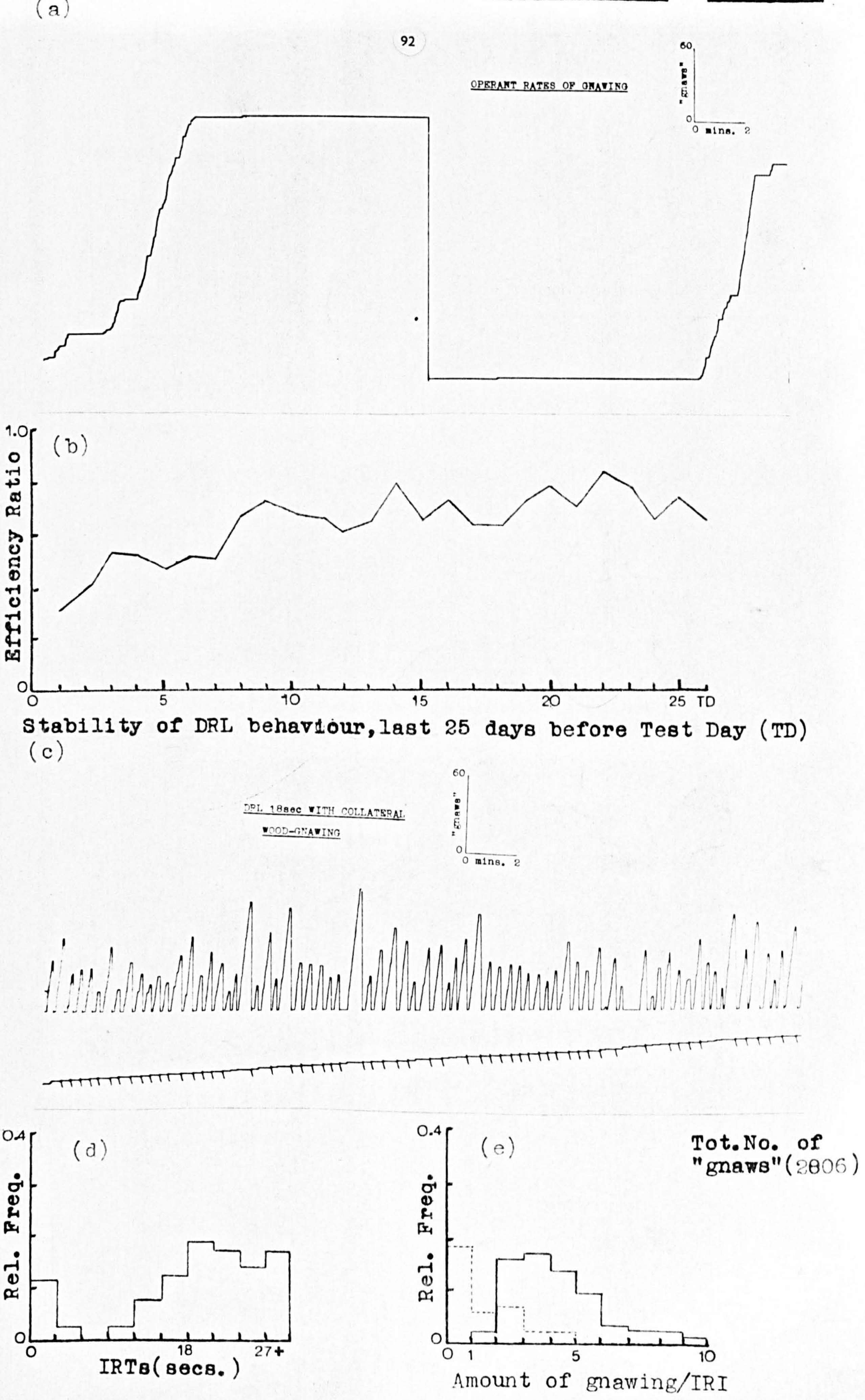
Expt. 1 Rat 9 **Figure 7**



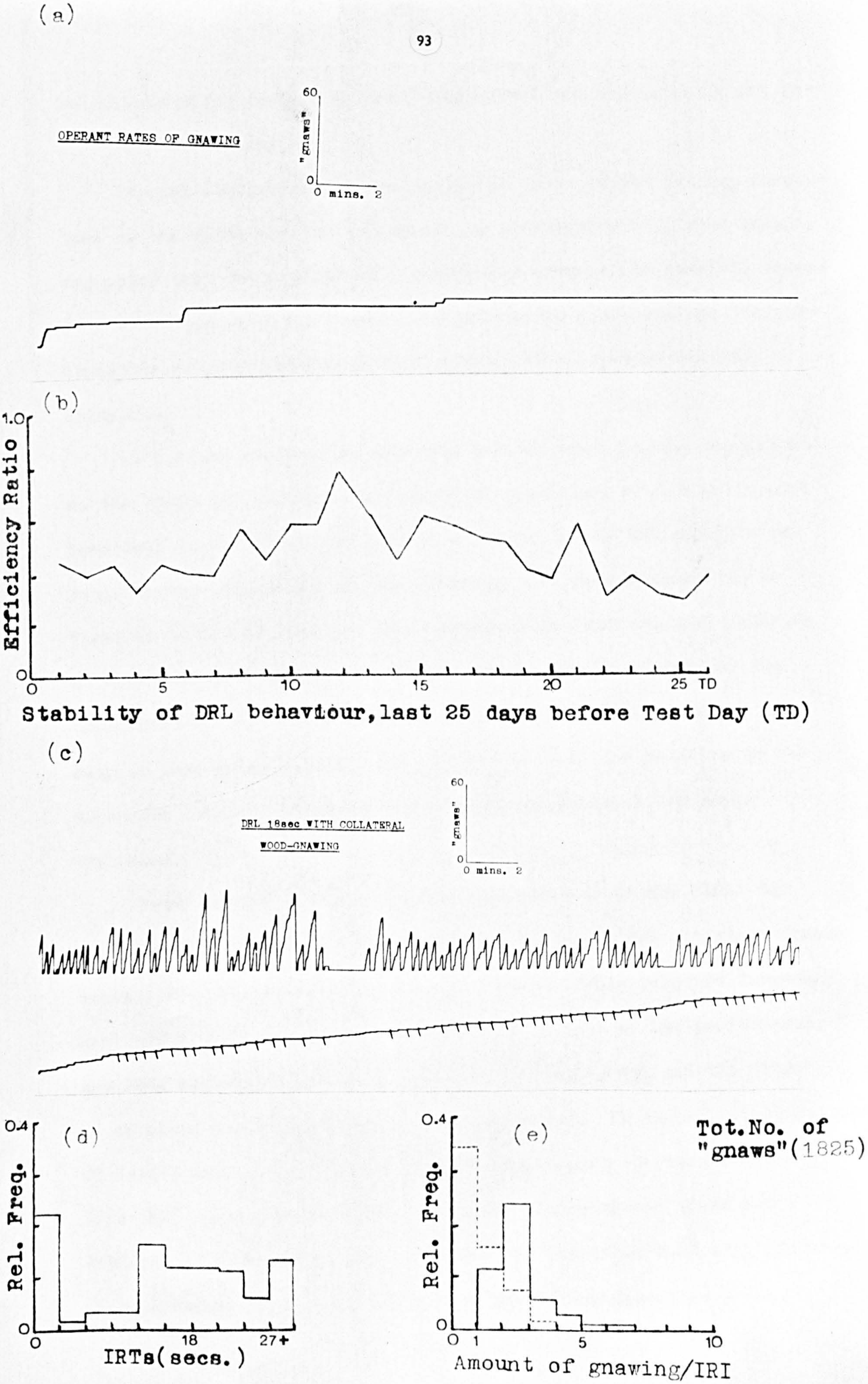
Expt. 1 Rat 10 **Figure 8**



Expt. 1 Rat 11 **Figure 9**



Expt. 1 Rat 12 Figure 10



behaviours might produce a "gnaw" signal but not consistently and relatively infrequently.

Visual comparisons of the amount of wood gnawing between responses on the final day, and the amount of pre-experimental wood gnawing suggested that there might be a connection between the absolute amount of stereotyped collateral behaviour emitted by a subject and the probability of wood gnawing by that subject in a pre-experimental situation.

A further observation was made between wood gnawing topographies on the final day and those on the first appearance of the collateral behaviour in the first few days of exposure to the DRL schedule requirements. Initially the wood gnawing behaviour appeared to be vigorous with much body and head movement and frequent rapid changes in body position relative to the woodblock. By the final day the topography of the woodgnawing was very stable, little movement of body or head being evident, and changes in position relative to the woodblock occurred infrequently between successive lever press responses.

More details of the subjects' performances on the final day are presented in the relative frequency distributions of interresponse times (IRTs) in seconds (Figures 5 - 10:d). These relative frequency histograms show the bimodal distribution typical of DRL performance, one mode occurring in the short (0-3 sec.) category, and the other on or about the criterion IRT value (18 sec.). In the IRT distributions of Rats 7 and 11 this second mode is less clearly defined because all IRTs >27 secs were placed in a terminal category and these two subjects produced more long IRTs than did the other subjects. However in both cases the distributions were bimodal as described above.

In addition to categorising the duration between any two responses as an interresponse time (IRT) it is also possible to refer to the interresponse interval (IRI) measured by the amount of wood gnawing which occurred during the interval. This IRI categorisation makes no attempt to estimate the duration of the interval in seconds as does the IRT analysis. Figures 5 - 10:e show the relative frequencies of IRIs categorised by the amount of woodgnawing in each IRI. It was evident from this data that the amount of woodgnawing prior to a reinforced response (solid lines) was nearly always greater than the amount of gnawing prior to a non-reinforced response (interrupted lines).

The detailed analysis of the woodgnawing behaviour (Tables I - VI) suggests that, irrespective of whether wood-gnawing followed a reinforced or a non-reinforced response, the rates of wood gnawing (measured as the mean time, in seconds, to complete ten "gnaws": DECADE) did not vary significantly within IRIs. Tables I - VI show the woodgnawing on the final day categorised by the number of decades of woodgnawing within each IRI. Each category is divided into successive decades of woodgnawing. That is, the first ordinal decade for each category contains the mean time in seconds to emit the first ten "gnaws", the second ordinal decade contains the mean time in seconds to emit the second decade of gnawing and so forth. Underneath the mean times are the variances of the different times which went up to make each mean time value. The "n" value on the extreme right shows the total number of IRIs (with that number of decades of woodgnawing) which occurred in the session. The IRIs are further subdivided into two matrices: those IRIs occurring after a reinforced response and those occurring after a non reinforced response.

TABLES I - VI

The Table is divided into two Matrices. The upper one is an analysis of all inter-response intervals which followed a reinforced response and the lower a similar analysis of IRIs which followed a non reinforced response. Final Day Performance.

Each cell within a matrix shows ✱ the mean time to complete ten "gnaws" and ✝ the variance of the times which make up the mean time, for all instances of a decade occurring at that ordinal position in an IRI with that amount of gnawing.

The number of IRIs in any category is given by the "n" value on the extreme right. Example:- For Rat 7, the mean of all the times (in seconds) to complete the 3rd decade of gnawing in the two IRIs which contained 6 decades of gnawing is 5.3 seconds : the variance of these times is 2.9.

Expt. 1 Rat 7 Table I

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	7.8 * – †										1
2	9.6 1.4	3.5 0.2									9
3	9.7 2.6	3.6 0.4	3.7 0.5								18
4	9.3 1.3	3.6 0.7	4.0 1.0	3.5 1.0							17
5	9.0 0.5	3.2 0.8	3.7 0.4	3.7 0.3	3.4 0.2						10
6	9.5 0.1	3.0 0.06	5.3 2.9	3.3 0.1	4.4 0.5	3.9 2.4					2
7	7.9 0.1	3.4 0.6	3.0 0.1	3.6 0.5	4.4 1.8	2.7 0.01	3.1 0.2				2
8	7.1 –	5.0 –	3.2 –	4.8 –	3.6 –	3.2 –	4.4 –	3.4 –			1
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	– – –										
2	7.3 3.7	2.9 0.7									5
3	6.5 2.9	3.7 0.6	4.3 1.8								5
4	– – –	– – –	– – –	– – –							
5	7.2 1.9	3.4 1.0	3.7 0.6	4.4 3.6	3.4 1.0						7
6	5.6 1.3	4.6 2.3	4.1 7.6	3.0 1.1	3.0 1.8	2.8 1,1					2
7	7.3 1.6	4.8 7.2	4.9 9.3	3.7 0.6	4.2 5.7	4.1 0.6	4.1 0.02				2
8	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –			
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	10.8* – †										1
2	8.7 0.4	3.5 0.6									5
3	8.5 1.9	3.1 0.3	3.2 0.5								16
4	8.2 1.2	3.2 0.6	3.1 0.4	3.5 0.2							15
5	7.8 2.2	3.1 1.4	3.6 0.4	3.4 0.3	3.3 0.3						6
6	7.4 1.4	2.8 0.01	3.3 0.02	3.6 0.03	3.5 1.0	2.8 0.05					2
7	6.3 –	3.1 –	2.6 –	3.4 –	4.5 –	3.0 –	3.7 –				1
8	8.4 2.5	2.8 0.3	2.8 0.3	6.9 14.4	5.8 10.5	3.2 0.1	3.8 1.0	3.2 0.3			3
9	– – –	– –	– – –	– –	– – –	– –	– – –	– – –	– – –		
10	7.0 –	2.8 –	2.4 –	4.7 –	9.4 –	2.5 –	3.2 –	3.5 –	2.9 –	4.2 –	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	8.6 2.9										2
2	8.9 6.2	3.4 0.6									5
3	7.2 1.3	3.3 0.4	3.7 0.3								7
4	8.3 1.7	3.8 0.6	3.5 0.9	3.5 0.5							10
5	8.1 5.4	2.7 0.1	3.6 0.6	3.3 0.3	3.2 0.02						5
6	7.4 –	3.5 –	4.5 –	3.6 –	2.8 –	3.2 –					1
7	– – –	– –	– – –	– –	– – –	– –	– – –				
8	– – –	– – –	– – –	– –	– – –	– –	– – –	– –			
9	– – –	– – –	– – –	– –	– – –	– –	– – –	– –	– – –		
10	– – –	– –	– – –	– –	– – –	– –	– – –	– –	– – –	– –	

Expt. 1 Rat 9 Table III

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	11.5 * 8.0 †										3
2	10.1 3.6	4.1 1.3									16
3	10.2 3.0	3.7 1.7	3.7 0.4								15
4	9.2 7.1	4.6 9.7	3.7 0.7	4.1 0.4							6
5	7.5 0.8	3.7 1.5	6.8 17.6	4.7 3.7	3.9 2.5						2
6	12.2 -	12.3 -	4.6 -	2.9 -	3.7 -	5.2 -					1
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	8.8 7.7										5
2	10.2 36.1	4.6 3.1									10
3	8.2 3.2	4.4 1.4	4.0 0.6								9
4	7.5 8.7	5.3 7.7	4.2 4.8	3.7 0.7							10
5	7.3 0.1	3.5 1.2	8.2 41.3	3.2 1.1	3.0 0.04						2
6	9.3 -	4.3 -	2.7 -	3.0 -	2.2 -	3.6 -					1
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

Expt. 1 Rat 10

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	10.0 19.2	* †									2
2	9.9 3.4	3.4 1.5									11
3	9.8 14.2	3.1 0.3	3.1 0.2								11
4	8.9 2.1	3.4 1.8	2.9 0.2	2.7 0.3							21
5	8.9 2.8	3.1 0.4	3.5 0.7	3.3 1.2	3.1 0.1						6
6	7.3 0.2	2.8 0.1	3.9 2.8	3.2 1.0	4.0 1.2	2.5 0.1					5
7	6.6 0.4	3.3 2.8	2.7 0.2	3.7 4.5	3.4 1.0	2.9 0.1	3.0 0.5				3
8	7.1 -	2.4 -	2.4 -	2.2 -	3.0 -	2.3 -	3.3 -	5.1 -			1
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	12.6 44.7										2
2	---	---									
3	6.5 2.3	2.7 0.1	3.1 0.3								7
4	5.9 6.8	2.6 0.01	3.1 0.7	3.5 0.5							2
5	7.9 1.3	2.7 0.2	3.2 0.01	2.7 0.01	3.3 0.1						2
6	5.5 2.5	2.5 0.2	4.0 4.6	2.9 0.2	2.9 0.1	3.1 0.2					4
7	---	---	---	---	---	---	---				
8	7.6 3.0	3.1 0.1	5.3 9.9	3.5 1.9	5.2 16.9	2.9 0.01	2.3 0.03	2.8 0.1			2
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

Table V

Expt.1 Rat11

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	10.8 * 0.8 †										6
2	9.9 3.1	4.2 1.7									18
3	10.6 2.6	3.6 0.9	3.6 0.3								16
4	10.1 2.1	3.8 0.2	4.1 1.3	3.8 0.9							7
5	9.7 0.9	4.3 1.0	3.7 1.1	3.1 0.8	3.0 0.1						5
6	7.9 0.7	3.6 1.2	3.5 0.3	3.6 0.3	3.9 0.6	3.3 0.03					3
7	8.4 -	2.6 -	4.1 -	3.2 -	2.9 -	2.9 -	3.3 -				1
8	- - -	- - -	- - -	- -	- - -	- - -	- - -	- -			
9	- - -	- - -	- - -	- -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- -	- - -	- - -	- - -	- - -	- - -	- -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.5 -										1
2	6.7 2.9	3.1 0.5									2
3	7.4 -	2.3 -	3.2 -								1
4	7.9 9.8	3.5 1.0	4.0 1.0	3.7 1.3							7
5	6.6 3.2	3.6 0.7	3.5 0.07	3.6 0.5	2.8 0.1						3
6	- - -	- - -	- - -	- -	- - -	- -					
7	6.1 -	3.6 -	2.6 -	4.1 -	3.2 -	3.2 -	4.2 -				1
8	7.3 0.3	2.5 0.06	4.3 0.03	2.9 0.03	3.3 0.1	3.0 0.03	2.9 3.4	2.9 0.3			2
9	4.8 -	4.2 -	3.8 -	3.3 -	3.6 -	3.0 -	3.4 -	2.5 -	3.9 -		1
10	- - -	- - -	- - -	- -	- - -	- -	- - -	- -	- - -	- -	

Table VI

Expt. 1 Rat 12

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	10.7 * 7.6 †										21
2	9.7 2.5	9.0 13.6									18
3	8.7 4.7	6.0 5.2	5.2 2.8								5
4	7.8 -	5.1 -	3.8 -	7.1 -							1
5	- - -	- - -	- - -	- - -	- - -						
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.6 5.0										10
2	9.3 12.5	6.1 6.9									15
3	6.1 3.7	4.9 0.4	4.7 0.9								3
4	11.6 8.7	5.8 0.9	4.0 0.5	6.0 0.04							2
5	9.9 -	3.0 -	3.9 -	5.4 -	5.3 -						1
6	5.9 -	3.2 -	6.6 -	4.3 -	5.2 -	4.2 -					1
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

Pearson Product Moment correlation coefficients were obtained for the mean time data in each IRI category (and in each matrix) which contained two or more decades of woodgnawing occurring after the first ordinal decade (which was excluded from the analysis). As the behaviour of Rat 12 appeared atypical it's data was also excluded from these calculations. Out of the resulting 49 product moment correlation coefficients 20 were positive and 29 were negative. Assuming that the probability of a negative correlation were 0.5, this result is not significant (0.1264 probability of occurrence by chance).

The first ordinal decade time included the time taken to eat the food pellet (in the case of IRIs following reinforcement) and the time taken to return to the woodblock (the duration of this period of unrecorded behaviour will be called the "post response pause"). Consequently these decade times cannot be compared with decades occurring later in the IRI as these later decades measure the time for a decade of gnawing only.

Excluding the data, therefore, from the first ordinal decades, there was no consistent pattern in changes of woodgnawing "rates" within the IRI categories (Figures 11 - 16). However visual inspection of the variance values of the times which make up the mean decade time suggested that within an IRI category there was a trend to lower variance values in later decades. A Pearson Product Moment correlation analysis of this variance data in each IRI was carried out for each IRI category (in each matrix) which contained two or more decades of woodgnawing occurring after the first ordinal decade, which was excluded. As the behaviour of Rat 12 appeared atypical it's data was also excluded from these calculations. Out of the resulting 40 correlation coefficients 12 were positive and 28 were negative. Assuming that the probability of a negative value is

TABLE VII

The Pearson Product Moment correlation coefficients for the variance values of the mean times to complete 10 "gnaws" data. For each subject, and within each IRI category, the upper value shows the correlation coefficient for the post reinforcement IRIs and the lower value for the post non-reinforced response IRIs.

RAT NO.

IRI (decades/IRI)	7	8	9	10	11	12
1	- - -	- -	- - -	- -	- - -	- -
2	- - -	- -	- - -	- -	- - -	- -
3	+1 +1	+1 -1	-1 -1	-1 +1	-1	- -
4	+.9 +.3	-1 -.2	-.9 -.9	-.8 +.7	+.6 +.9	- -
5	-.9 -.5	-.8 -.3	-.2 -.3	-.01 -.4	-.9 -.6	- -
6	+.3 -.8	+.4	- - -	-.2 -.4	-.7 +.5	- -
7	-.1	-.2	- - -	-.5 -.2	- - -	- -
8	- - -	- -	- - -	- -	- - -	- -
9	- - -	- -	- - -	- -	- - -	- -
10	- - -	- -	- - -	- -	- - -	- -

Results of Pearson Product Moment correlation

[redacted]

TABLES VII a and b

(a) 't' tests for differences between "rate" measures in post-reinforced response IRIs and post-non reinforced response IRIs.

In the 't' tests on the next page 't' was calculated given the means and standard deviations:-

$$t = \frac{\bar{x}_1 - \bar{x}_2}{p\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

where $$p = \sqrt{\frac{(N_1-1)\sigma_1^2 + (N_1-1)\sigma_1^2}{N_1 + N_2 - 2}}$$

where $\bar{x}_1$ and $\bar{x}_2$ are the means, σ_1 and σ_2 are the standard deviations, and N_1 and N_2 are the number of values in each sample.

't' values which are underlined are significant;-

x.x sig. at 0.05 level

x.x sig. at 0.01 level

(The results overleaf support the contention that there was no significant difference between mean decade times in post reinforced response IRIs and post non-reinforced response IRIs.)

(b)

Correlation coefficients between the mean duration of the post-response "pause" and the amount of stereotyped collateral behaviour in the ensuing interresponse intervals (IRIs).

TABLES VIIa and b

(a)

't' test values for similarly placed mean decade times in post-reinforced and post non-reinforced matrices.

Inter-response Interval (Decades of gnawing/IRI)

Expt.1	Ordinal decade number						
Rat 7	2	3	4	5	6	7	8
2	1.8						
3	-0.3	-1.2					
4							
5	-0.4	0.0	-1.1	0.0			
6	-1.5	0.5	0.4	1.3	0.8		
7	0.7	-0.9	-0.1	0.1	-2.5	-3.0	
Rat 8							
2	0.2						
3	-0.8	-1.7					
4	-1.9	-1.3	0.0				
5	0.7	0.0	0.3	0.4			
Rat 9							
2	-0.9						
3	-1.3	-1.0					
4	-0.5	-0.5	1.0				
5	0.2	-0.3	1.0	0.8			
Rat 10							
2							
3	1.7	0.0					
4	0.8	-0.6	-1.9				
5	0.8	0.5	0.7	-0.8			
6	1.2	-0.1	0.6	1.9	-2.4		
Rat 11							
2	1.2						
3							
4	0.7	0.2	0.2				
5	1.0	0.3	-0.8	0.9			
Rat 12							
2	2.6						
3	0.8	0.5					

(b)

Correlation coefficients between the mean duration of the post-response "pause" and the amount of stereotyped collateral behaviour in the ensuing inter-response intervals (IRIs).

Expt.1	Rat 7	Rat 8	Rat 9	Rat 10	Rat 11	Rat 12
Post reinforced response IRIs	-0.42	-0.76	-0.17	-0.94	-0.86	-0.99
Post non-reinforced response IRIs	-0.19	-0.58	-0.33	-0.54	-0.43	-0.26

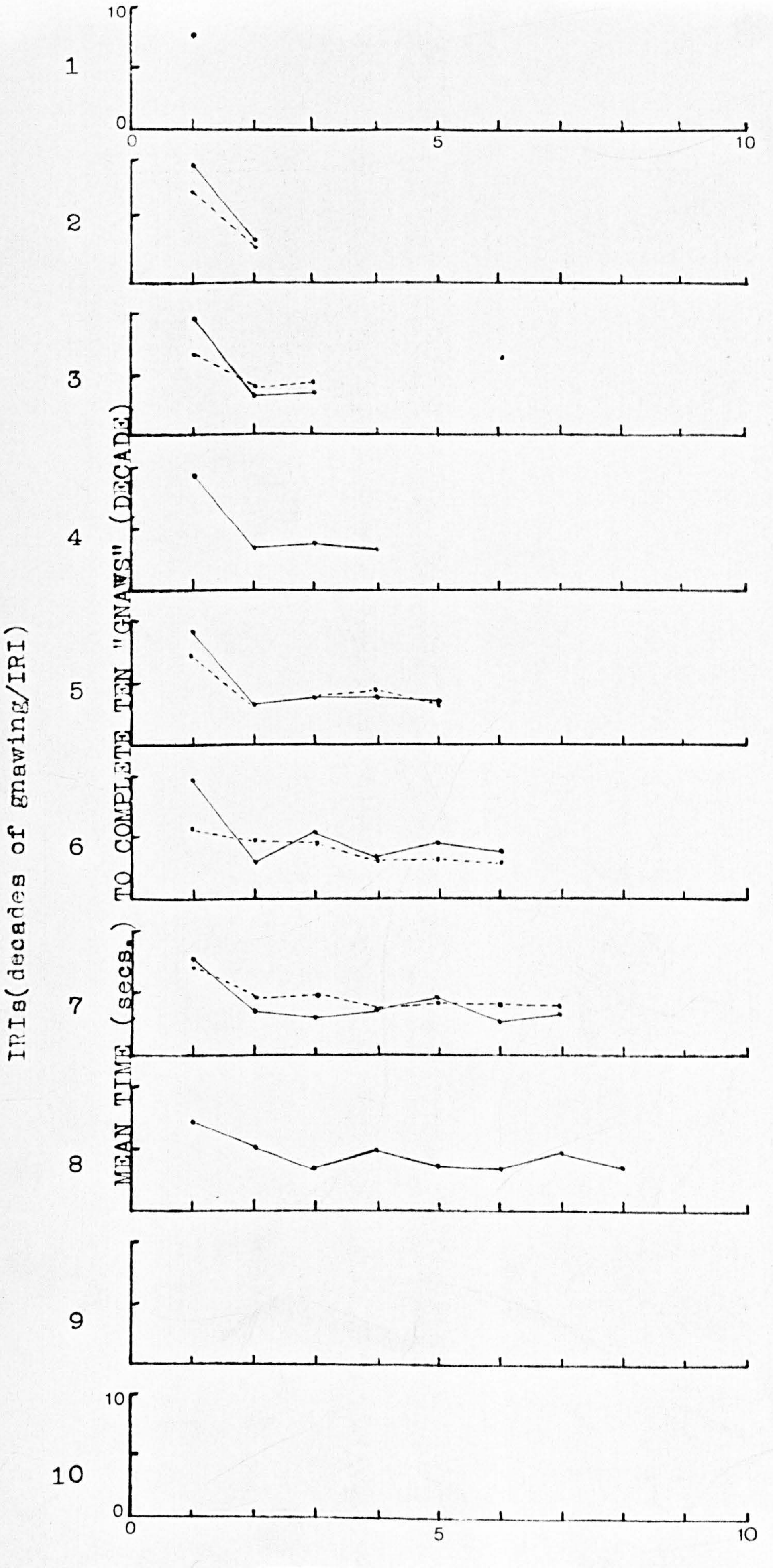
(These negative correlation coefficients confirm the observation that the shorter the post response time the greater the amount of gnawing in the remainder of the IRI.)

FIGURES 11 - 16

The values for the mean time to complete ten "gnaws" from Tables I - VI are plotted graphically. The data from the post reinforcement IRIs matrix are plotted in solid lines. That from the post-nonreinforcement IRIs in interrupted lines.

Figure 11

Expt. 1 Rat 7



Expt. 1 Rat 8

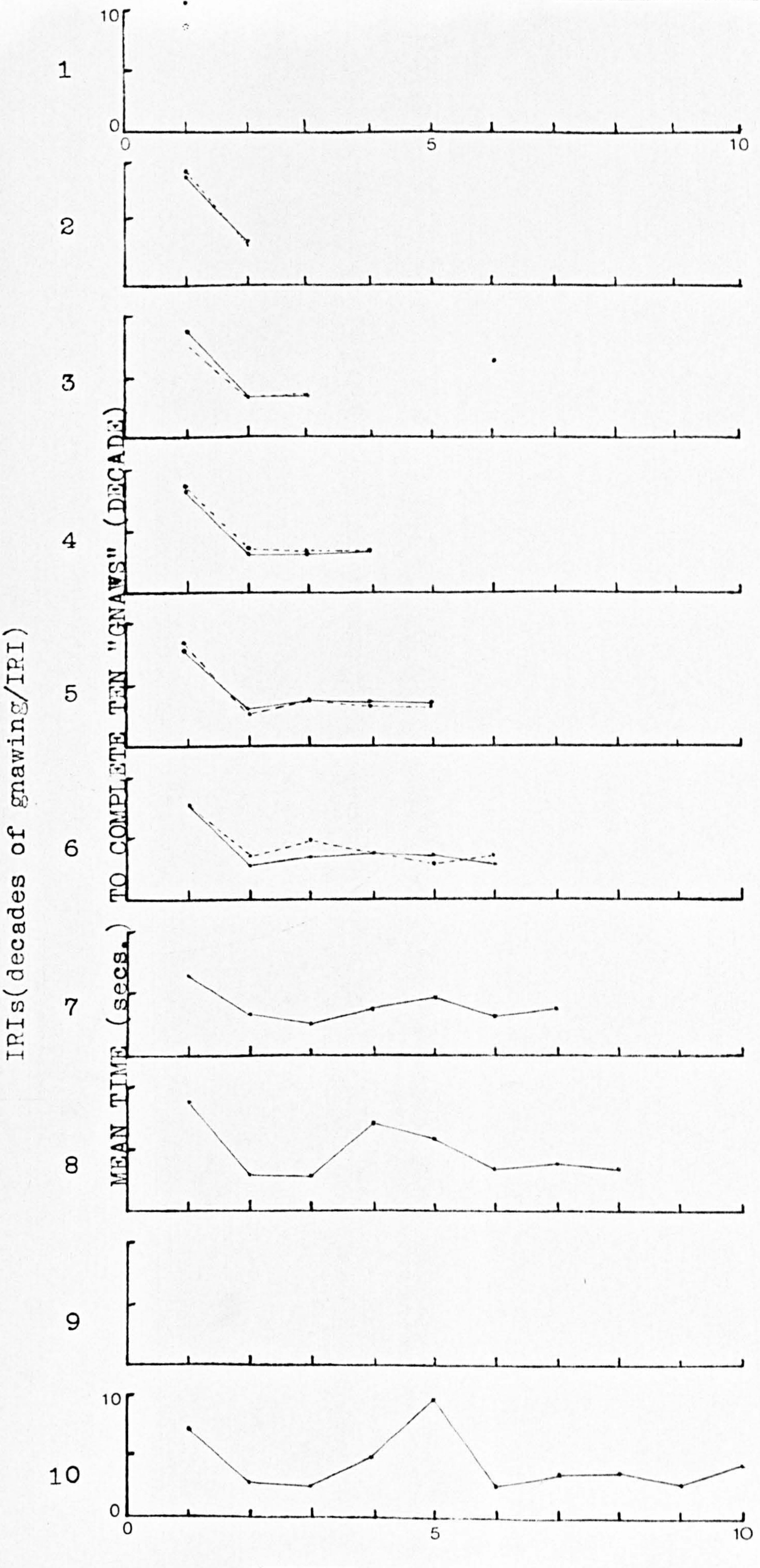

10
0
0
5
10
1
2
3
4
5
6
7
8
9
10
IRIs(decades of gnawing/IRI)
MEAN TIME (secs.) TO COMPLETE TEN "GNAWS" (DECADE)
ORDINAL DECADE NUMBER

Figure13

Expt. 1 Rat 9

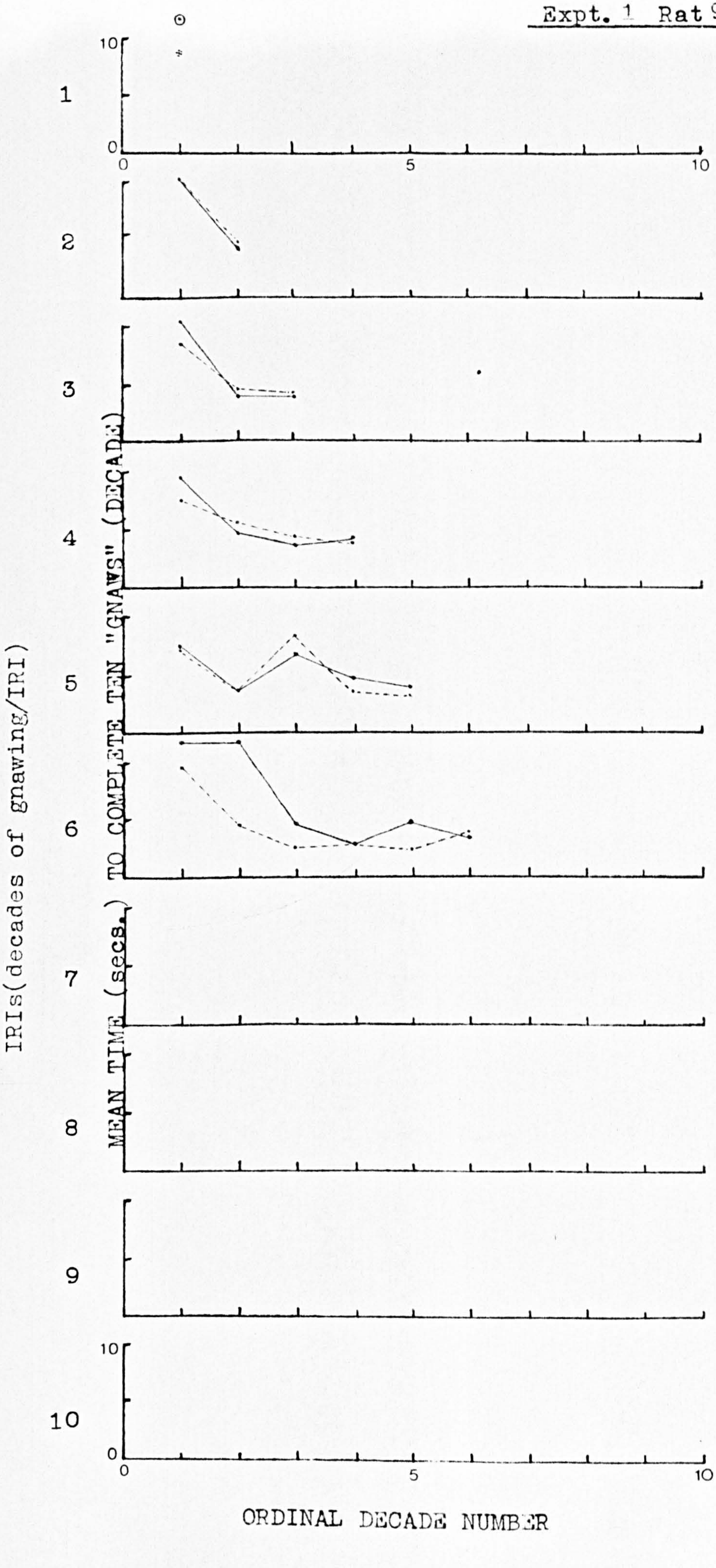


Figure 14

Expt. 1 Rat 10

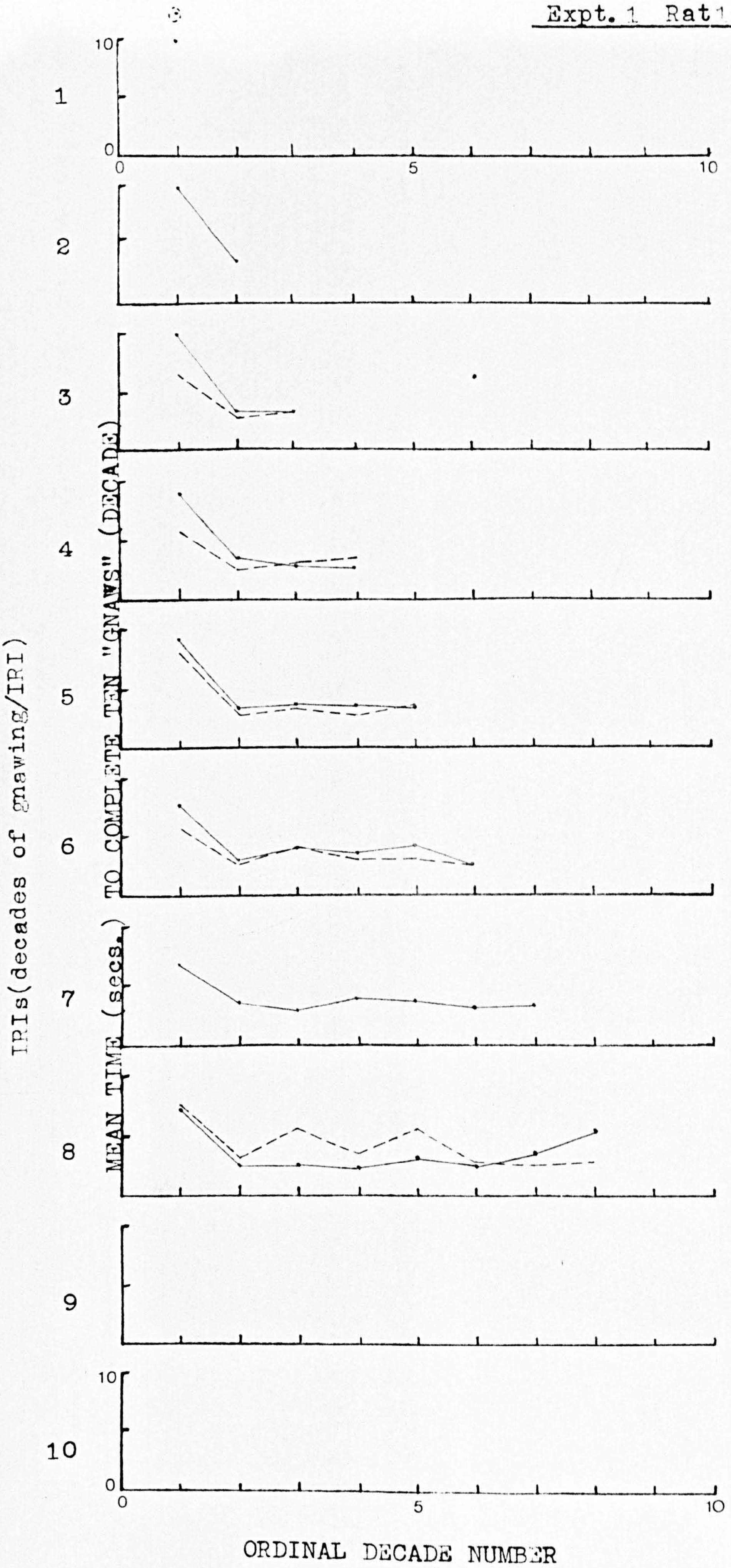


Figure 15

Expt. 1 Rat 11

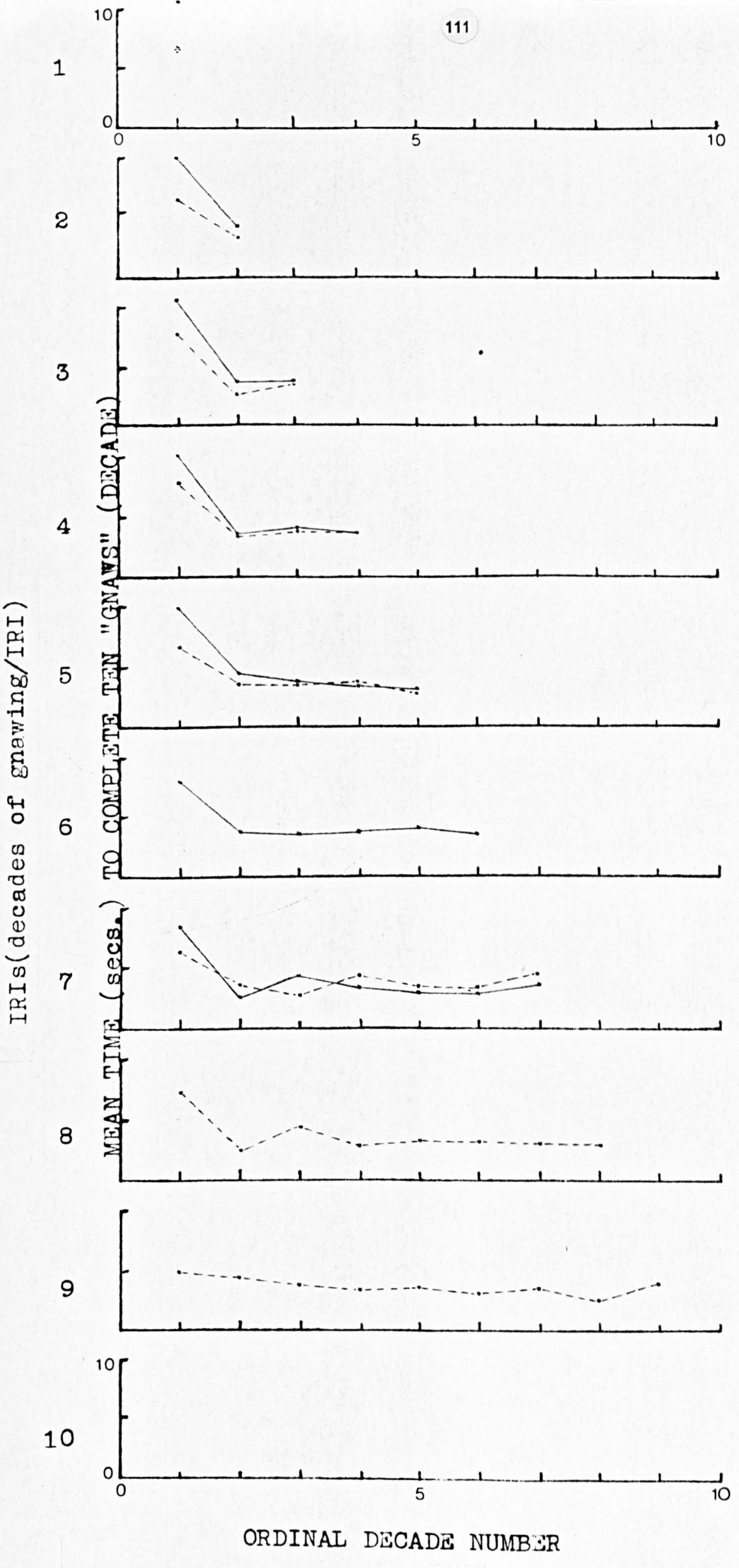
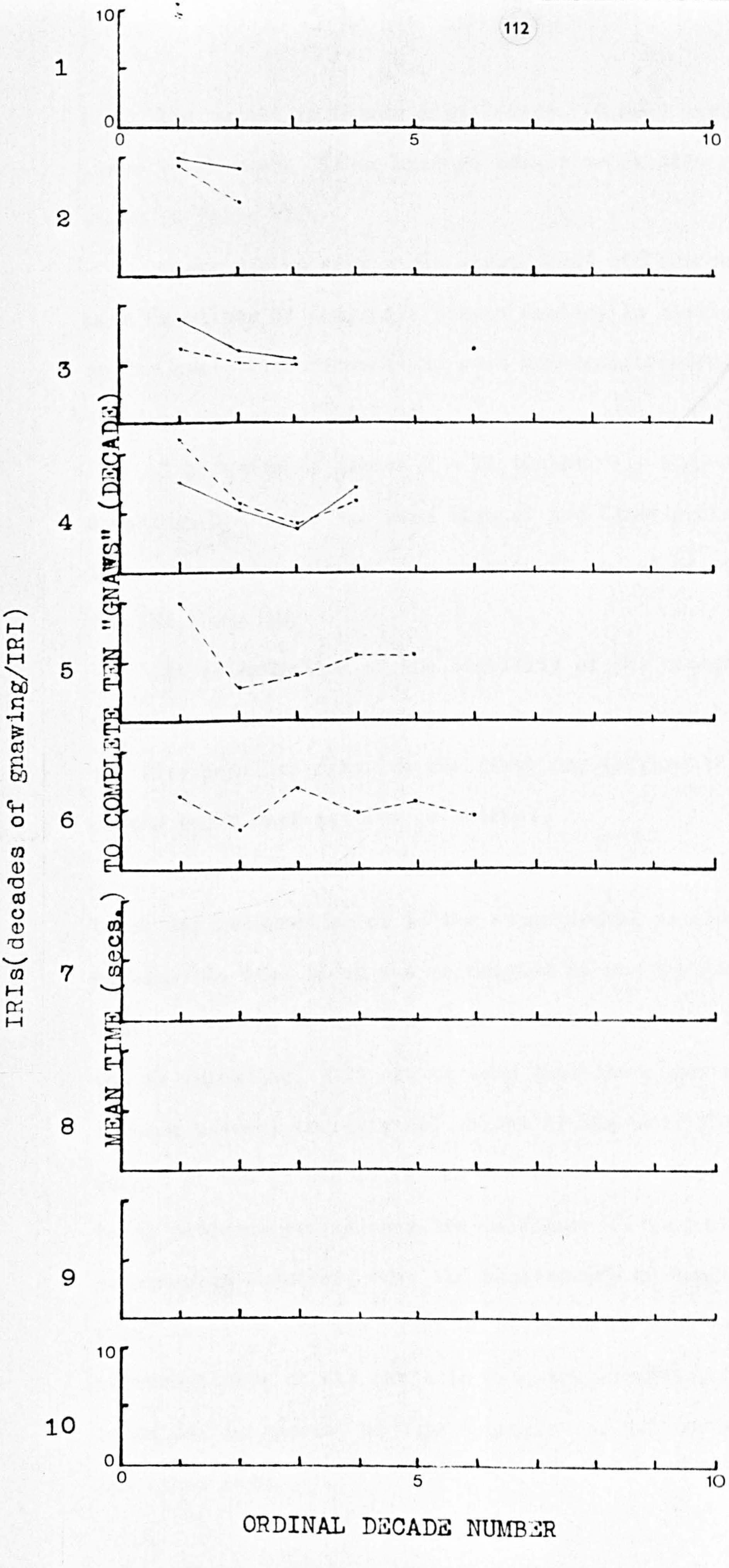


Figure 16

Expt. 1 Rat 12



0.5, this result is highly significant. (0.0083 probability of occurrance by chance). These product moment correlation coefficients are shown in Table VII.

There was no consistent significant difference between the mean durations of similarly placed decades in similar IRI categories in the post-reinforcement and post non-reinforcement IRI matrices (a 't' test was used).(Table VIIa)

Inspection of Tables I - VI tentatively suggests that, generally speaking, the lower the mean time of the first ordinal decade in an IRI category the greater the subsequent amount of woodgnawing in the IRI.(Table VIIb)

An illustration of the stability of the woodgnawing behaviour is shown in the tooth mark patterns on the gnawed blocks of wood in the five sessions prior to the final day (Figure 17). The stereotypy of the tooth mark pattern is evidant.

On each of these 5 days the weight of each subject's wood block was recorded prior to the experimental session. After each session the wood block was re-weighed as was the (dried) wood chip detritus in the refuse tray (the detritus was dried to remove moisture due to urination). It can be seen that there was only a small difference between the original weight of the wood block and the combined weight of the gnawed block and the detritus. The subject s whose tooth patterns are illustrated in Figure 17 were arbitrarily chosen as examples; however, both the consistency of tooth marks across final sessions and the lack of evidence of wood ingestion are representative of all subjects with the exception of Rat 12 whose behaviour in general on this schedule was not the same as that of the other rats.

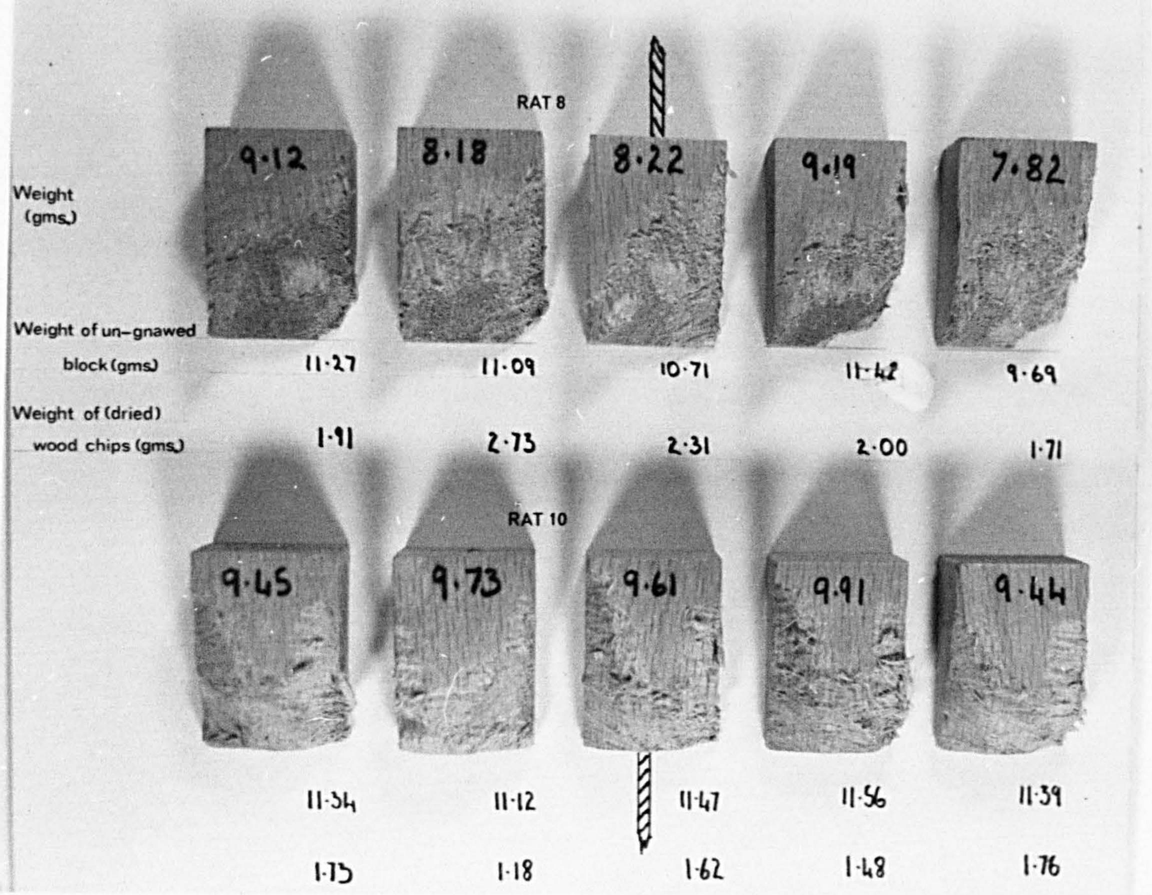
FIGURE 17

This illustrates the stereotypy of the tooth mark patterns on the gnawed wood blocks for two Rats (8 and 10) in the last 5 sessions prior to the final day.

Weight values (in grams) for each wood block are given:- ungnawed wood block, gnawed wood block and weight of dried wood chips taken from refuse tray.

The position of the sensor rod for each group of wood blocks is indicated.

Stereotypy of Gnawing Patterns: 5 Consecutive Sessions (examples produced minimal excreta thus increasing reliability of measures.)



RAT 8

Weight (gms.)	9·12	8·18	8·22	9·19	7·82
Weight of un-gnawed block (gms.)	11·27	11·09	10·71	11·42	9·69
Weight of (dried) wood chips (gms.)	1·91	2·73	2·31	2·00	1·71

RAT 10

Weight (gms.)	9·45	9·73	9·61	9·91	9·44
Weight of un-gnawed block (gms.)	11·34	11·12	11·47	11·56	11·39
Weight of (dried) wood chips (gms.)	1·73	1·18	1·62	1·48	1·76

Figure 17

Discussion

Perhaps the most important finding to emerge from this experiment is the general one that it did not appear to be difficult to obtain relatively consistent patterns of similar collateral behaviour between subjects. With the exception of the final subject, all animals produced woodgnawing and lever press behaviour and little other unrecorded behaviour. The failure of Rat 12 to achieve stable DRL performance of the kind observed in the other subjects cannot be explained with any degree of accuracy. It was noted throughout this investigation that occasionally the last subject to be run each day produced behaviour which was atypical of behaviour emitted by the other subjects in the group. This is believed to be due to the timing of feeding in the home cage. Following a daily group of subject sessions all subjects were weighed and fed. It may be that the relatively close temporal order of completing an experimental session and being fed several grams of food in the home cage affected the performance of the subject which was run last of the group.

For the other subjects in this experiment the results indicated that, on the final day, lever press response performances compared well with other reported DRL 18 sec. schedule performances by rats (Laties et al., 1969). The relative frequency distributions of IRTs, for example, compare favourably with the other reported data. There were indications of the characteristic response "bursts" in the first of the two modes in the IRT distributions, the second mode occurring on, or about, the criterion IRT (18 sec.) value. The cumulative was more variable early in the IRI.

Other evidence from these results tentatively suggests that the former interpretation is more likely. Inspection of the cumulative records shows that very brief pauses did occur frequently between sequences of woodgnawing. However an unequivocal explanation of the increased stereotypy of woodgnawing towards the end of IRIs must await unambiguous recordings of such behaviour.

That the highly significant trend to less variable mean times in later decades of the IRIs is not more obvious from visual inspection and comparisons between terminal decade variances and the variances of decades earlier in the IRI category may be due to the limitations of the type of measurement employed in this and subsequent experiments, which have been mentioned previously. A terminal decade, could, in fact, be separated from the response terminating the IRI by up to 9 "gnaws". Therefore data on the final few "gnaws" in some IRIs were inevitably lost. This method of measuring woodgnawing, therefore, also limits the degree of detail with which it is appropriate to analyse this data.

The "rate" variance result can possibly best be summarised by saying that in the latter half of woodgnawing sequences within IRTs, the times required for 10 "gnaws" to occur were less variable (or more stereotyped) than corresponding measures in the earlier half of such sequences.

One observation which is not easy to explain is the apparent inverse relationship between the mean duration of the first decade in an IRI category and the subsequent amount of wood gnawing in that IRI category. It is not the case that the IRI is of fixed duration so that less time spent in a post response "pause" plus first ten "gnaws" must mean more time spent wood gnawing. The difference between the mean times for the first ordinal decade in IRIs with two decades as opposed to IRIs with six decades, is only 2 - 3 seconds while the difference in actual IRI durations may be 10 - 15 seconds or more. The fact that the first ordinal decade compounded the durations of the post response "pause" and the first ten "gnaws" leads one to query whether the amount of gnawing following the first ordinal decade varied as a consequence of (1) the duration of the post response "pause" or (2) the rate at which the first ten "gnaws" were emitted or (3) a combination of both (1) and (2). Further investigation of this result is obviously required.

It was observed that there did not appear to be any significant difference in "rates" of woodgnawing between IRIs following reinforcement and IRIs following non-reinforced lever press responses. Lowe and Harzem (1973) demonstrated that in rats on a two component DRL schedule, where a second criterion IRT value was contingent on a non-reinforced response, the distribution of lever press responses following a reinforced or non-reinforced response, were controlled by the fate of this prior response. Where the second IRT value was smaller than the IRT value following a reinforced response, two distinct IRT distributions were obtained for responses which followed a reinforced and a non-reinforced response. This being the case it is perfectly possible that the collateral behaviour following a reinforced or a non-reinforced response on a single value DRL might be different in some way. It is apparent that as far as "rate" differences are concerned this did not seem to be the case in the present experiment. The finding that wood gnawing is more stereotyped in the latter half of IRIs could be construed as supporting a number of explanations of the function of collateral behaviours in DRL performance.

It could be regarded as the uniform rate behaviour equivalent of the "scalloped" responding which might be expected if collateral behaviour were maintained by non-contingent delayed reinforcement. Alternatively it could be construed as a consequence of more pronounced inhibition of a lever press response in the later stages of an IRT when lever press response probability is greater.

The only explanation mentioned in the previous chapter which does not readily accommodate this result is the "counting" hypothesis. If the organism were using amount of collateral behaviour as a cue for lever press responding it is not immediately obvious why such counting should be more "accurate", or evenly spaced, later in an IRT. It would seem that a pure "counting" hypothesis based on amount, rather than duration, of collateral behaviour is the least useful explanation of the present result, although this result does not entirely invalidate that explanation.

This experiment has established that it is possible to obtain and analyse stable DRL 18 sec. schedule performance with stereotyped collateral woodgnawing behaviour. Analysis of the wood gnawing suggested that the times to complete 10 "gnaws" were consistently less variable in the second half of the IRIs.

The results of this experiment clearly confirm and extend the findings of Laties et al. (1969) in analysing examples of a DRL stereotyped collateral behaviour. However the function of such a behaviour in efficient DRL performance is still unclear: the knowledge that it is possible to obtain and measure stable behaviour of this type encouraged the following investigation into the nature of these behaviours.

SUMMARY OF EXPERIMENT 1

SUMMARY

The stable performance of five out of the six rats exposed to the DRL 18 sec. schedule was analysed in detail and the results may be summarised as follows:

(1) The DRL performances obtained compared well with other reported performances on the DRL 18 sec. schedule.

(2) Woodgnawing as a collateral behaviour was consistently produced by five out of six subjects.

(3) There was considerable stereotypy in woodgnawing patterns over at least the last 5 sessions as revealed by the teeth marks on the woodblocks.

(4) The mean times to complete 10 "gnaws" were consistently less variable in the second half of the IRIs.

(5) There was some evidence that the amount of woodgnawing following the first decade of "gnaws" in an IRI varied inversely with the duration of the first ordinal decade.

The sixth rat did not produce stable DRL performance and the collateral behaviour emitted was a-typical of the behaviour produced by the other subjects. Consequently the data from this subject was not used in the analyses of the data.

CHAPTER V

EXPERIMENTS 2, 3, and 4

MANIPULATIONS OF THE COLLATERAL BEHAVIOUR WHILE MAINTAINING THE DRL SCHEDULE REQUIREMENTS

EXPERIMENT 2

Introduction

This experiment was the first of a group of three experiments which attempted to manipulate the stereotyped collateral behaviour while maintaining the DRL schedule requirements.

Having ascertained from Experiment 1 that Rats 7 - 11 (inclusive) were emitting stable DRL 18 sec. performance with stereotyped collateral woodgnawing, the aim of this experiment was to obtain detailed data on the effect of removing the opportunity to emit woodgnawing by removing the woodblock.

Laties, Weiss and Weiss (1969) have clearly demonstrated that removing the opportunity to emit the stereotyped collateral behaviour markedly reduced reinforcement frequency, and increased lever press rates on a DRL 18 sec. schedule. Reintroduction of the opportunity to emit the stereotyped collateral behaviour immediately restored the DRL 18 sec. performance to it's previous level of efficiently spaced lever-press responding. The present experiment looked, in detail, at the breakdown of efficient DRL 18 sec. performance when the woodblock was removed.

Method

Subjects: Rats 7, 8, 9, 10, 11 used in the previous experiment. Rat 12 was not used, as it did not emit either efficient DRL 18 sec. lever press responding, or stable stereotyped collateral behaviour of a homogeneous and recordable nature.

Apparatus: As described in the General Method section and in Experiment 1.

Procedure: Following Experiment 1 the subjects had been restored to a free food regime in their home cages. This condition lasted for 21 days following which they were again gradually food deprived until their bodyweights returned to the 85% free feeding bodyweight values which had been maintained in the first experiment.

All subjects were then given 10 daily sessions on the DRL 18 sec. schedule with wood present. Following this, on the next 5 days, the door of the experimental chamber was opened 15 minutes after the beginning of the session. The experimenter placed his hand on the woodblock for 3 seconds and then withdrew his hand leaving the woodblock in position. The chamber door was then closed and the session proceeded as usual. This procedure was introduced to adapt the subjects to the disruptive procedure used on the test day. On that day the session proceeded as in the previous 5 days except that the experimenter detached the woodblock from the sensor rod and removed it from the test chamber before closing the chamber door again. For the remainder of the session the DRL 18 sec. requirements remained in operation but with the wood removed.

Results

On reintroduction to the DRL 18 sec. schedule all 5 subjects, previously used in Experiment 1, were emitting stable efficient DRL performance with stereotyped collateral woodgnawing by the 5th session, with the exception of Rat 9 which took a further 3 sessions to return to previous behaviour patterns. Figures 18 - 22:a show the efficiency ratios for the 15 daily sessions prior to the final (Test) day. The last 5 sessions prior to the final day involved the interruption procedure described in the Procedure section. The disruptive effects of the interruption procedure were minimal and transitory. The typical effect, on introduction of the procedure, was to cause a cessation of all recorded behaviour for approximately 30 seconds,

Figures 18 - 22

a) Shows the efficiency ratios for the 15 daily sessions prior to the test day.

b) Shows the cumulative record for the test day. The first 15 minutes of typical DRL 18 sec. schedule performance is shown followed by the lever press responding record after wood removal.* Each upward step of the upper cumulative record indicates a "gnaw". A lever press response resets the upper pen and in addition makes a "hatchmark" indicating a response when the reset procedure does not. A "hatchmark" on the lower cumulative record indicates a reinforced response.

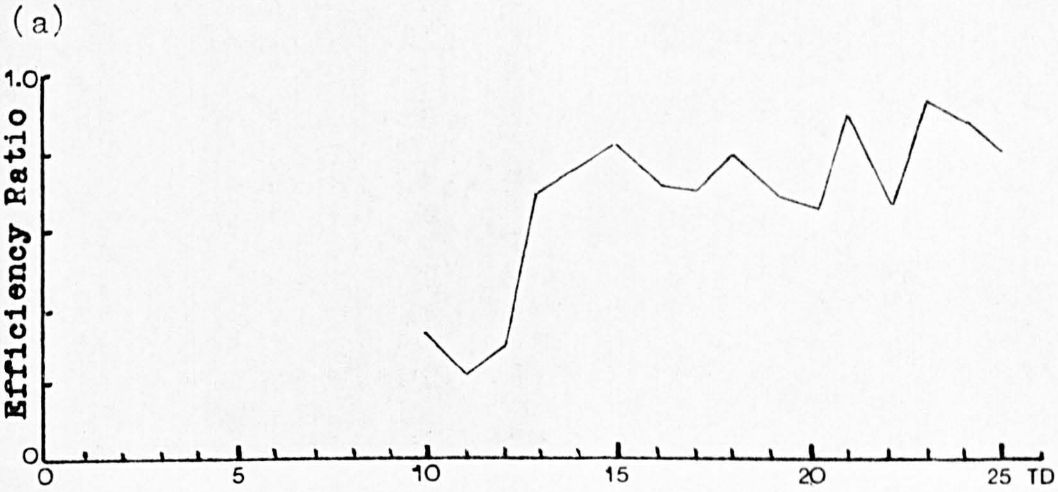
c) The relative frequency histogram of IRTs prior to wood removal (solid lines) and after wood removal (interrupted lines).

c) The relative frequency histogram of IRIs categorised by the amount of gnawing ("gnaws" ÷ 10)

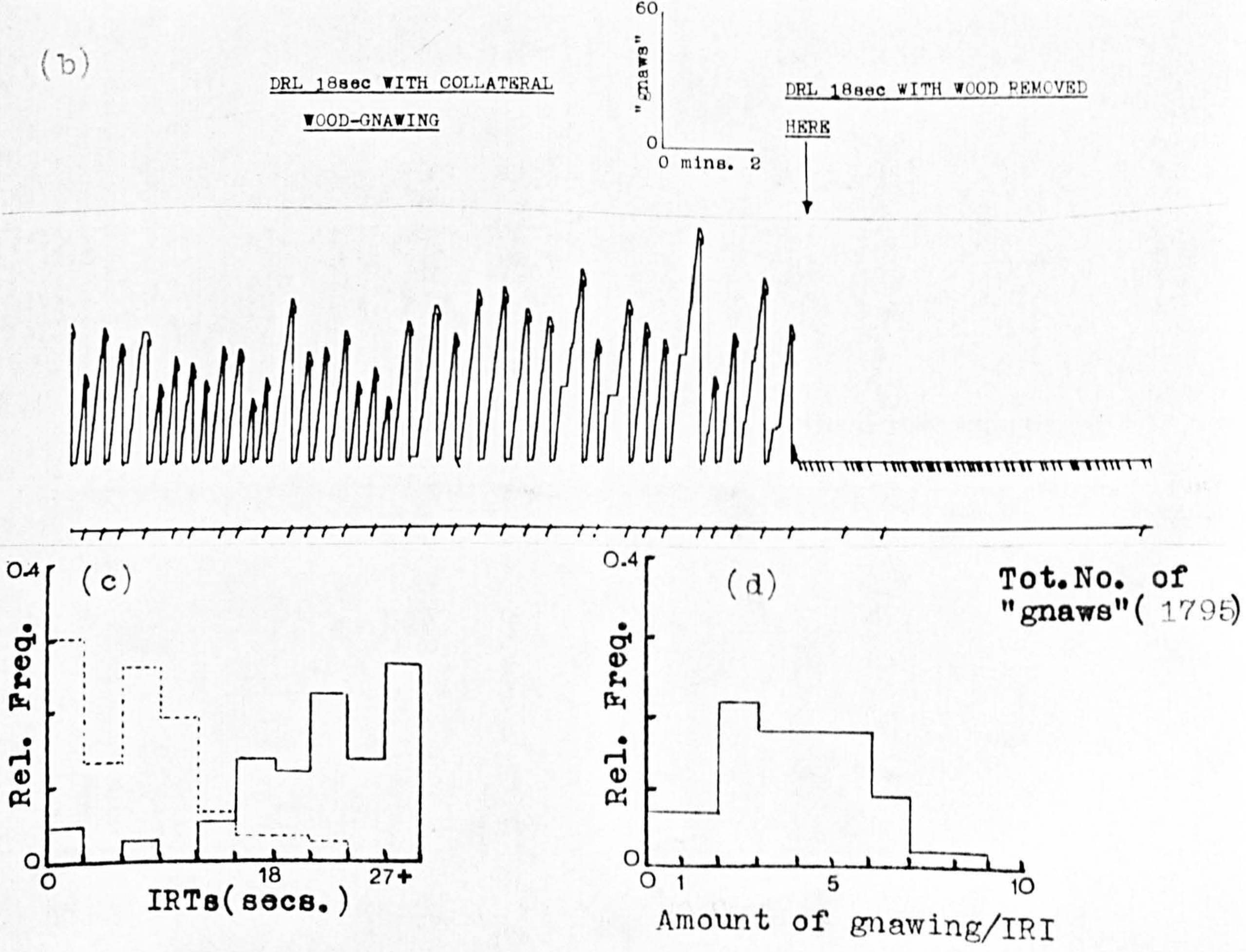
---

*The first 8 min. following wood removal are shown, as it was this transition data which was analysed in detail.

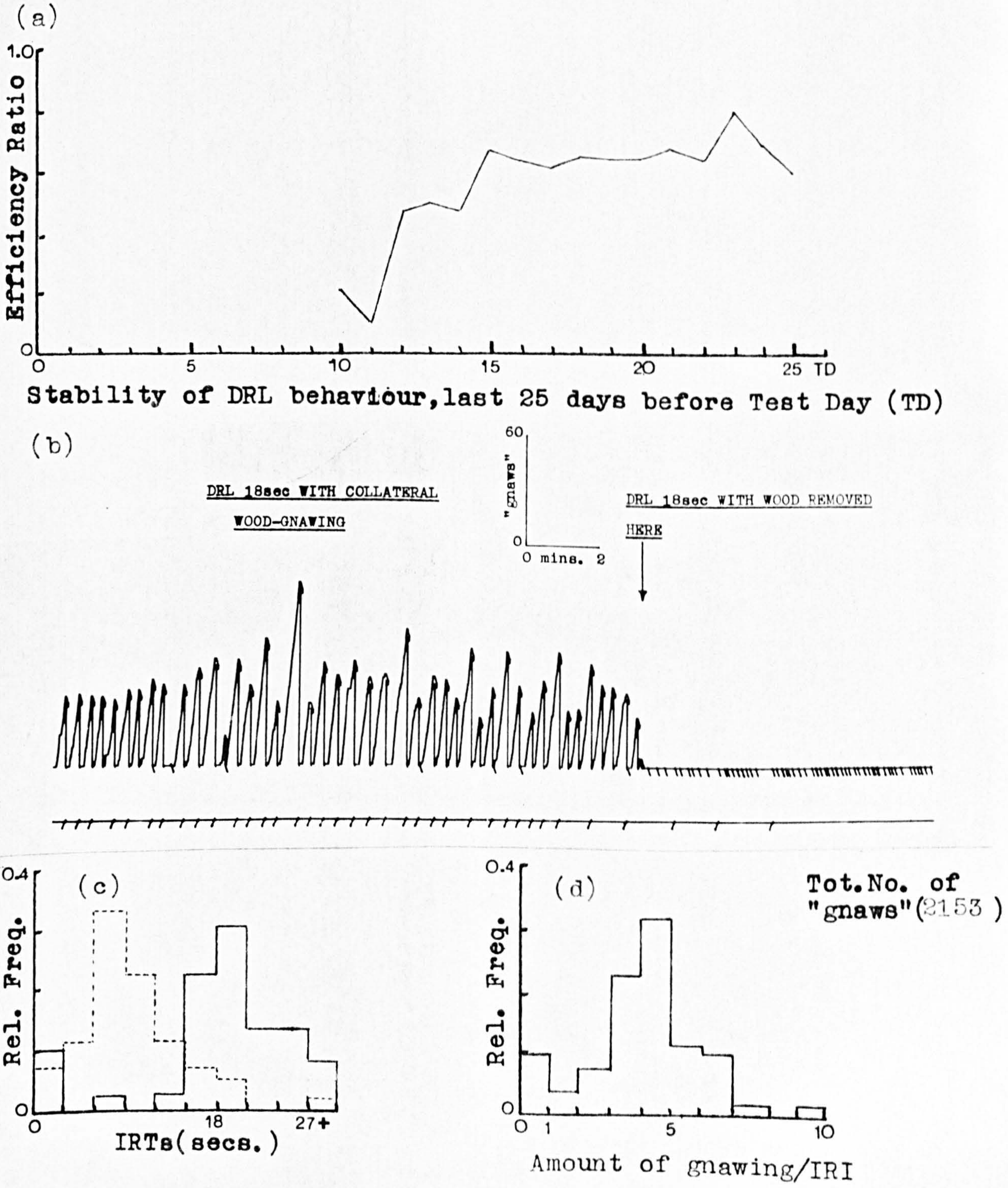
Expt. 2 Rat 7 **Figure 18**



Stability of DRL behaviour, last 25 days before Test Day (TD)

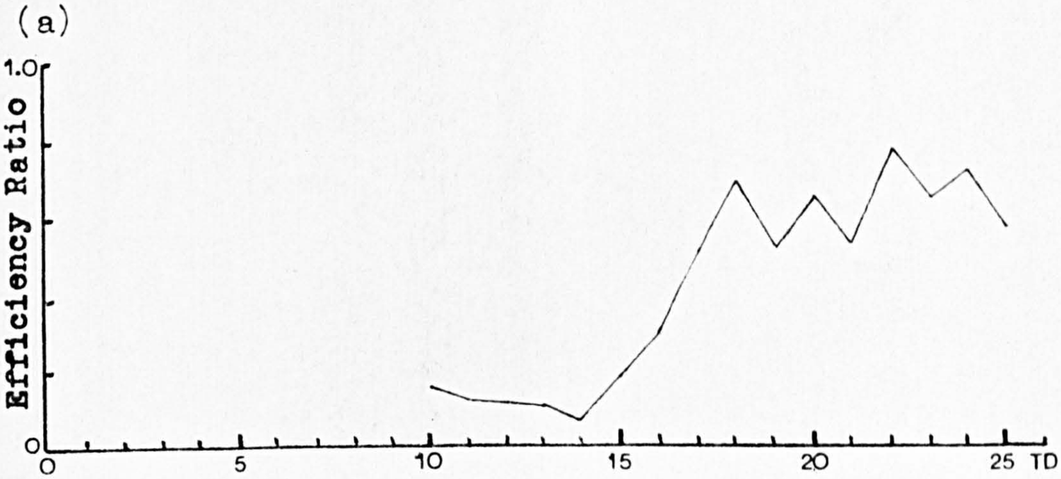


Expt.2 Rat 8 **Figure19**

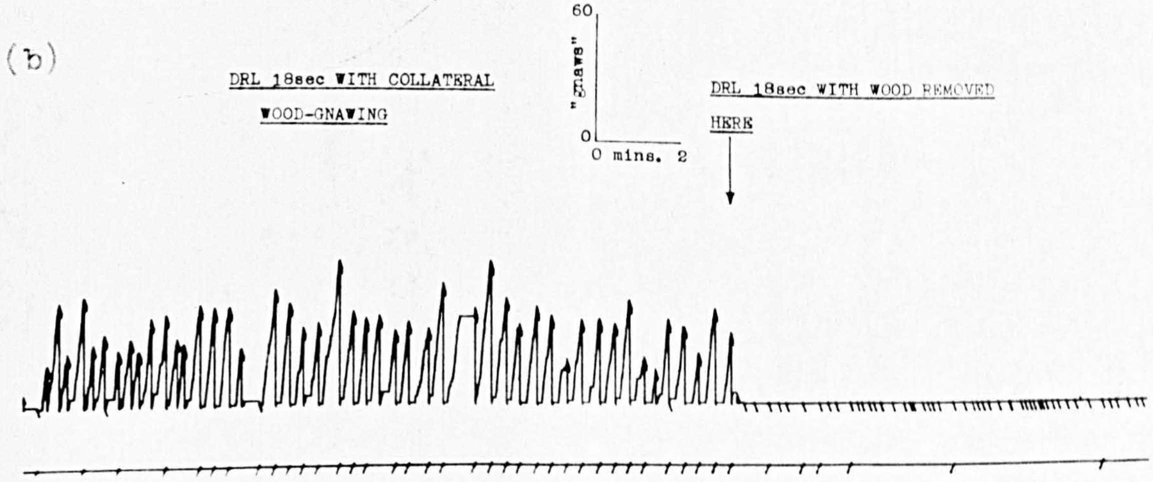


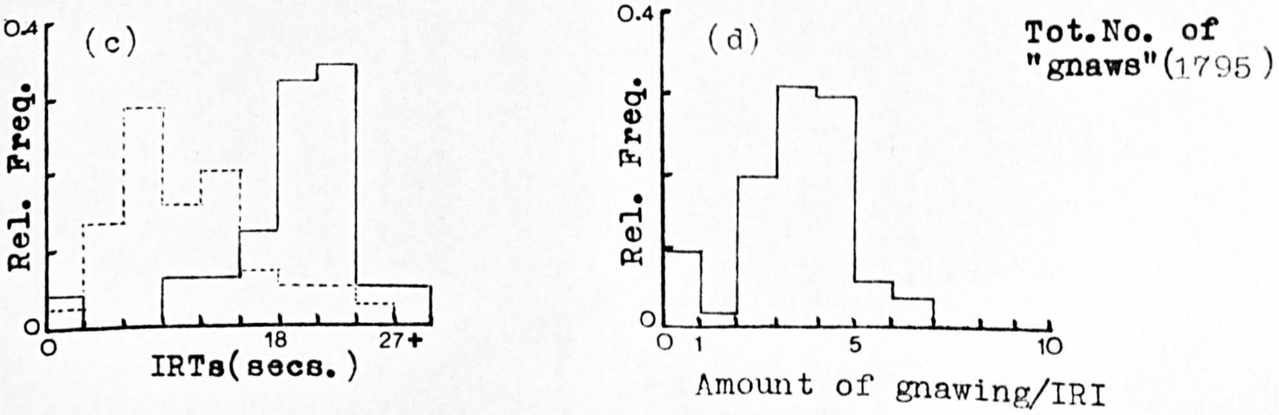
Tot.No. of "gnaws"(2153)

Expt. 2 Rat 9 Figure 20

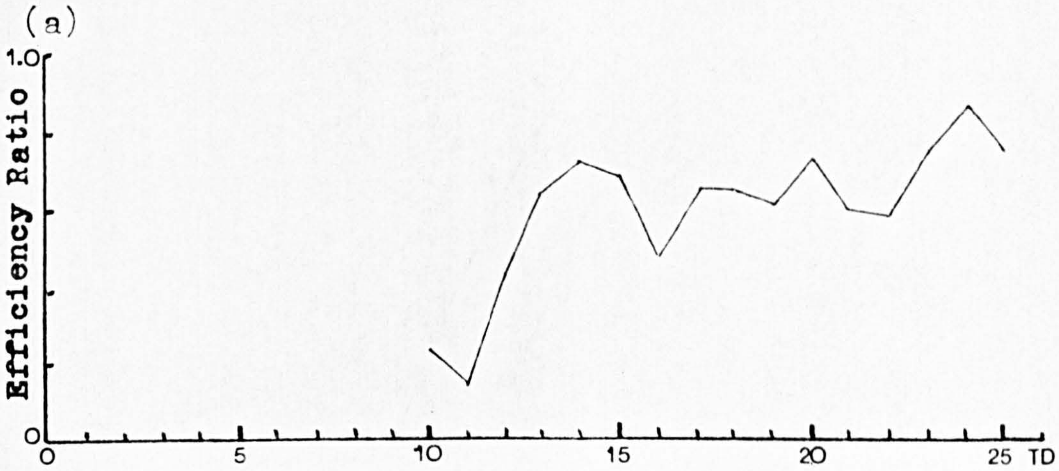


Stability of DRL behaviour, last 25 days before Test Day (TD)

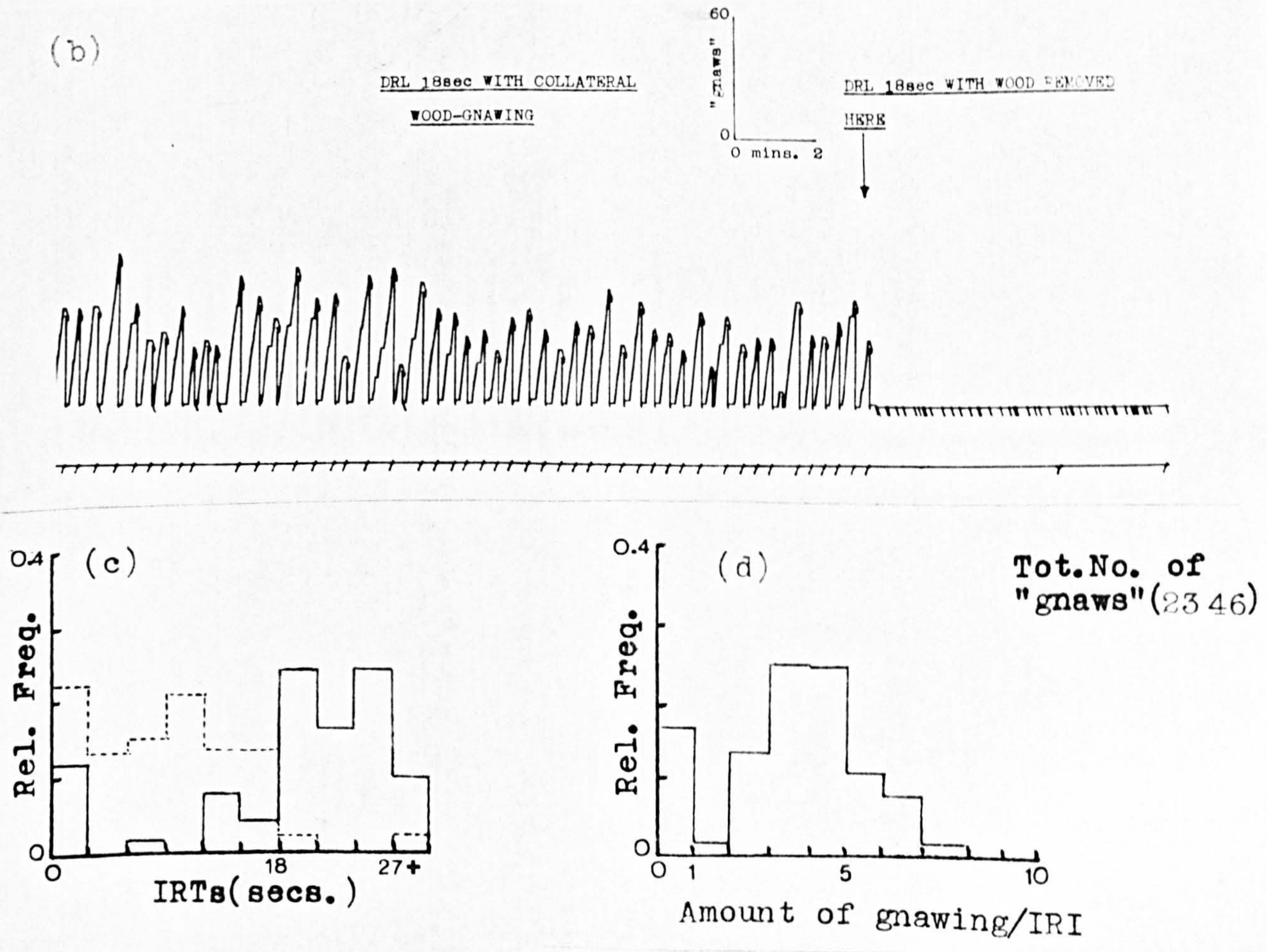




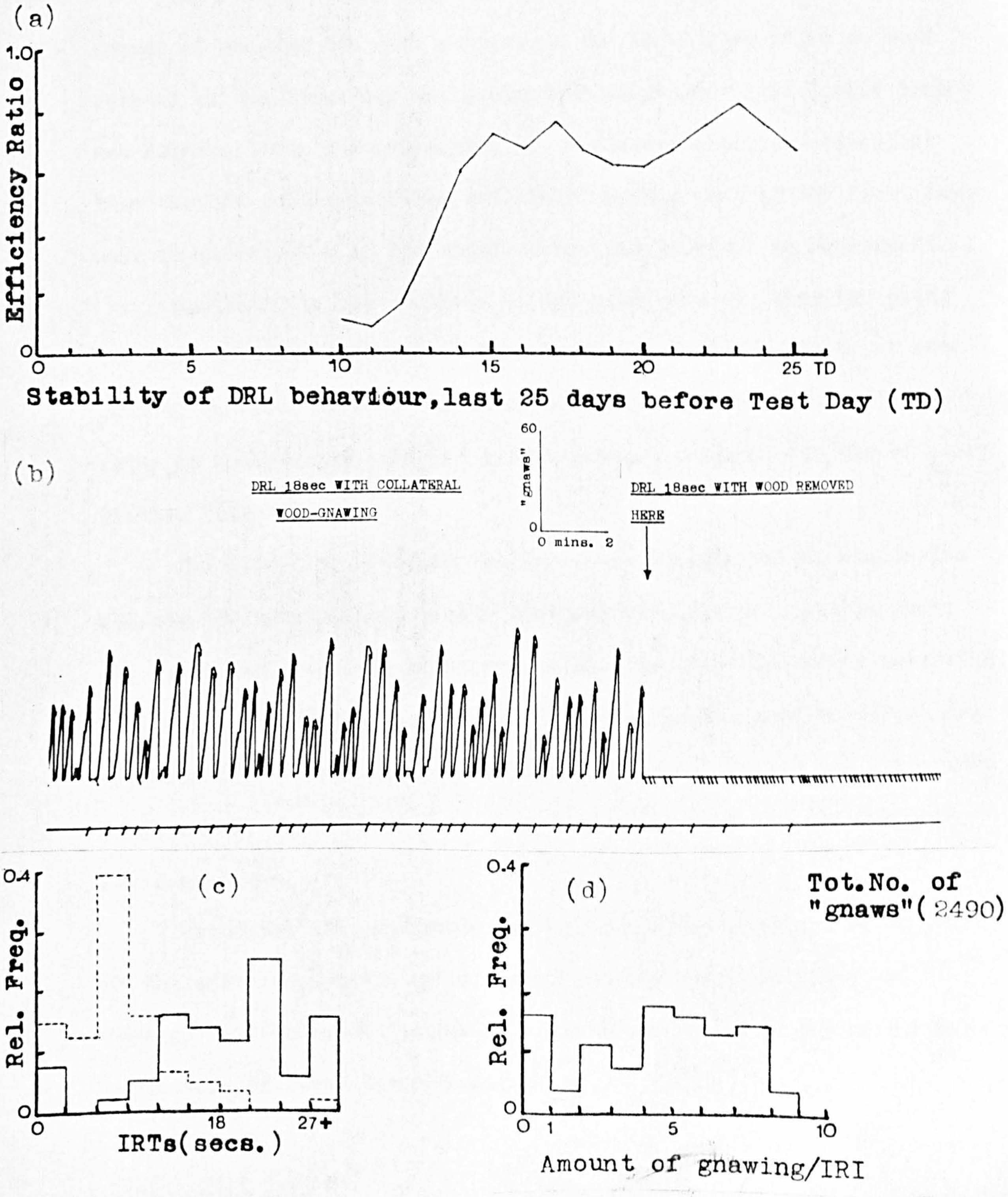
Expt. 2 Rat 10 **Figure 21**



Stability of DRL behaviour, last 25 days before Test Day (TD)



Expt.2 Rat 11 **Figure 22**



after which normal DRL performance was resumed. Even this minimal disruption was reduced in later sessions.

The DRL performance on the test day prior to the removal of the wood block is shown in the cumulative records of this test session (Figures 18 - 22:b). Note the different format employed in this experiment to put all the behaviour on one record (see Legend).

The relative frequency distributions of IRTs/sec. and IRI/amount of gnawing for each subject in the 15 minutes prior to wood removal on the final day are shown in Figures 18c - 22c (solid lines) and Figures 18d - 22d respectively. These distributions establish that the DRL performance and collateral woodgnawing on the final day were representative of the stable behaviour reported in Experiment 1.

Similarly in the analysis of the wood gnawing behaviour using the same matrices employed in Experiment 1, similar patterns of wood gnawing emerged, although because the data represented only 15 minutes of woodgnawing, the "n" values are not large in any one category (Tables VIII-XII).

The effect of removing the woodblock is seen in the cumulative records for each subject on the test day (Figures 18 - 22:b). There was an almost immediate breakdown in DRL response efficiency resulting in a marked shift in the IRT distributions towards shorter IRT values (Figures 18 - 22:c : interrupted lines). These results are summarised in Figure 23 where the two frequency distributions for all subjects are reproduced.

While the DRL performance of all subjects deteriorated in terms of the efficiency ratio (as a result of high response rates and lowered reinforcement frequency), the degree to which the performance broke down differed between subjects.

Tables VIII - XII

The detailed analysis of woodgnawing as in Experiment 1. The table is divided into two matrices. The upper one for post reinforcement IRIs, the lower one for IRIs which follow a non-reinforced response.

Each cell within a matrix shows, the mean time to complete ten "gnaws" and the variance of the times which make up the mean time, for all instances of a decade occurring at that ordinal position in an IRI with that amount of gnawing.

The number of IRIs in any category is given by the "n" value on the extreme right.

Table VIII

Expt.2 Rat 7

POST REINFORCEMENT IRIs

IRIs(decades of gnawing/IRI)	ORDINAL DECADE NUMBER										n
	1	2	3	4	5	6	7	8	9	10	
1	– – –	* †									
2	9.5 0.001	3.6 0.6									2
3	8.6 1.4	3.1 0.7	2.9 0.4								6
4	8.3 0.1	3.0 0.3	3.4 0.9	3.4 0.3							4
5	8.7 1.0	3.3 0.2	3.1 0.6	3.4 0.7	3.1 0.2						7
6	9.3 3.4	4.2 11.1	4.6 16.1	3.3 0.2	3.1 0.2	3.0 0.1					8
7	8.9 0.4	4.0 1.3	4.1 0.1	2.9 0.01	4.1 0.4	3.4 0.3	3.7 0.02				3
8	8.6 –	3.5 –	2.4 –	10.0 –	5.4 –	2.4 –	4.6 –	2.5 –			1
9	9.1 –	2.4 –	3.2 –	2.3 –	10.3 –	2.7 –	3.6 –	2.9 –	3.3 –		1
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

IRIs(decades of gnawing/IRI)	ORDINAL DECADE NUMBER										n
	1	2	3	4	5	6	7	8	9	10	
1	– – –										
2	8.1 –	3.6 –									1
3	8.7 2.6	3.2 0.1	3.3 0.1								4
4	7.7 4.9	3.1 0.2	3.0 0.4	3.3 0.6							4
5	9.6 –	2.8 –	2.6 –	2.3 –	3.3 –						1
6	– – –	– – –	– – –	– – –	– – –	– –					
7	7.1	3.5	3.4	3.0	3.3	3.1	2.9				1
8	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –			
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	

Table IX

Expt.2 Rat 8

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	14.6	* †									1
2	7.8 0.01	3.3 0.05									2
3	9.0 1.6	3.9 1.1	3.4 1.2								9
4	8.4 1.2	2.9 0.2	3.0 0.2	3.0 0.3							10
5	8.6 0.6	2.8 0.2	2.7 0.2	2.8 0.2	4.4 5.5						4
6	8.4 0.03	2.1 0.06	3.3 0.6	2.7 0.02	2.7 0.6	2.8 0.2					2
7	12.7 –	2.4 –	3.0 –	3.1 –	4.4 –	2.9 –	2.6 –				1
8	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –			
9	8.7 –	3.7 –	2.6 –	2.8 –	3.1 –	2.5 –	3.2 –	2.6 –	2.3 –		1
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	– – –	– –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	5.4 –										1
2	9.5 0.03	2.8 0.9									2
3	8.7 4.0	3.2 0.06	3.0 0.3								3
4	8.2 2.4	3.2 0.3	2.9 0.1	3.7 4.5							7
5	5.7 3.9	3.3 0.6	2.8 0.6	2.5 0.6	2.8 0.01						2
6	6.5 1.3	2.3 0.01	2.9 0.01	3.8 1.5	2.9 0.05	2.2 0.01					2
7	– – –	– – –	– – –	– –	– – –	– – –	– – –				
8	– – –	– – –	– – –	– –	– – –	– – –	– – –	– –			
9	– – –	– – –	– – –	– –	– – –	– – –	– – –	– –	– – –		
10	– – –	– – –	– – –	– –	– – –	– – –	– – –	– –	– – –	– –	

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	13.4 -	* †									1
2	10.8 5.9	5.7 11.1									6
3	11.1 12.0	3.8 0.7	3.1 1.0								12
4	10.1 2.2	3.1 0.3	3.0 0.6	3.3 0.5							11
5	7.4 0.9	2.7 0.01	4.4 2.1	2.8 0.01	2.9 0.6						2
6	7.2 2.1	3.2 0.3	4.3 3.6	4.3 5.3	3.3 0.2	2.7 0.1					2
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	6.7 28.4	3.4 0.9									4
3	11.8 10.2	3.0 0.6	3.9 0.1								4
4	8.5 8.4	3.1 0.2	3.5 1.7	2.6 0.2							4
5	10.5 -	3.4 -	3.1 -	3.0 -	2.5 -						1
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

Expt. 2 Rat 10

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	5.9 * - †										1
2	10.7 2.8	3.6 0.1									7
3	10.0 2.6	3.6 2.1	3.5 0.3								15
4	9.2 2.3	3.0 0.3	3.9 3.3	3.4 1.2							14
5	9.3 2.0	3.9 0.1	3.3 0.6	3.2 0.1	4.6 4.3						5
6	8.5 9.6	4.8 5.2	4.6 7.8	5.4 5.5	3.3 0.02	3.2 0.6					3
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	6.8 3.2	3.0 0.1									2
3	5.0 3.1	3.3 0.02	3.5 0.5								2
4	5.4 1.0	2.7 0.05	5.2 15.2	3.0 0.2							2
5	5.9 0.2	2.8 0.1	3.6 0.1	5.3 6.2	3.0 0.3						2
6	9.9 32.6	2.4 0.01	3.2 0.1	3.6 0.1	4.0 1.2	2.8 0.001					2
7	7.7 -	2.8 -	4.1 -	3.3 -	3.2 -	2.4 -	3.2 -				1
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

Expt. 2 Rat 11

Table XII

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	8.6 * - †										1
2	7.9 3.2	3.2 0.4									4
3	9.3 8.1	3.5 0.3	3.2 0.3								3
4	8.7 3.6	3.0 0.1	3.0 0.01	2.8 0.003							3
5	7.4 3.0	2.8 0.2	3.3 1.6	2.7 0.07	3.1 0.2						7
6	8.7 3.5	3.1 0.5	3.2 0.01	4.0 5.9	2.8 0.4	2.4 0.01					3
7	8.0 6.4	2.7 0.5	2.8 0.3	2.8 0.5	2.8 0.06	3.1 0.4	3.1 0.4				4
8	7.7 -	2.5 -	3.2 -	2.4 -	3.6 -	2.5 -	3.9 -	2.7 -			1
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.4 -										1
2	5.7 0.9	3.3 0.04									2
3	4.6 -	3.2 -	4.5 -								1
4	5.9 0.6	2.7 0.6	2.6 0.5	2.8 0.3							7
5	4.7 0.2	3.3 0.3	4.1 0.3	3.8 0.02	2.4 0.3						2
6	4.8 0.2	3.1 0.6	2.9 0.06	2.8 0.2	3.0 0.1	3.4 0.2					4
7	5.7 0.3	2.8 0.2	2.6 0.1	3.1 0.3	2.8 0.1	2.9 0.1	3.0 0.7				4
8	5.0 -	3.2 -	3.3 -	2.7 -	3.0 -	3.4 -	3.1 -	2.7 -			1
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

The mean IRT (secs.) value for each subject in the first 8 minutes of DRL performance without the opportunity to emit the collateral behaviour is shown in Table XIII : f.

During this test period a gradually increasing rate of lever press responding was observed. Following this test period of 8 minutes the remaining 7 minutes until the end of the session was characterised by high response rates for all subjects (These high response rates tended to obscure the differences evident in responding in the first 8 minutes when the 15 minute period following wood removal was initially analysed as a whole). Consequently both the mean IRT values for both the 8 minutes following wood removal and for the 7 minutes following this test period are shown in Table XIII :

Inspection of the IRT and IRI distributions for each subject prior to wood removal shows that:

(1) Rats 7 and 11 produced a large number of > 27 secs. IRTs: these subjects produced the smallest mean IRTs in the 8 minute test period.

(2) Rats 8 and 9 produced fewer >27 sec. IRTs and their IRT distributions show a marked modal IRT category on, or about, the criterion IRT value. These rats produced the largest mean IRTs in the test period.

(3) The equivalent IRT data for Rat 10 shows that it's performance fell between those produced by the two groups formed by Rats 7 and 11, and Rats 8 and 9.

(4) Similarly the distributions of woodgnawing in the IRIs fall into 2 groups. Rats 7 and 11 show a greater number of IRIs containing large amounts of woodgnawing than do Rats 8 and 1 with the data for Rat 10's behaviour being intermediate.

Table XIII

Shows several aspects of the performance of each subject in the five days prior to the test day:

a: Mean amount fed in home cage after each experimental session.

b: Mean of total lever press responses in each experimental session.

c: Mean of total number of reinforcements in each experimental session.

d: Mean of total "gnaws" in each sessions.

f: The mean IRT value in the first 8 minutes following wood removal on the test session.

g: The mean IRT value in the 7 minutes until the end of the test session following the first 8 minutes (see f: above)

Expt.2

Table XIII

RAT NO.	Food in home cage (grams)	Total lever press resps.	Total rein-forcements	Total "gnaws"	Efficiency ratio	Mean IRT in 8 min. test period (in secs.)	Mean IRT in7 min. after f (in secs)
	(a)	(b)	(c)	(d)	(e)	(f)	(g)
R.7	12	77	64	3050	0.83	6.9	5.2
R.8	12	91	63	3700	0.69	10.7	6.3
R.9	13	97	50	3070	0.51	11.0	5.9
R.10	11	76	55	2440	0.72	8.7	6.7
R.11	12	82	62	3220	0.76	7.8	4.9

Data from test day for each subject
(a)is average amount fed over previous 5 days

The mean amount fed in the home cage (in grams), the mean lever press, reinforcement and 'gnaws' data for each subject averaged over the five days prior to the test day are shown in Table XIII.

Discussion:

The results of this experiment confirm the results of intervention studies such as Laties et al. (1965, 1969), and Hodos et al. (1962). When the opportunity to emit the stereotyped collateral behaviour on the DRL schedule was removed there was a rapid and marked increase in lever press response rates, and a decrease in reinforcement frequency.

However these present results extend the above findings by suggesting that (1) the degree to which the DRL performance deteriorates may be a function of the prior DRL lever press performance, and (2) that the breakdown is not immediate, but that during a transition period (roughly the five minutes following wood block removal) there was some evidence that lever press responses were still being spaced differentially with respect to time.

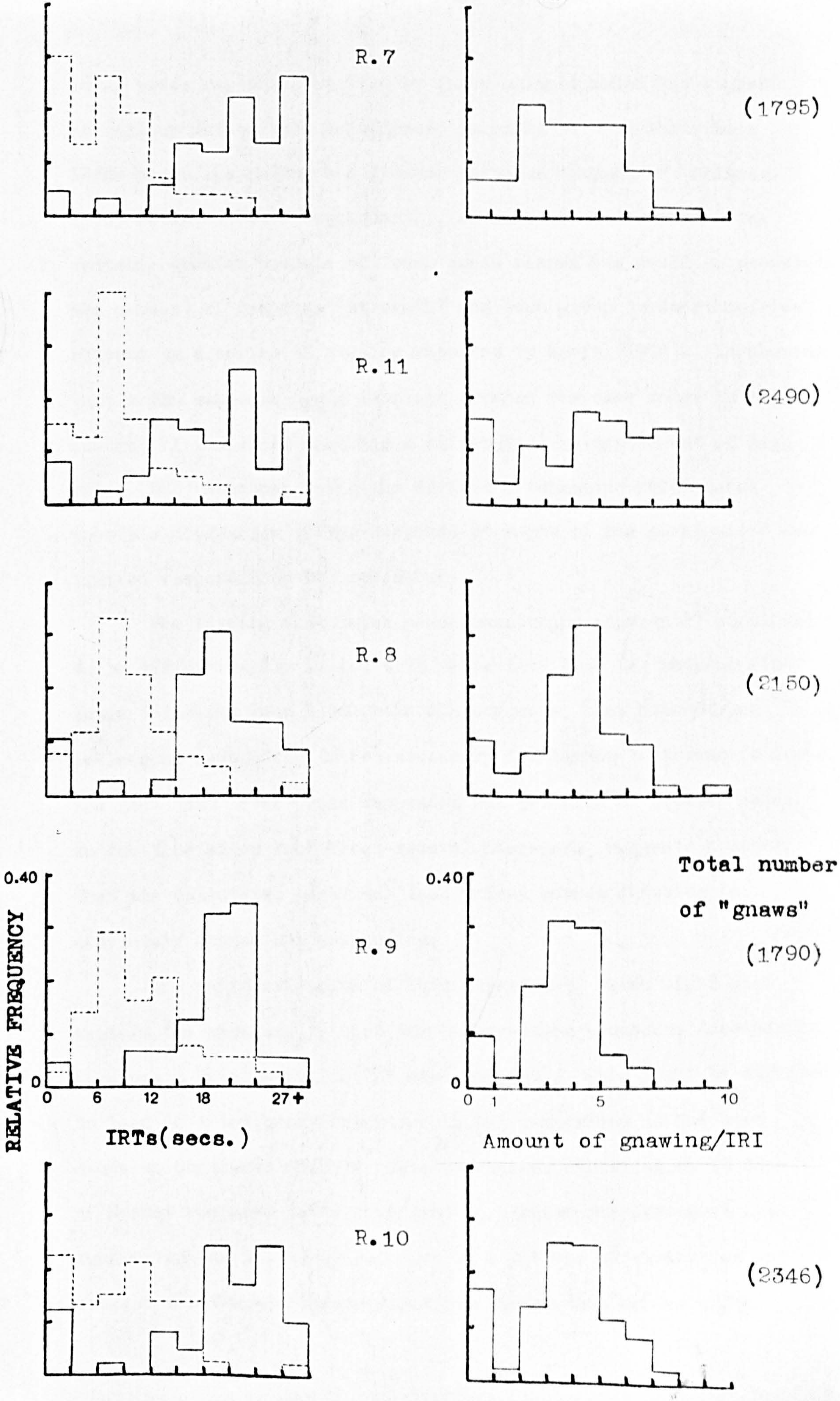
The number of subjects involved in this experiment was small, and therefore generalizations from the results must be tentative. However the considerable differences between IRT distributions (and efficiency ratios) prior to wood removal, and the subsequent differences between mean IRT values following wood removal, suggest that there was a relationship between the efficiency of DRL performance prior to wood removal and the lever press response rates following wood removal.

This in turn suggests that wood gnawing may have been inhibiting lever press responses. In the sense that more of the

Figure 23:

Shows the combined data for all five subjects. Data taken from Figures 18 - 22 : c and d.

Expt. 2 Rats 7,8,9,10,11. **Figure 23**



lever press responses emitted by those animals which had higher efficiency ratios were reinforced, it could be said that their lever press responding had greater response "strength" (Skinner, 1938; Nevin, 1974). Consequently, on removal of the inhibiting variable greater amounts of lever press responding would be expected. The concept of response "strength" has been given greater empirical support by a series of studies reported by Nevin (1974). In showing that a DRL schedule would maintain greater response rates in a preceding VI component than did a differential reinforcement of high rates (DRH) schedule Nevin has devised a technique which makes possible discussion of the response strength of the constrained and limited responding on DRL schedules.

The finding that lever press responding apparently continued to be differentially spaced with respect to time for several minutes following wood block removal , suggests that stereotyped collateral responding is not necessary for timing behaviour to occur. The fact that lever press responding was produced at greater rates as the time since wood block removal increased, suggests, however, that the collateral behaviour does indeed have a function in accurately spaced DRL responding.

One valid criticism of this experiment, which might also explain the results, is that the intervention procedure necessarily involves a novel stimulus (no wood present). This might be expected to lead to a temporary breakdown in DRL responding as has been shown by Contrucci et al (1971) This breakdown, consisting as it does of higher response rates, must lead to reduced reinforcement frequency on the DRL schedule, which, by a process of extinction, may disrupt the temporal discrimination. Under this schema wood gnawing would be a functionless adjunct to ongoing timing behaviour. This criticism, put forward by Shapiro and Miller (1965) and Willoughby (1973), is a strong argument for treating with reserve the results of intervention studies of this type, at least until the disruptive effects of the intervention procedure can be quantified.

EXPERIMENT 3

Introduction

Laties et al.(1969) have described the manipulations of the topographies of the stereotyped collateral behaviour of two rats (Rats 3-2, 3-0). In the first case(Rat 3-2)gained most reinforcements on a DRL 18 sec. schedule when woodgnawing was the collateral behaviour. When tail nibbling was the stereotyped collateral behaviour the DRL performance became less efficient, fewer reinforcemments were obtained. Rat 3-0 was the exact opposite of Rat 3-2, favouring tail nibbling over woodgnawing.

The fact that there was a difference in IRT distributions for each rat with each collateral behaviour is interesting but equivocal evidence. The collaterals may have had a direct and necessary functional relationship with timingbehaviour, in which case different topographies of collateral behaviour might be expectedto cause different IRT distributions, or,the altered collateral behaviour topography, even if not necessary for timing behaviour may have caused some physiological or deprivational change which in turn did effect the accurate spacing of responses in time.

However the findings of Laties et al.(1969) in this matter were sufficiently interesting to suggest that they might be replicated under more controlled conditions. The aim of thepresent experiment was to encourage the development of three different collateral behaviours in turn, allowing the DRL performance to stabilize under each condition. It was hoped that a structured experiment would support and possibly extend the observations of Laties et al.(1969).

Method

Subjects: Four rats (Laboratory Numbers 15, 16, 17 and 19) were maintained as described in the General Method section (Ch.III).

Apparatus: As described in the General Method section except that for certain conditions a drinking tube, rather than the woodblock, was available in the experimental space. The drinking tube entered the experimental space through the drinkometer hole (see Figure 1). The drinkometer was apparatus which permitted measurement of individual licks at the drinking tube. The water container, attached to the drinking tube, but secured outside the experimental space, was marked in graduations and records of amount drunk per session were kept. A similar record of amount drunk in the home cage was also obtained using similar apparatus.

Procedure: The subjects were run on a DRL 12 sec. schedule throughout the experiment. Following pre-training as described in the General Method sections, two subjects (Rats 15 and 16) were run on the DRL 12 sec. schedule with the woodblock present in the experimental space. The other two subjects (Rats 17 and 19) were run on the same schedule but with the drinking tube rather the woodblock being available in the experimental space. These conditions lasted for 40 sessions, each lasting 30 minutes. Following the final day on this condition, the conditions were reversed for the two groups of subjects. This new condition lasted for 45 sessions. During both conditions the water intake for those animals with access to the drinking tube in the experimental space was recorded both in the experimental space and in the home cage.

For the final 30 days of the experiment all subjects were run on the DRL 12 sec. schedule without woodblock or water bottle present in the experimental space. The development of unrecorded collateral was observed.

Results

It was generally observed throughout this study that there was a consistent relationship between the amount of stereotyped collateral behaviour in a session and the efficiency ratio for that session (Figures 25-28).

For the two subjects (Rats 17 and 19), who first developed licking collateral behaviour, and then woodgnawing collateral behaviour, it was evident that the removal of one collateral manipulandum (drinking tube), and the substitution of it by another (woodblock), resulted in a sharp drop in efficiency ratios until the new collateral behaviour developed. Withdrawal of this second collateral manipulandum coincided with another drop in efficiency ratios until the third collateral behaviour became established. This third collateral behaviour, in both cases, involved gnawing of the bars forming the floor of the experimental space.

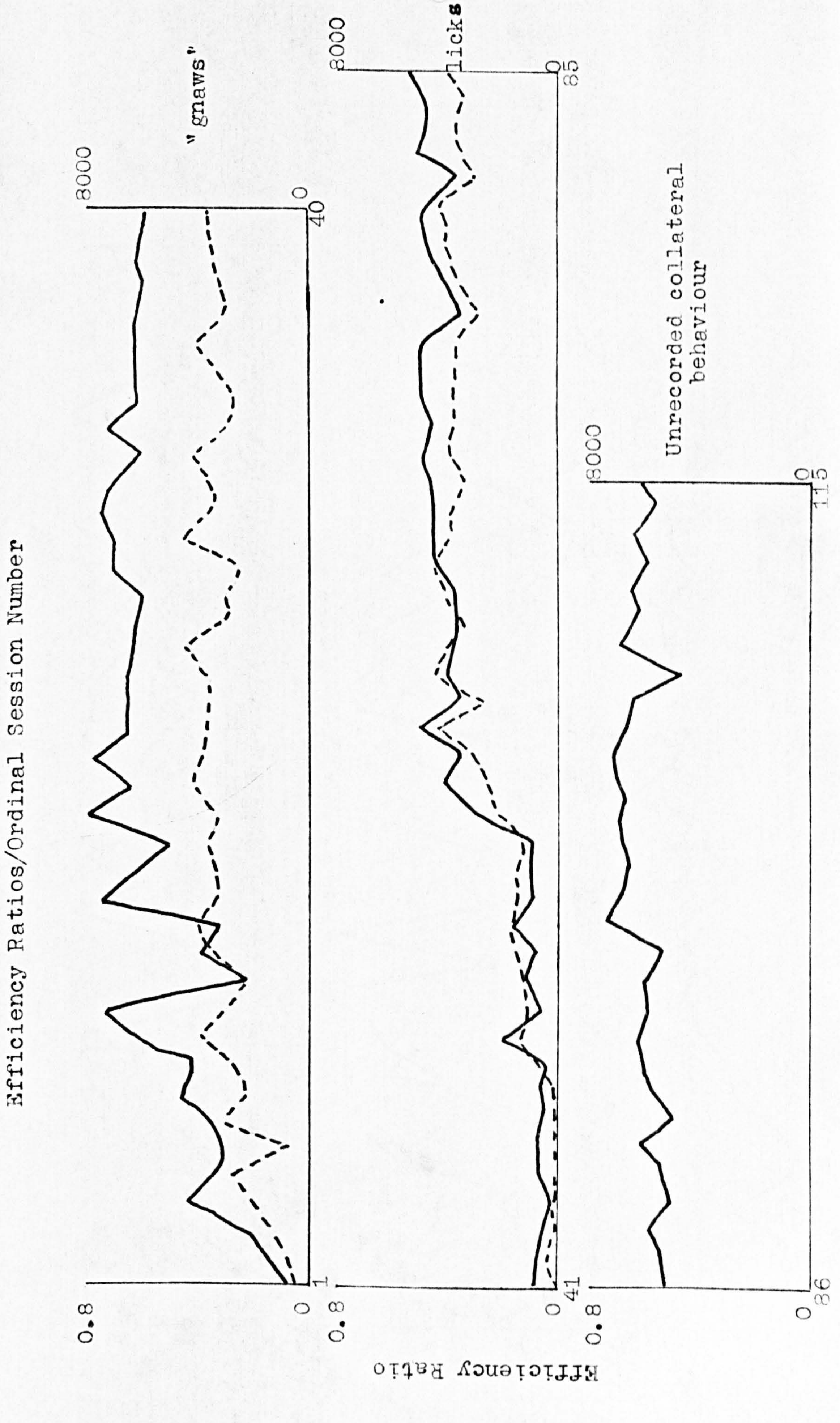
For the two subjects (Rats 15 and 16) who were exposed to the woodblock first and then transferred to the drinking tube the results were as follows:-

Rat 15:- in the first condition, amounts of woodgnawing and session efficiency ratios appeared to increase together. Later on in this condition, it was a frequent observation that large amounts of woodgnawing in one session were followed by high efficiency ratios in the next session but not necessarily large amounts of woodgnawing. On the removal of the woodblock efficiency ratios fell until both amounts of licking at the introduced drinking tube, and efficiency ratios, again were observed to increase together. It was a feature of the DRL performance in this condition that drinking was almost exclusively a post food event. Following a non reinforced response

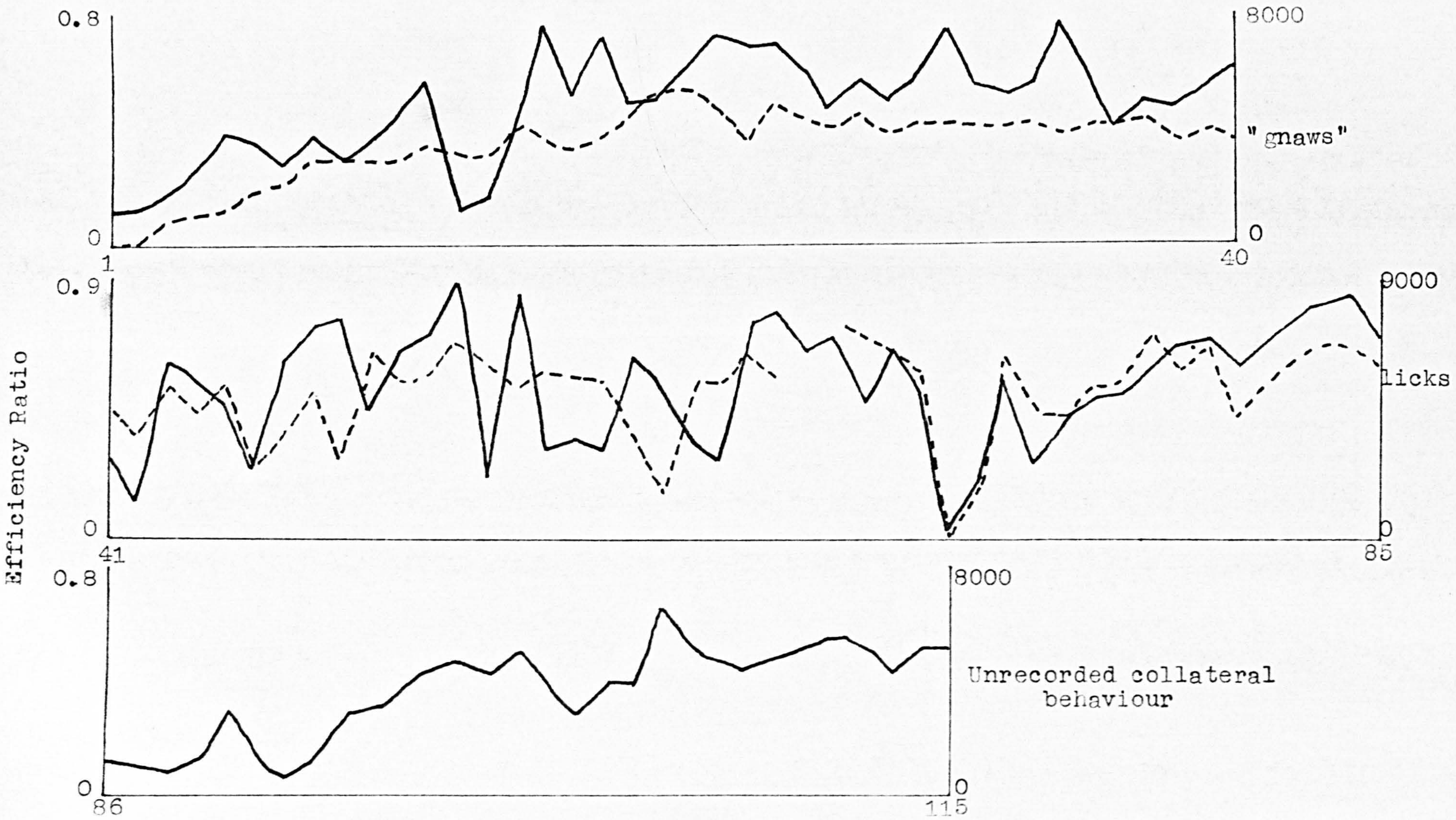
FIGURES 25 - 28

Shows the efficiency ratios for each session throughout the experiment and the total amount of recorded collateral behaviour during each session. Where no data is available for a session that day has been left blank.

Expt.3 Rat 15 Figure 25



Efficiency Ratio per Ordinal Session Number



Expt.3 Rat 16 Figure 26

Efficiency Ratio per Ordinal Session Number

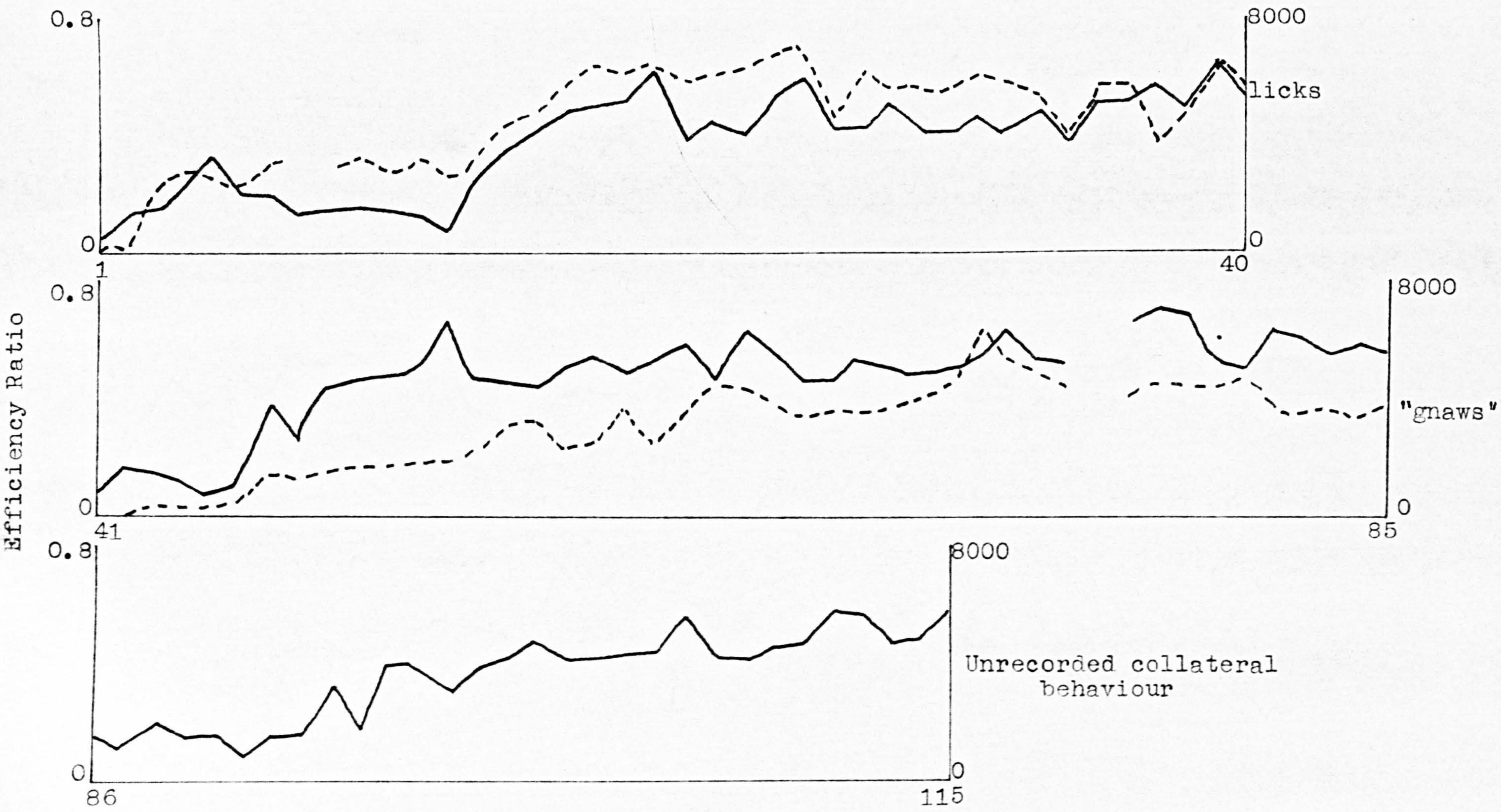
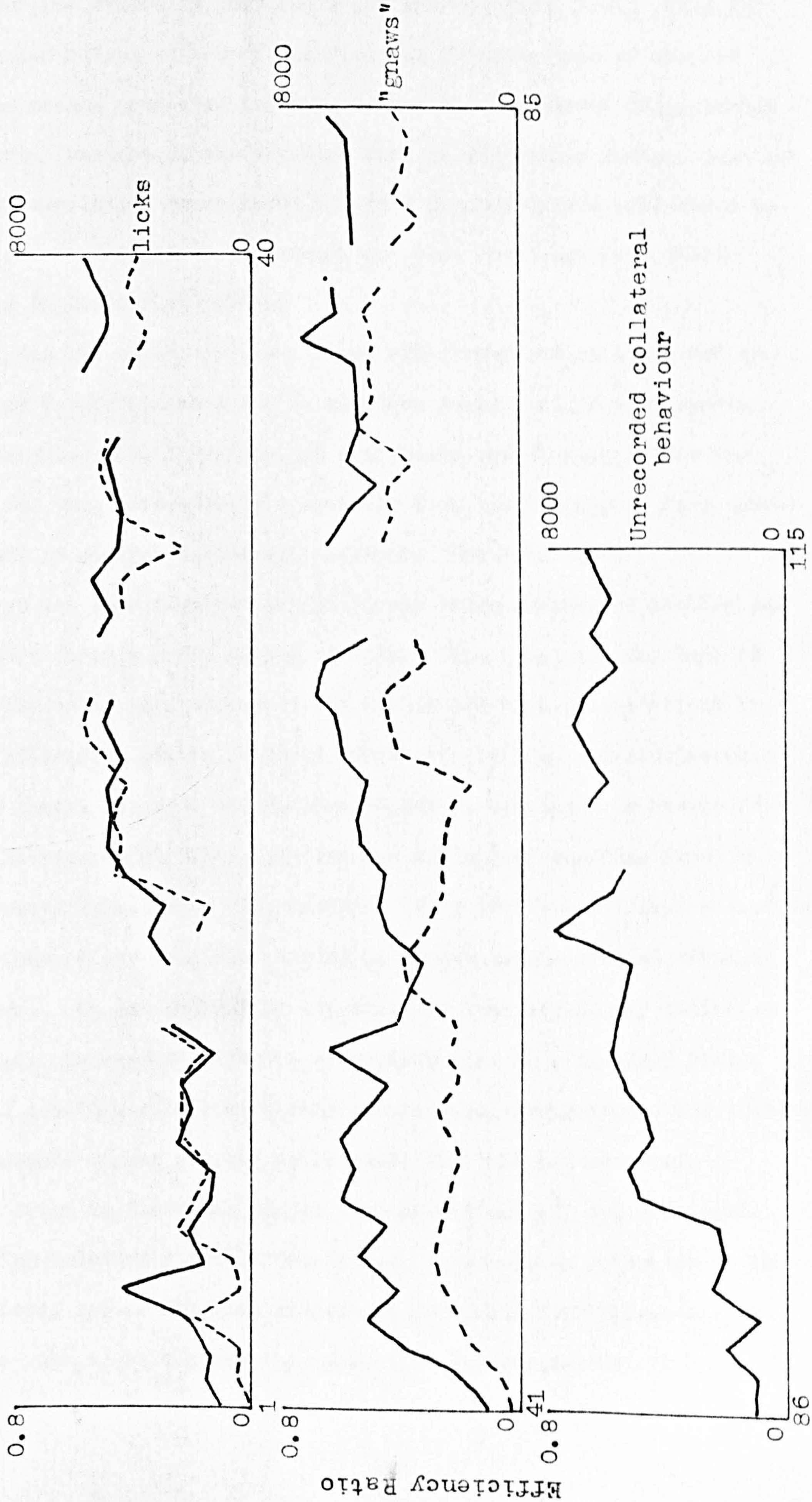


Figure 27 Expt.3 Rat 17

Expt. 3 Rat 19 Figure 28



the subject typically produced a bar gnawing collateral. This is evidenced in the effect of removing the drinking tube at the end of the second condition leaving no specific collateral manipulandum present. Instead of the expected drop in efficiency ratios, this subject immediately transferred it's post non reinforced collateral behaviour to all IRIs. The result was that there was very little change in efficiency ratios.

Rat 16: again woodgnawing and efficiency ratios increased together in the first condition and then stabilized. On wood removal, and drinking tube insertion, the efficiency ratios dropped for two sessions then increased to relatively high levels only to fall almost to zero in several subsequent sessions. The licking behaviour of this subject was characterised by relatively large amounts of licking and consumption of a great volume of water. The final ten sessions in this condition were comparatively stable and were characterised by high efficiency ratios, a great amount of licking, and considerable water intake (over 40 ml. in each 30 minute session). A result of this increased and stable performance efficiency was that fewer non reinforced lever press were emitted. Very little consistent collateral behaviour of any type was emitted in a post non-reinforced response interval. On the removal of the drinking tube efficiency ratios dropped. Concurrent with the subsequent rise in efficiency ratios in the condition where no specific collateral manipulandum was present, an increase in bar gnawing collateral behaviour was observed.

Prior to the final day in each condition, all subjects were emitting relatively stable DRL 12 sec. behaviour as reflected in the efficiency ratios for each subject in each condition (Figures 25-28). Figure 29: a, b, c shows the cumulative records for Rat 19 on the final day of each condition. These records are representative of the behaviour emitted by all subjects under the three conditions, with the exception of Rat 16, who drank more than the other subjects when licking was the stereotyped collateral behaviour. The cumulative record of the final day performance for this rat under this condition is shown in Figure 29:d. The higher level of the licking behaviour can be clearly seen. On the final day of this condition Rat 16 drank 41 ml. of water in the 30 minute session compared to 11 ml. in the previous 23:5 hours in its home cage. This licking behaviour by Rat 16 on the DRL 12 sec. differed only in the amount of inter response interval licking, the topography of the licking behaviour being apparently similar to that emitted by the other three subjects.

The cumulative records and other data taken from the two conditions involving wood gnawing and unrecorded collateral behaviour show wood gnawing patterns similar to those in Experiments 1 and 2 Lever press behaviour in the unrecorded collateral behaviour condition are similar to other such DRL performances in the literature (Wilson and Keller, 1953).

Tables XIV ÷ XXI show the analysis of the two measurable collateral behaviours in the manner of the two previous experiments. The extreme stereotypy of the licking behaviour is shown in the analysis of "rates" of licking (Tables XIV, XVI, XVIII, XX: Figures 34, 35B, 36 and 37). There was virtually no change in "rates" of licking within an IRI category and little between them. There was however an appreciable lack of stereotypy in the licking which occasionally followed a non-reinforced response. The "rates" and variances in this matrix are markedly different from those in the

FIGURE 29

a) Cumulative record of the final day on DRL 12 sec. with wood gnawing as collateral behaviour for Rat 19. Each "gnaw" steps top pen up once. Responses reset this pen and deliver a downward "hatchmark". Reinforcements are recorded by downward "hatchmark" of lower pen.

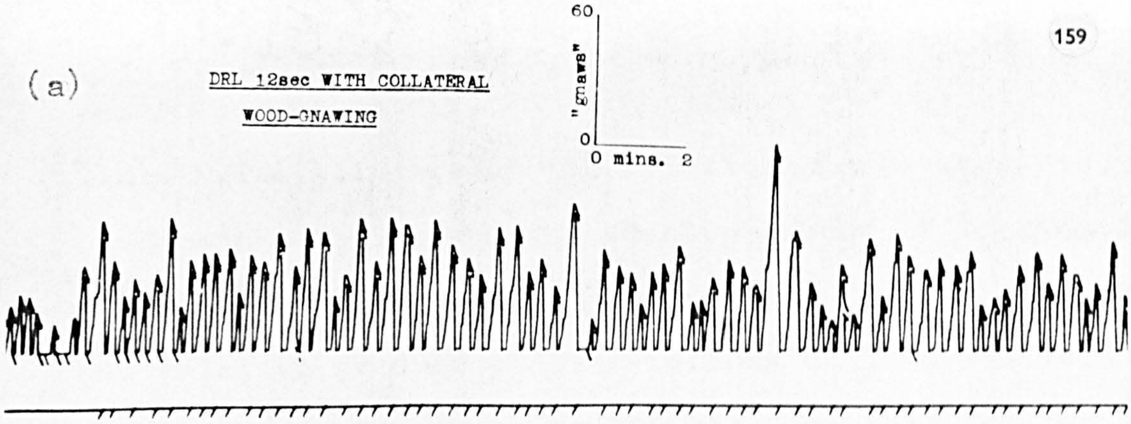
b) Cumulative record of the final day on DRL 12 sec. with water licking as collateral behaviour for Rat 19. Each lick steps the pen up once, otherwise as in (a) above.

c) Cumulative record of the final day on DRL 12 sec. with unrecorded collateral behaviour for Rat 19. Each lever press response steps the pen upwards once. A reinforced response in indicated by a downward "hatchmark".

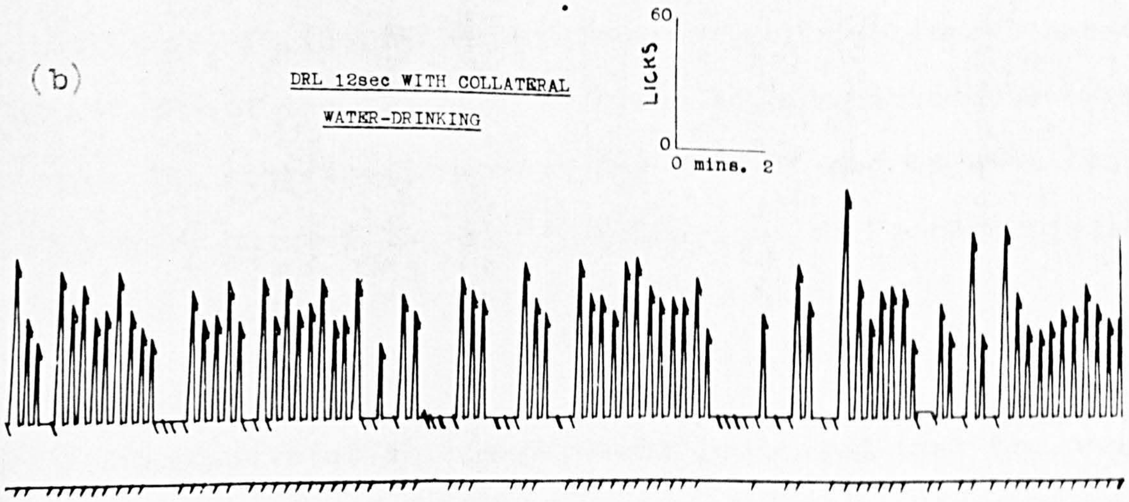
d) Cumulative record for final day on DRL 12 sec. with water licking as collateral behaviour for Rat 16. Interpret as (b) above.

Expt. 3 **Figure 29**

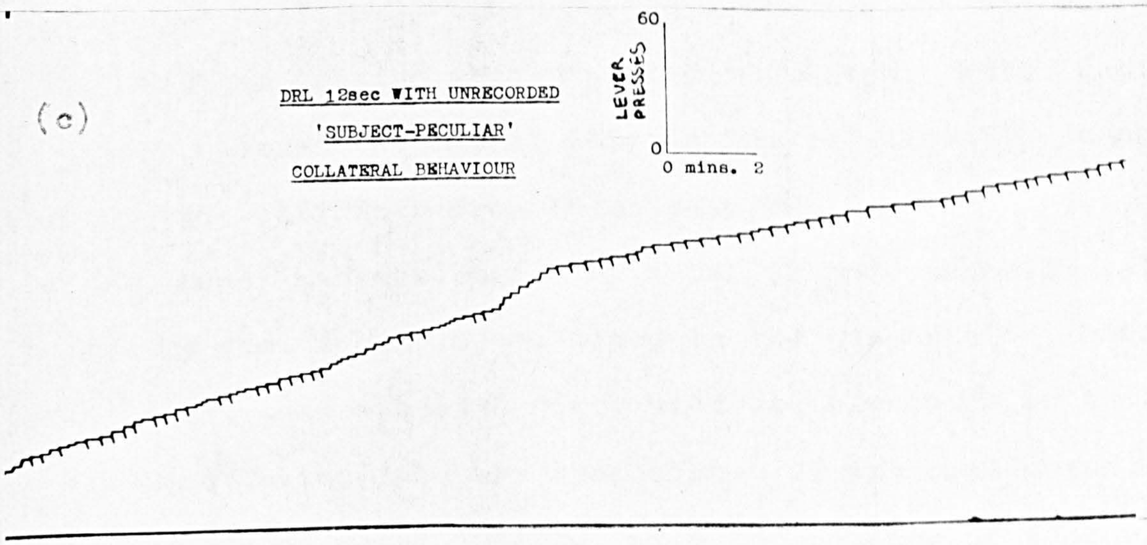
(a) DRL 12sec WITH COLLATERAL WOOD-GNAWING



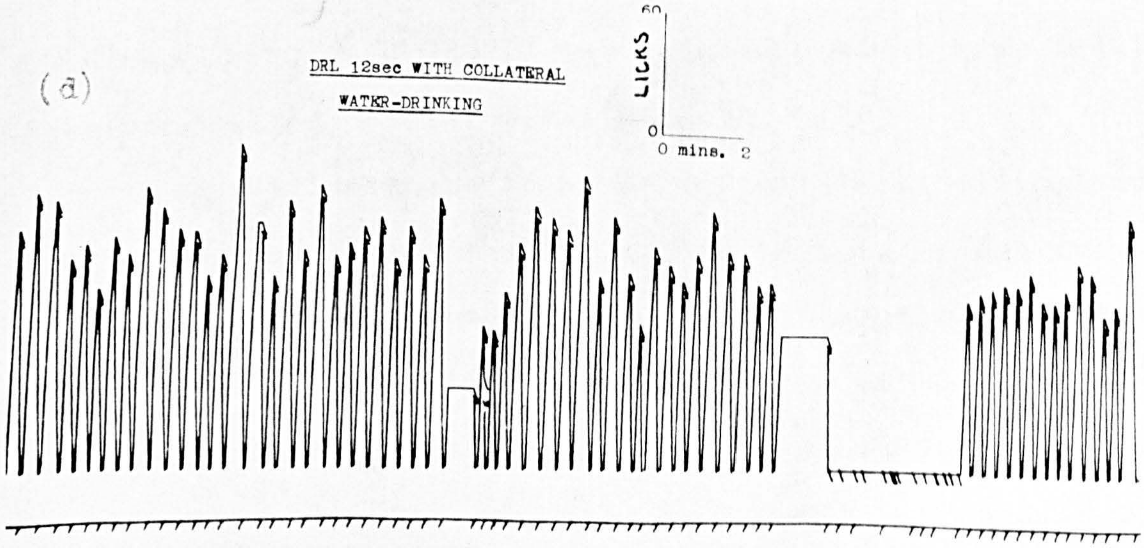
(b) DRL 12sec WITH COLLATERAL WATER-DRINKING



(c) DRL 12sec WITH UNRECORDED 'SUBJECT-PECULIAR' COLLATERAL BEHAVIOUR



(d) DRL 12sec WITH COLLATERAL WATER-DRINKING



post reinforcement matrix.

Table XVIIa illustrates the relationship between first ordinal decade duration and the ensuing amount of licking in the IRI.

The relative frequency distributions of IRIs and IRTs for each subject under the three conditions show that for two subjects Rats 15 and 17 the different stereotyped collateral behaviours did not affect the IRT distributions to any noticeable extent. However the corresponding data for Rats 16 and 19 show considerable differences between the IRT distributions for each subject in each condition (Figures 30 - 33).

Discussion

The results of this experiment indicated that the amounts of stereotyped collateral behaviour in a session and the efficiency ratio for that session were positively related. Which factor, if either, played the causal role in the relationship cannot be stated with certainty from these results.

The experimenters choice of a DRL 12 sec. schedule rather than the DRL 18 sec. schedule was based on the supposition, borne out in the results, that subjects might produce polydipsia in the condition where the drinking tube was available. It was considered that large amounts of water imbibed as a consequence of schedule induced licking on a DRL 18 sec. schedule might have deleterious and uncontrolled physiological effects.

The condition where no specific collateral manipulandum was present was run last for all subjects because it was felt that should the subjects develop a collateral behaviour involving a piece of apparatus which could not be removed in subsequent conditions, there would be no reason for any change in collateral behaviour. The fact that all four subjects developed a bar gnawing collateral

behaviour

FIGURES 30 - 33

a) The IRT/sec. relative frequency distributions (left) of lever press responses on DRL 12 sec. with unrecorded collateral behaviour. Final day performance.

b) The relative frequency distributions of IRT/sec. (left) and IRI/decades of licking (right) on DRL 12 sec. with water licking as the collateral behaviour, on the final day of this condition. Total of licks and the amount drunk in the 30 minute session is given in the top right of each figure.

c) The relative frequency distributions of IRT/sec (left) and IRI/amount of wood gnawing on DRL 12 sec. with wood gnawing as the collateral behaviour, on the final day of this condition. Total of "gnaws" in the 30 minute session is given in the top right of each figure.

Figure 30

Expt. 3 Rat 15

(a) Unrecorded collateral behaviour.

(b)Collateral drinking.

(c)Collateral gnawing.

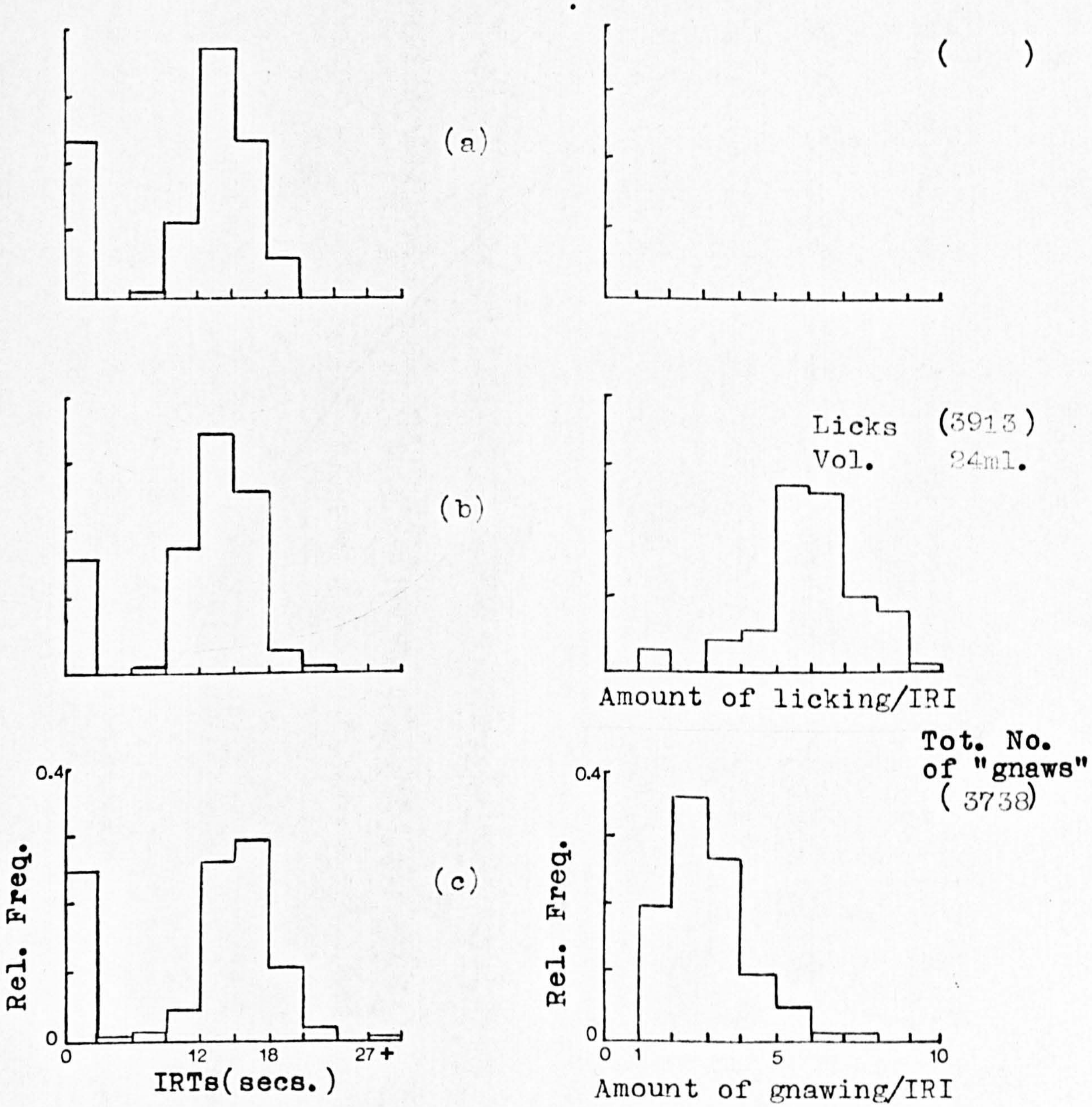


Figure 31

Expt. 3 Rat 16

(a) Unrecorded collateral behaviour.

(b) Collateral drinking.

(c) Collateral gnawing.

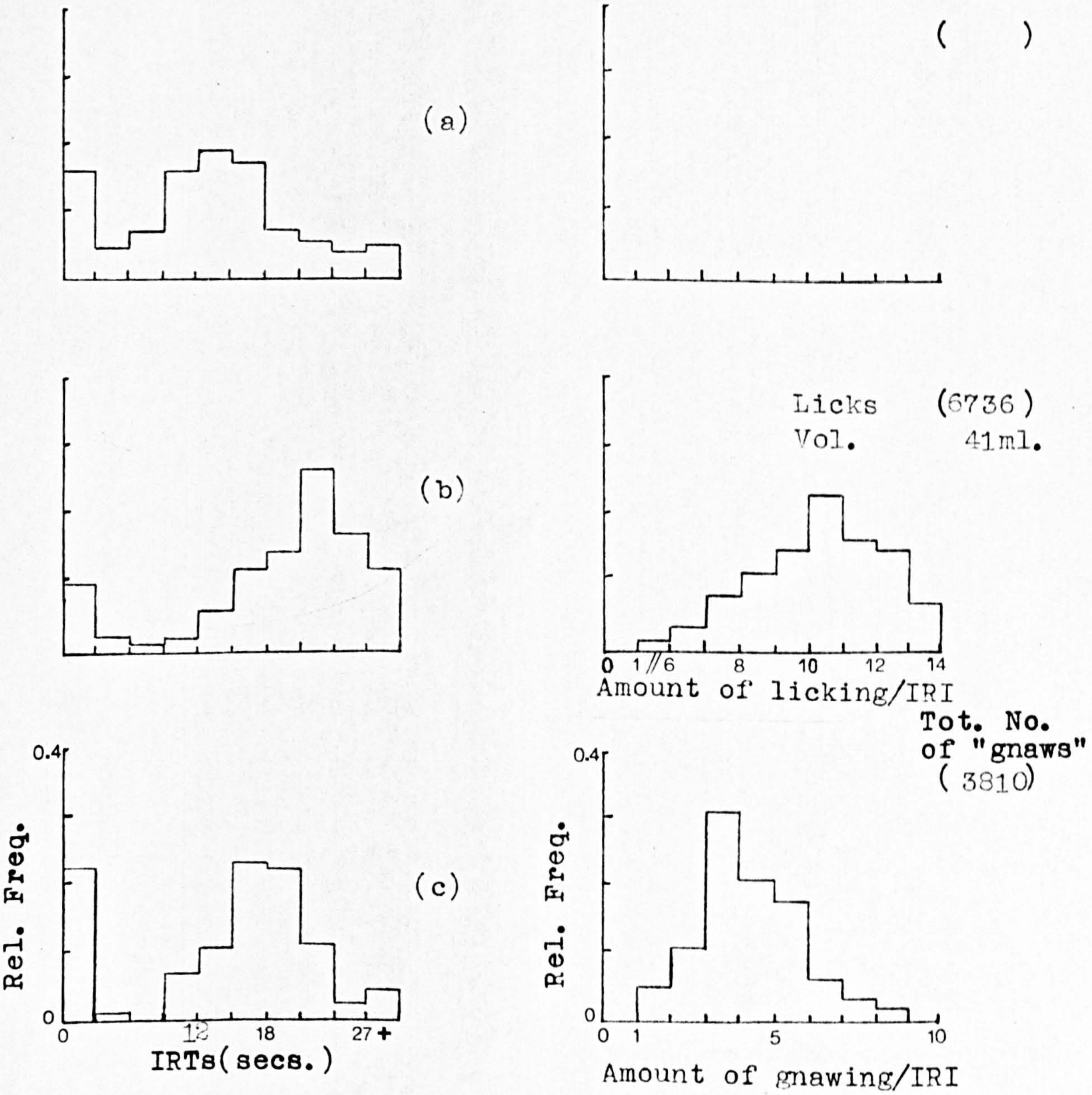


Figure 32

Expt. 3 Rat 17

(a) Unrecorded collateral behaviour.

(b) Collateral drinking.

(c) Collateral gnawing.

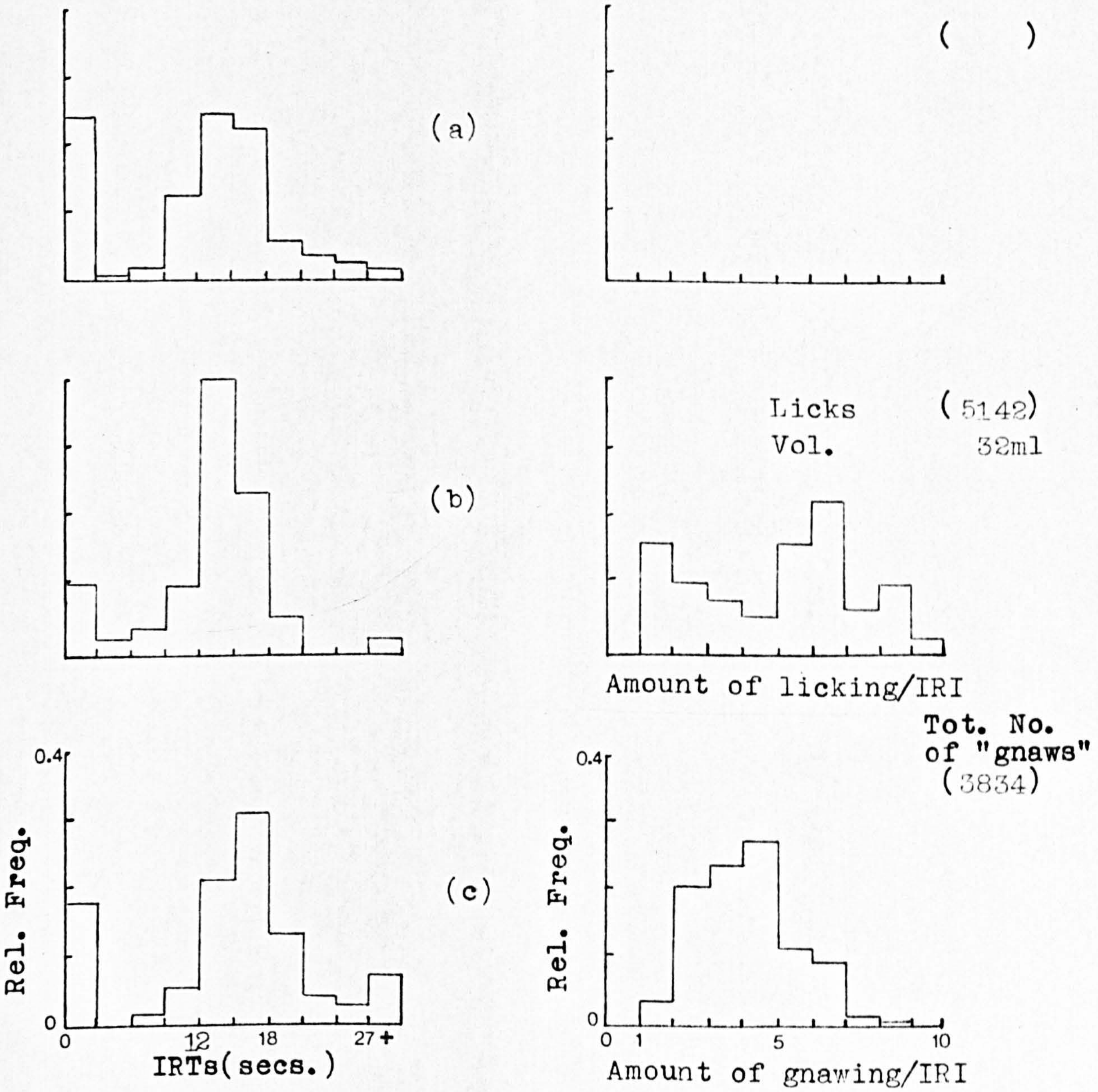


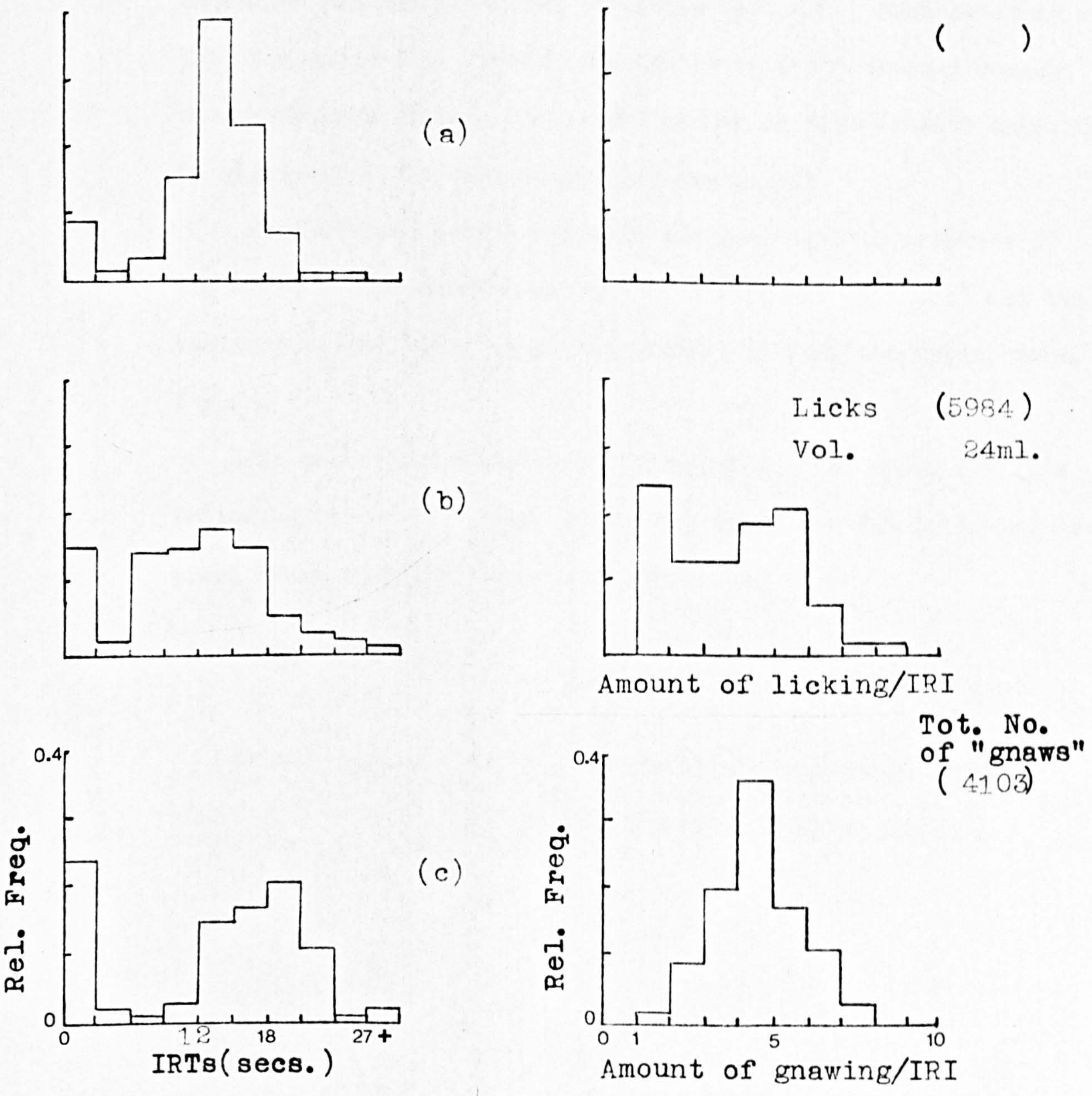
Figure 33

Expt. 3 Rat 19

(a) Unrecorded collateral behaviour.

(b) Collateral drinking.

(c) Collateral gnawing.



TABLES XIV - XXI

Analysis of stereotyped collateral behaviours occurring with DRL 12 sec lever press behaviour on the final day of two conditions. Tables show the analysis of woodgnawing and the analysis of wator licking. The inter response intervals IRIs are categorized by the amount of collateral behaviour within each IRI. Each category of IRI is divided into ordinal decades (i.e. first ordinal decade second ordinal decade, etc). The number of IRIs in each category is given under the "n" column (extreme right).

Each ordinal decade contains the mean time to complete 10 instances of the collateral behaviour ("gnaws" or licks) and the variance of the times which were meaned to find the upper, mean, figure.

The tables are divided into 2 matrices, the upper for IRIs following reinforced lever press, the lower for IRI following lever press responses which were not reinforced.

Table XVIIa shows:-

Correlation coefficients between the mean duration of the post-response 'pause' and the amount of stereotyped collateral behaviour in the ensuing inter-response intervals (IRIs).

Expt. 3 Rat 15

Table XIV

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	- - -	* †									
2	- - -	- -									
3	7.3 0.3	1.4 0.01	1.4 0.01								3
4	8.1 3.0	1.5 0.01	1.5 0.05	1.6 0.01							11
5	7.2 0.9	1.5 0.02	1.5 0.01	1.5 0.01	1.5 0.01						19
6	6.4 1.9	1.5 0.02	1.5 0.01	1.5 0.01	1.5 0.01	1.5 0.01					16
7	5.9 0.9	1.6 0.02	1.4 0.01	1.5 0.01	1.6 0.01	1.5 0.01	1.6 0.03				7
8	5.0 0.2	1.5 0.03	1.5 0.02	1.5 0.01	1.5 0.01	1.5 0.01	1.5 0.01	1.5 0.01			5
9	- - -	- -	- - -	- -	- - -	- -	- - -	- -	- - -		
10	6.5 -	1.4 -	1.1 -	1.5 -	1.5 -	1.5 -	1.5 -	1.6 -	1.5 -	1.8 -	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

IRIs(decades of licking/IRI)

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	10.8 168.4										2
2	- - -	- -									
3	- - -	- -	- - -								
4	- - -	- -	- - -	- -							
5	- - -	- -	- - -	- -	- - -						
6	4.7 1.2	1.5 0.02	1.6 0.07	1.3 0.01	1.5 0.01	1.7 0.09					2
7	4.2 -	1.7 -	1.5 -	1.4 -	1.4 -	1.5 -	1.5 -				1
8	3.5 -	1.7 -	1.4 -	1.5 -	1.4 -	1.5 -	1.4 -	1.5 -			1
9	4.6 -	1.4 -	1.5 -	1.4 -	1.8 -	1.4 -	1.5 -	1.7 -	1.5 -		
10	- - -	- -	- - -	- -	- - -	- -	- - -	- -	- - -	- -	

LICKING on a DRL 12 sec.

POST REINFORCEMENT IRIs

IRIs(decades of licking/IRI)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10		n
1	17.6* - †											1
// 6	5.4 -	1.8 -	1.5 -	1.7 -	1.6 -	1.7 -						1
7	4.5 1 0.8	1.8 0.1	1.6 0.01	1.6 0.01	1.6 0.01	1.8 0.05	1.7 0.01					4
8	4.8 1.6	1.9 0.1	1.6 0.03	1.7 0.01	1.6 0.01	1.7 ·0.02	1.7 0.03	1.7 0.01				6
9	5.1 3.6	2.0 0.4	1.6 0.01	1.6 0.01	1.6 0.01	1.6 0.01	1.7 0.03	1.7 0.01	1.8 0.07			8
10	4.3 0.6	2.0 0.1	1.6 0.01	1.6 0.01	1.6 0.01	1.7 0.01	1.8 0.09	1.7 0.01	1.7 0.03	1.7 0.01		13
11	4.4 0.4	1.7 0.02	1.7 0.05	1.7 0.04	1.6 0.01	1.6 0.01	1.7 0.01	1.7 0.01	1.7 0.01	1.7 0.01	rec.	10
12	4.4 0.9	1.8 0.06	1.7 0.02	1.7 0.01	1.6 0.01	1.7 0.01	1.6 0.01	1.7 0.01	1.7 0.02	1.7 0.01	rec.	9
13	4.0 0.2	1.7 0.02	1.6 0.01	1.6 0.01	1.6 0.01	1.7 0.01	1.7 0.01	1.7 0.01	1.7 0.01	1.7 0.01	rec.	3
14	4.7 -	2.0 -	1.5 -	1.8 -	1.6 -	1.6 -	1.6 -	1.7 -	1.6 -	1.7 -	rec.	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

rec. Recurring until the end of IRT.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10		n
1	- - -											
// 6	- - -	- -										
7	3.5 -	3.2 -	1.6 -	1.7 -	1.6 -	1.7 -	1.6 -					1
8	4.7 -	2.1 -	1.5 -	2.1 -	1.6 -	2.2 -	1.6 -	1.7 -				1
9	4.5 -	1.5 -	1.8 -	1.6 -	1.8 -	1.8 -	1.6 -	1.6 -	1.7 -			1
10	2.3 -	2.0 -	2.1 -	1.6 -	1.8 -	1.7 -	1.6 -	1.7 -	1.6 -	1.7 -		1
11	- - -	- -	- - -	- -	- - -	- -	- - -					
12	- - -	- -	- - -	- -	- - -	- -	- - -	- -				
13	3.7 -	1.6 -	1.5 -	1.6 -	1.6 -	1.6 -	1.9 -	1.6 -	1.6 -	1.9 -	rec.	1
14	- - -	- - -	- - -	- -	- - -	- -	- - -	- - -	- - -	- -		

L I C K I N G on a DRL 12 sec.

Expt. 3 Rat 17

Table XVI

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	- - -	* †									
2	- - -	- -									
3	7.5 8.7	1.7 0.01	1.6 0.3								2
4	5.5 0.8	1.6 0.01	1.5 0.01	1.5 0.01							5
5	5.5 0.3	1.6 0.05	1.5 0.02	1.5 0.04	1.6 0.03						14
6	5.4 0.4	1.6 0.05	1.6 0.05	1.5 0.03	1.5 0.01	1.5 0.01					19
7	5.3 0.2	1.5 0.06	1.5 0.02	1.5 0.01	1.6 0.02	1.5 0.01	1.6 0.01				6
8	4.9 0.1	1.4 0.01	1.5 0.01	1.5 0.01	1.6 0.01	1.6 0.04	1.6 0.01	1.5 0.01			9
9	5.3 0.06	1.4 0.01	1.5 0.01	1.4 0.01	1.5 0.01	1.6 0.01	1.6 0.01	2.7 2.8	3.1 5.8		2
10	4.6 -	1.4 -	1.5 -	1.4 -	1.8 -	1.6 -	1.6 -	1.5 -	1.7 -	1.8 -	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

IRIs(decades of licking/IRI)

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	9.6 14.6										14
2	6.2 7.3	3.4 16.3									9
3	6.5 6.2	2.5 5.2	3.1 5.4								5
4	- - -	- - -	- - -	- -							
5	- - -	- - -	- - -	- - -	- - -						
6	5.8 -	1.4 -	1.5 -	1.4 -	1.6 -	1.5 -					1
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	- - -	- -	

LICKING on a DRL 12 sec.

Expt. 3 Rat 19

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of licking/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	7.2 * – †										1
2	8.3 6.8	1.8 0.06									4
3	7.9 1.6	1.7 0.1	1.6 0.05								9
4	7.7 1.3	1.6 0.2	1.6 0.1	1.7 0.1							13
5	7.1 1.5	1.5 0.05	1.5 0.01	1.7 0.06	1.9 0.07						16
6	6.2 1.6	1.5 0.03	1.5 0.01	1.5 0.04	1.6 0.07	1.8 0.07					4
7	4.5 –	1.4 –	1.6 –	1.6 –	1.8 –	1.7 –	1.9 –				1
8	5.3 –	1.4 –	1.4 –	1.6 –	1.4 –	1.9 –	1.7 –	1.6 –			1
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	10.2 18.8										17
2	7.1 12.1	5.9 13.3									6
3	6.7 –	3.6 –	3.8 –								1
4	19.4 –	1.6 –	5.7 –	2.0 –							1
5	– – –	– – –	– – –	– – –	– – –						
6	6.2	1.8	1.9	1.5	1.5	1.4					1
7	– – –	– – –	– – –	– – –	– – –	– – –	– – –				
8	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –			
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	

LICKING on a DRL 12 sec.

TABLE XVIIa

Correlation coefficients between the mean duration of the post-response 'pause' and the amount of stereotyped collateral behaviour in the ensuing interresponse intervals (IRIs).

Expt. 3 (Licking data)

	Rat 15	Rat 16	Rat 17	Rat 19
Post reinforced response IRIS	-0.75	-0.59	-0.78	-0.83
Post non-reinforced response IRIs	-	-	-	-

(These negative correlation coefficients confirm the observation that the shorter the post response time the greater the amount of gnawing in the remainder of the IRI.)

Expt. 3 Rat 15

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	9.1 * 2.9 †										12
2	9.4 1.9	3.0 0.8									19
3	8.3 1.5	3.1 2.3	2.8 0.3								12
4	9.7 0.4	2.3 0.3	3.1 1.5	2.5 0.3							4
5	7.0	1.8	3.3	3.2	1.9						1
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	8.9 1.9										10
2	7.1 1.8	3.9 2.6									21
3	7.4 1.6	2.9 1.4	3.2 2.3								18
4	6.0 2.6	2.9 0.7	3.5 1.5	3.2 0.2							7
5	6.5 1.1	2.7 0.1	2.5 0.4	2.8 1.9	3.6 0.9						5
6	5.6 -	2.8 -	4.0 -	2.5 -	2.1 -	1.7 -					1
7	2.9 -	3.2 -	5.1 -	6.4 -	1.7 -	1.9 -	2.7 -				1
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

GNAWING on a DRL 12 sec.

Expt. 3 Rat 16 TableXIX

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	8.5 * 2.5 †										4
2	9.0 2.9	3.2 2.2									9
3	8.2 3.4	2.7 1.9	2.9 0.9								22
4	8.2 4.0	2.7 0.7	2.7 0.8	2.3 0.4							17
5	8.0 3.9	2.7 1.4	3.3 4.3	2.4 1.1	2.5 0.5						15
6	7.4 3.4	2.5 0.05	2.6 1.1	2.3 0.6	2.0 0.4	2.3 0.2					4
7	6.7 1.1	2.8 1.7	2.0 0.2	2.1 0.01	2.7 1.9	2.4 0.3	1.8 0.5				2
8	8.9 13.0	2.0 0.03	6.0 23.3	2.2 0.01	2.3 0.5	2.4 0.5	3.3 3.0	2.0 0.2			2
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	7.3 -										1
2	6.2 0.2	1.9 0.7									2
3	6.1 4.9	2.7 1.0	2.5 0.5								9
4	7.9 8.7	2.8 0.3	2.4 0.1	2.4 1.1							4
5	7.2 6.2	3.4 1.6	3.2 2.7	2.7 0.8	2.3 0.3						3
6	6.2 0.01	2.3 0.3	2.0 0.01	2.9 0.01	4.5 3.5	2.2 0.2					2
7	7.8 -	3.2 -	1.9 -	2.8 -	2.2 -	1.8 -	1.5 -				1
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

GNAWING on a DRL 12 sec.

Expt. 3 Rat 17 Table XX

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.1 3.3	* †									2
2	6.4 1.7	4.0 0.9									7
3	6.3 4.0	3.0 1.5	3.1 0.7								14
4	5.8 2.4	2.7 0.8	2.9 0.8	2.6 0.5							16
5	4.6 2.3	3.4 3.5	2.9 3.0	2.6 0.3	3.1 1.0						9
6	5.7 3.3	3.1 2.1	5.0 9.3	3.7 8.2	3.2 1.1	2.7 0.8					5
7	4.6 -	3.9 -	2.1 -	3.5 -	6.9 -	3.0 -	2.7 -				1
8	3.5 -	2.1 -	2.1 -	7.3 -	2.5 -	2.3 -	2.3 -	2.6 -			1
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	3.6 -	2.4 -	2.7 -	1.7 -	1.7 -	3.6 -	6.4 -	3.0 -	2.6 -	2.7 -	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.3 6.1										2
2	5.9 3.1	3.7 1.4									14
3	6.2 4.5	3.1 0.6	3.3 1.6								10
4	5.0 1.6	2.4 0.1	3.0 1.7	2.7 0.8							12
5	4.5 1.3	2.5 0.3	2.6 0.6	4.5 1.6	5.9 17.7						3
6	4.7 1.1	2.4 0.1	3.5 6.6	3.3 4.8	3.0 0.4	2.6 0.4					5
7	5.3 -	2.2 -	2.5 -	10.0 -	3.4 -	2.1 -	2.4 -				1
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

GNAWING on a DRL 12 sec.

Table XXI

Expt. 3 Rat 19

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	5.7 –	* †									1
2	5.9 0.2	2.8 1.4									5
3	6.6 3.1	3.3 1.6	3.2 0.9								12
4	6.6 3.5	3.3 0.9	2.9 1.0	2.8 0.3							19
5	6.8 3.1	3.2 0.3	2.6 0.5	2.3 0.6	2.9 0.8						7
6	7.5 6.6	2.9 0.9	3.0 1.0	2.6 0.3	2.9 1.2	2.4 0.6					6
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	8.0 –										1
2	7.5 9.5	3.1 0.01									4
3	6.1 3.2	3.1 2.7	2.8 1.0								8
4	5.5 3.8	3.0 2.0	2.8 0.8	3.0 0.9							17
5	5.8 1.4	2.3 0.1	2.3 0.5	2.5 0.9	2.8 0.5						10
6	6.1 1.4	2.2 0.1	2.8 0.6	2.4 0.3	3.0 1.1	2.8 0.4					5
7	4.4 6.0	2.4 0.6	3.7 8.2	4.9 7.1	2.2 0.3	2.1 0.2	3.0 1.5				3
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	

GNAWING on a DRL 12 sec.

FIGURES 34 - 37

The "rate" data from Tables XIV - XXI displayed in graph form for each animal. The "rates" for wood gnawing are shown in solid lines, the "rates" for water licking in interrupted lines.

Figure 34

Expt. 3 Rat 15

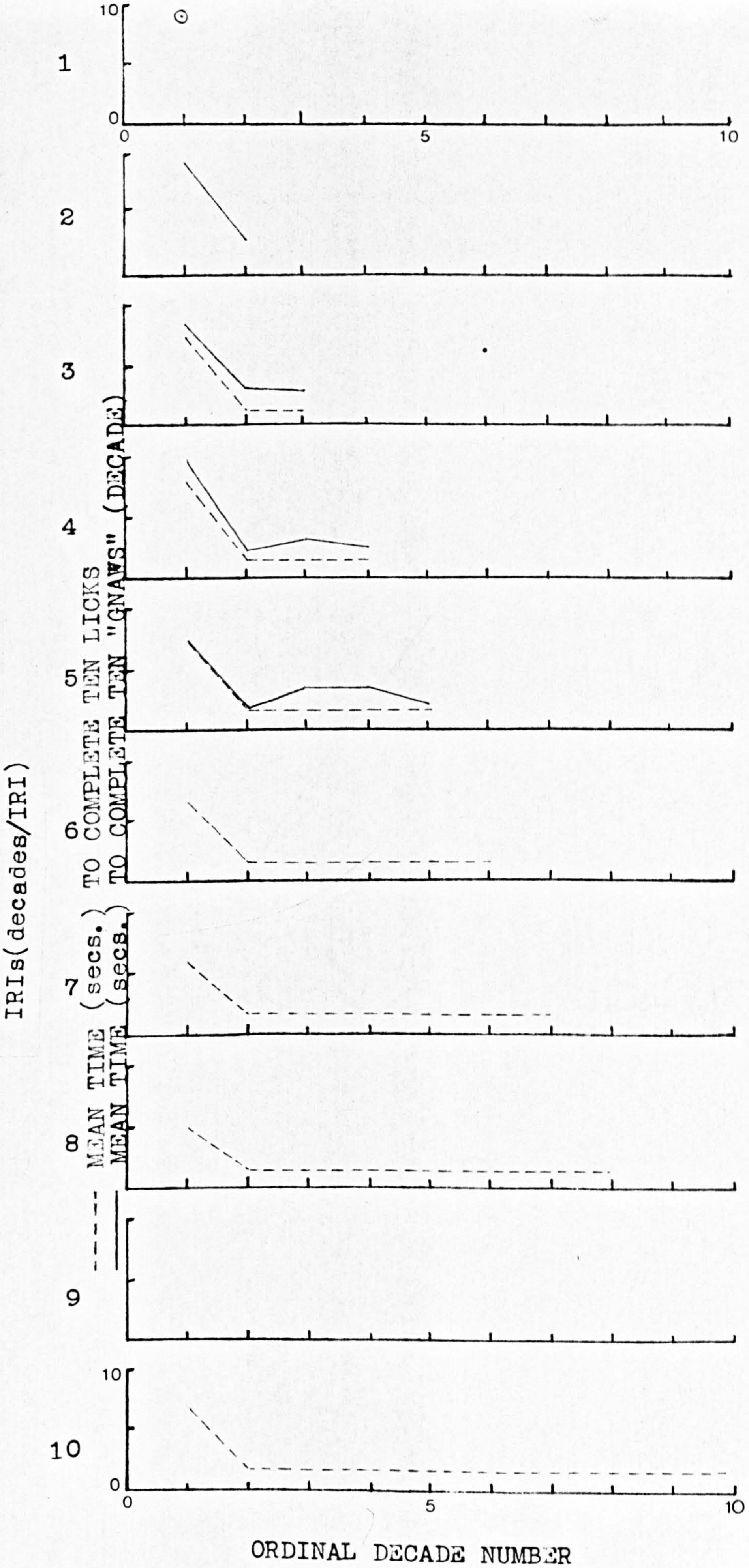


Figure 35a

Expt.3 Rat 16

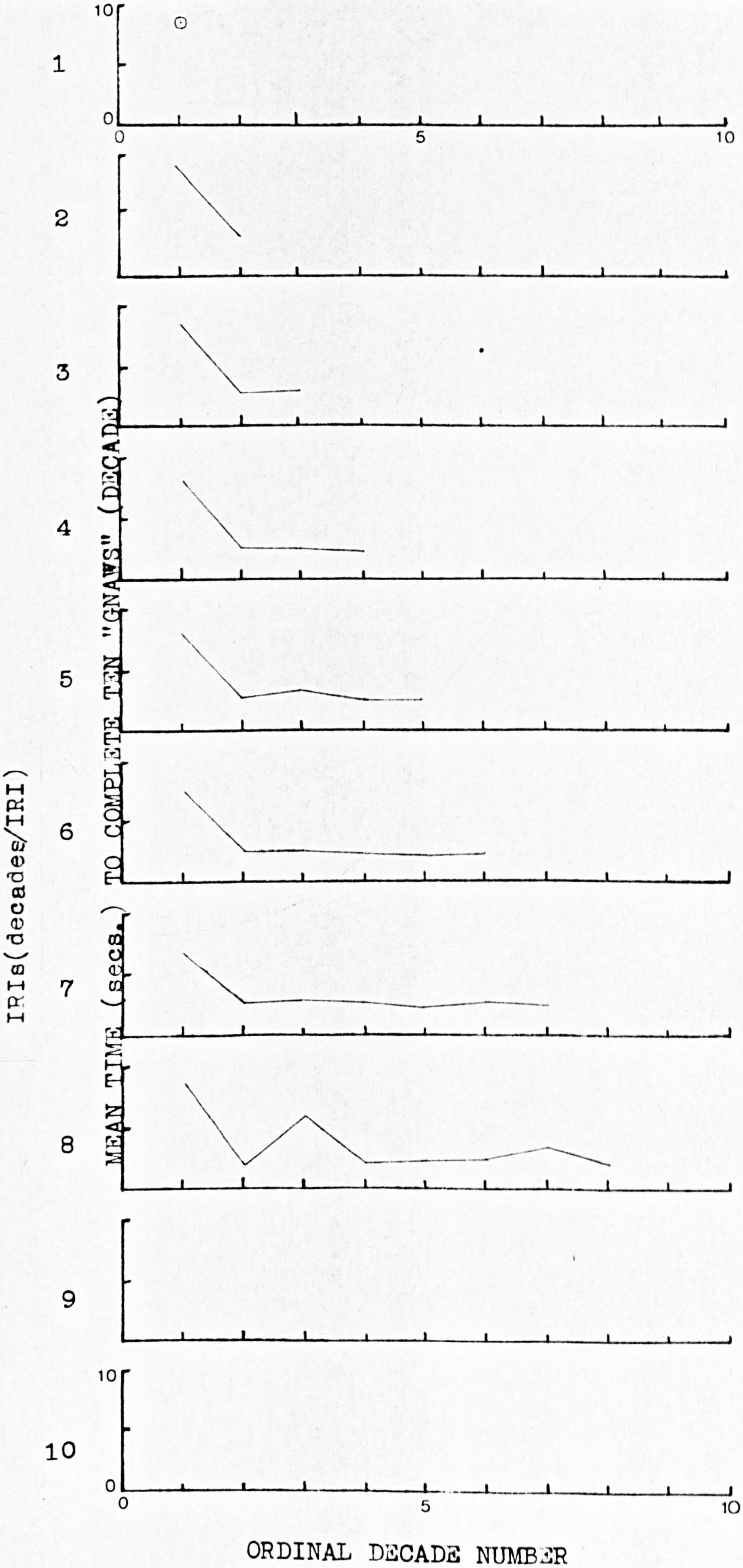


Figure 35b

Expt. 3 Rat 16

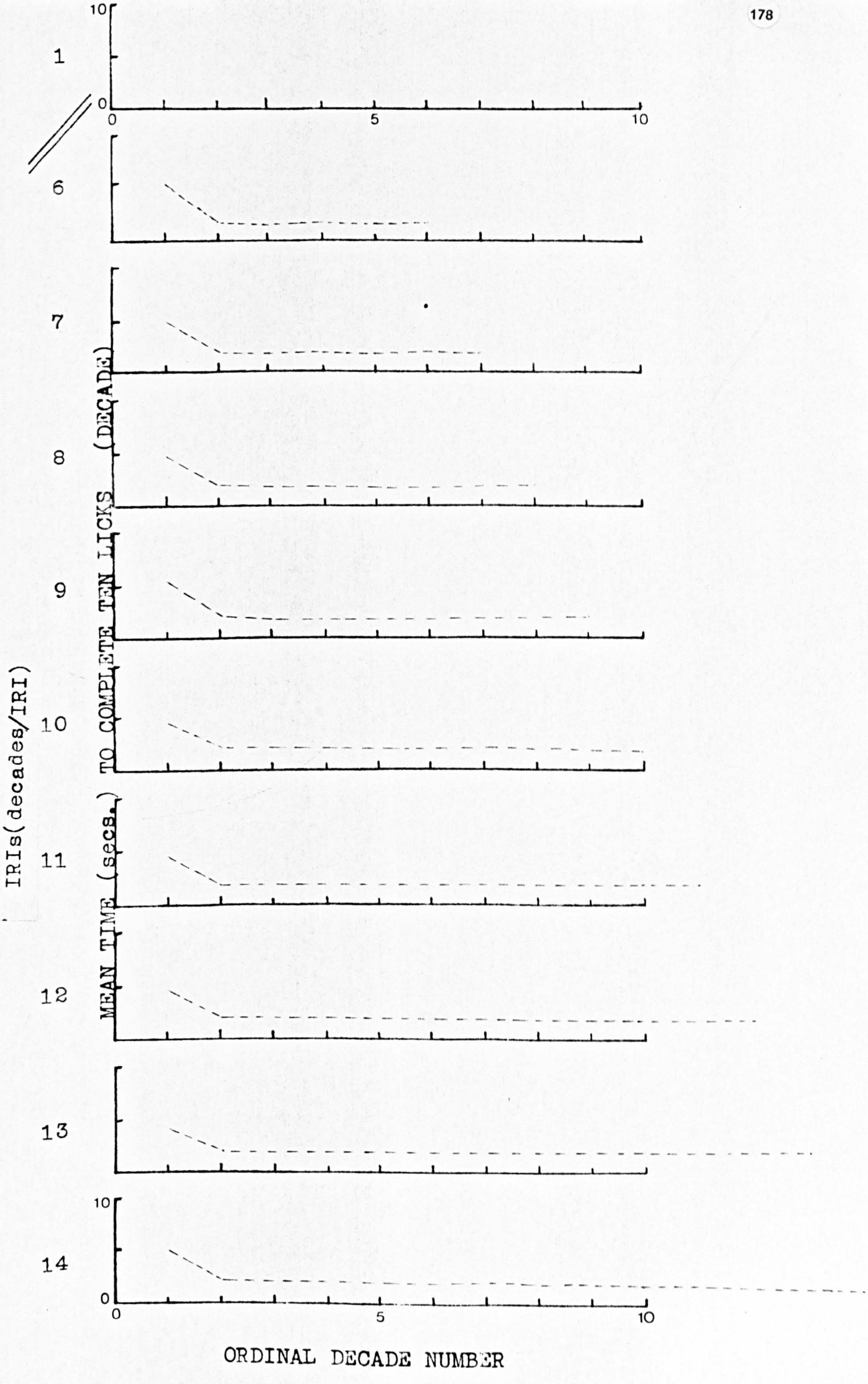


Figure 36

Expt. 3 Rat 17

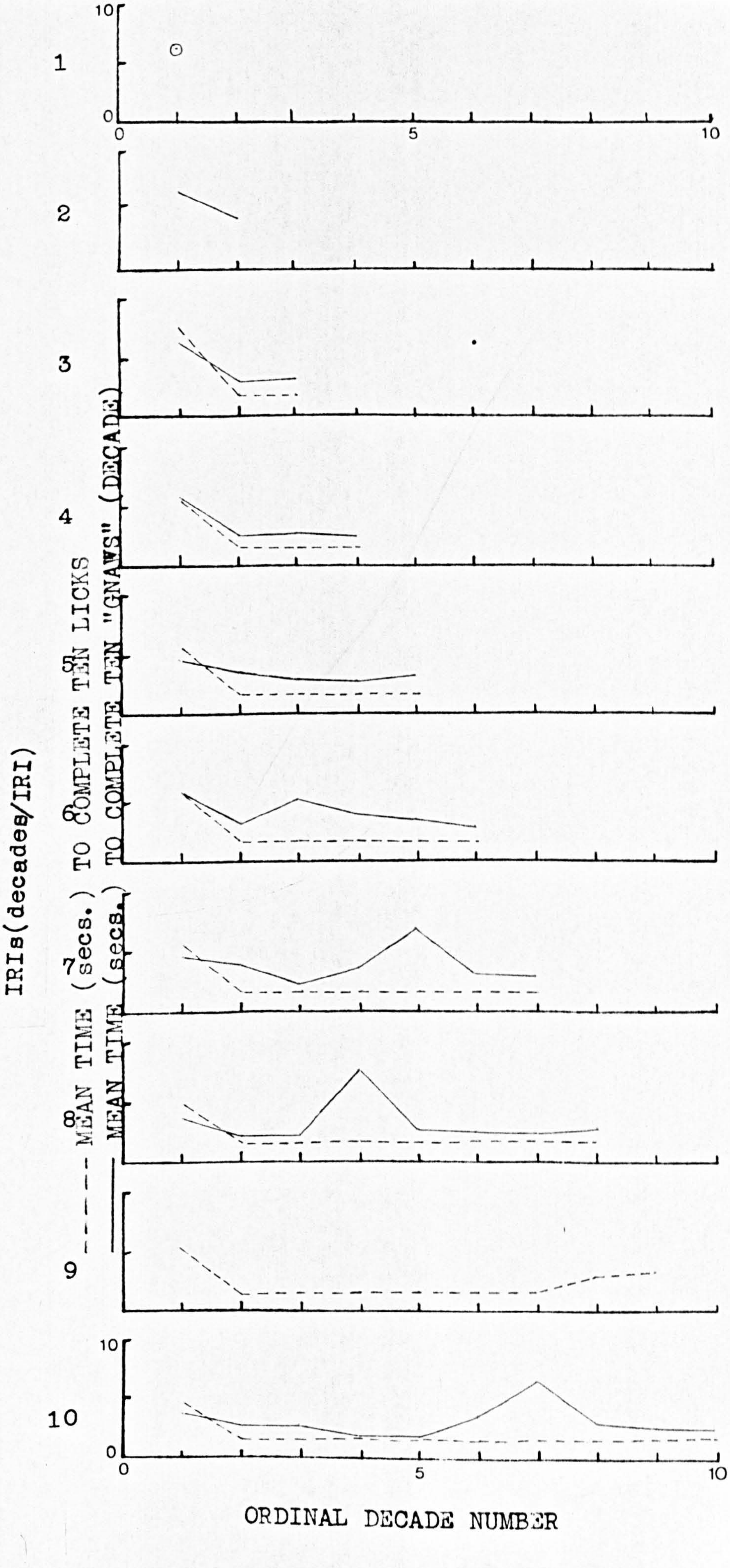
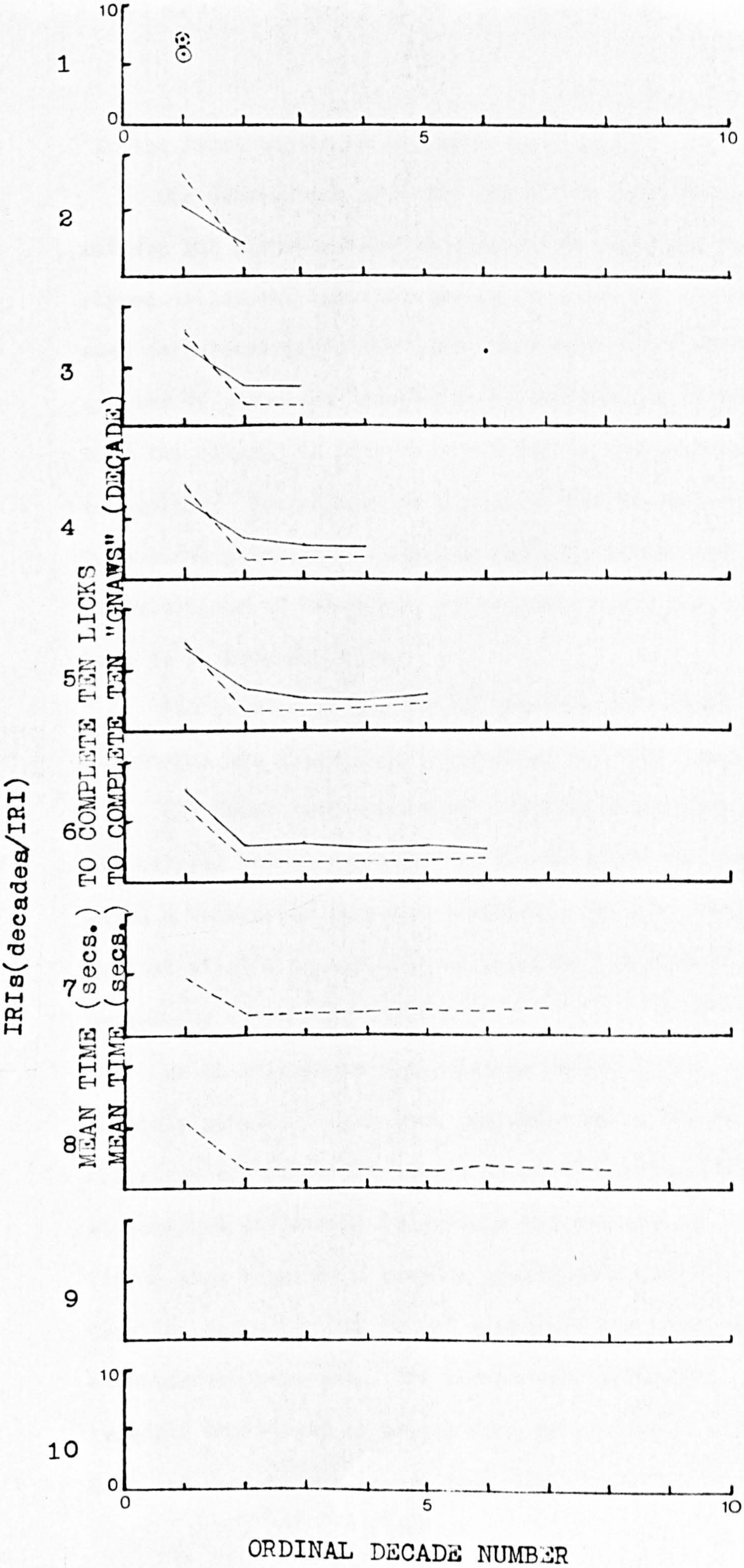


Figure 37

Expt. 3 Rat 19



in the final condition supports this belief.

The observation, that two out of the four subjects did emit altered IRT distributions as a result of emitting different stereotyped collateral behaviour, is interesting but equivocal data. If such collateral behaviour were completely non-functional and the spacing of responses totally under the control of some other factor than the changes in IRT distributions in these animals are difficult to explain. The changes in distributions do tentatively suggest a functional relationship of some kind, in which case the similar IRT distributions of the other two subjects under the three conditions have to be reckoned with.

The results of the DRL performance with water licking as the collateral are especially interesting for two reasons:-

(1) Under this condition, 3 subjects developed two distinct stereotyped collateral behaviours; one which was typically emitted after a reinforced response (licking), and the other which was emitted after a non-reinforced response (unrecorded but observed to be gnawing at the bar floor).

In an experiment with pigeons Boakes (1969) used a two component multiple schedule where each component had a DRL requirement but a different criterion IRT value. Boakes reported that two different stereotyped collateral behaviours did not appear. Lowe and Harzem (1973) have reported a similar experimental situation where the second (smaller criterion IRT value) component was introduced following any unreinforced response. The result was that each component of the schedule maintained an appropriate but different IRT distribution. Lowe and Harzem have argued that this demonstrates "the discriminative effects of reinforcement". In the light of their data, a similar amount of control over the collateral behaviour, after reinforced and unreinforced responses, is a possibility which might be expected.

This experiment would appear to confirm this possibility were it not for the criticism that several experimenters have suggested that schedule induced drinking is an exclusively post-food event. With the exception of Rosenblith (1970), who has presented evidence that rats will lick after a conditioned reinforcer on a second order schedule, most authoratitive writers (Falk, 1972; Segal and Holloway, 1963) agree on a post food definition of schedule induced drinking. In this present experiment the expected control over collateral behaviour occurring after reinforced and non reinforced responding might not be so much a function of the control exercised by the fate of the preseding response as by the limitations on the occurrence of schedule induced drinking. However the observation that a second stereotyped collateral behaviour was emitted following non-reinforced responses tends to support the Lowe and Harzem finding that the fate of a response (reinforced or not reinforced) on a DRL schedule may control immediately subsequent behaviour.

The occasional drinking after a non-reinforced response may either be put down to a loss of control by the fate ofthe preceding lever press response or, more likely possibly, the occurrence of inter meal drinking as opposed to post-pellet drinking. That these types of drinking do occur is attested to by Bond (1973).

(2) The second point of interest arising from the detailed analysis of the licking behaviour is the support that it gives to some observations about first decade times in Experiment 1.

The first ordinal decade in both licking and woodgnawing analyses incorporates what is usually termed the post-response or post-reinforcement "pause" (Staddon, 1970; Lowe, Davey and Harzem 1974) and the first ten "gnaws" or licks in the IRI. Due to the relatively variable gnawing "rates" it is possible, though unlikely, that the systematic inverse relationship between the first ordinal decade duration and the subsequent amount of collateral behaviour in the IRI, might be due to changes in gnawing "rate" for the first ten "gnaws". This might leave the post response "pause" constant for all IRIs. However the licking data shows that licking "rates" were very consistent. Therefore any changes, and there were systematic changes, in the duration of the first ordinal decade were probably due to changes in the duration of post response "pauses."

These results increase confidence in the observations made in Experiment 1. The duration of the post response "pause" (whether following a reinforced or an unreinforced response) appears to be a predictor of the amount of subsequent collateral behaviour in an IRI. Therefore, where the collateral behaviour is known to occur at a unform rate the post response "pause" on DRL schedules will be a predictor of the duration of the IRI within which it occurs.

EXPERIMENT 4

Introduction

Experiment 2 suggested that the stereotyped collateral behaviour, while not being directly responsible for the accurate spacing of lever press responses in time, might fulfil a lever press response inhibition function by keeping the subject away from the lever and the attendant situational stimuli for responding. It was suggested that this competing behaviour might be maintained by adventitious reinforcement from reinforced lever press responses. Experiment 2 left unanswered the questions of (1) how accurately spaced lever press responding in time is controlled, and (2), why the subject should cease to emit the competing or inhibiting behaviour at one comparitively consistent point in time rather than at any other?

The present experiment attempted to manipulate the distance from the lever at which the subject gnawed the wood to ascertain whether this variable could control lever press response rate or the accurate spacing of these responses in time.

Two strategies were open to the experimenter, either the rod attached to the normal wood block could be lengthened or the size of the woodblock itself could varied. In order to leave the subject as free as possible to behave where it would, three different lengths of wood were employed.

The order in which the alternative wood blocks could be presented also posed a problem. Either each length of wood could be presented to the subject over consecutive sessions until the subject was producing stable behaviour on that length of woodblock, whereupon the next woodblock length would have been presented, or, a different length of woodblock could be presented each session, the order being randomised within the limits of equal exposure to all woodblock lengths.

The first alternative would have meant a very long experiment, during which time gnawing patterns might change for uncontrolled reasons. For this reason the second alternative was employed.

Method

Subjects: Three rats (Laboratory Numbers 21, 22 and 23) were maintained as has been described in the General Method section.

Apparatus: As described in the General Method section except that two additional lengths of wood were used (but still one piece *per* session) The three different lengths of wood block were:- Small (normal size) 4 cm. Medium - 8 cm. and Large - 12 cm.

Procedure: All subjects were pre-trained as described in the General Method. Then all subjects were run for 60 daily (30 minute) sessions on a DRL 18 sec. schedule. The 60 sessions were divided into 20 groups of 3 sessions each. Within each group of 3 sessions there was one session with each size of wood block. The order of presentation of woodblock size within any group of 3 sessions was randomised. The final group of 3 sessions was arranged so that each subject received the small, medium and large woodblocks in that order over the 3 final sessions. These three final days were test days in the sense that performances on these days were analysed in detail.

Results

The stability of the DRL performances, especially over the last 15 days was very satisfactory for all subjects (Figure 38). The cumulative records for each animal in each test session were typical of what the experimenter had come to expect of the performances with stereotyped collateral woodgnawing. The cumulative records for Rat 22 are shown (Figure 39) and are also representative of the other two

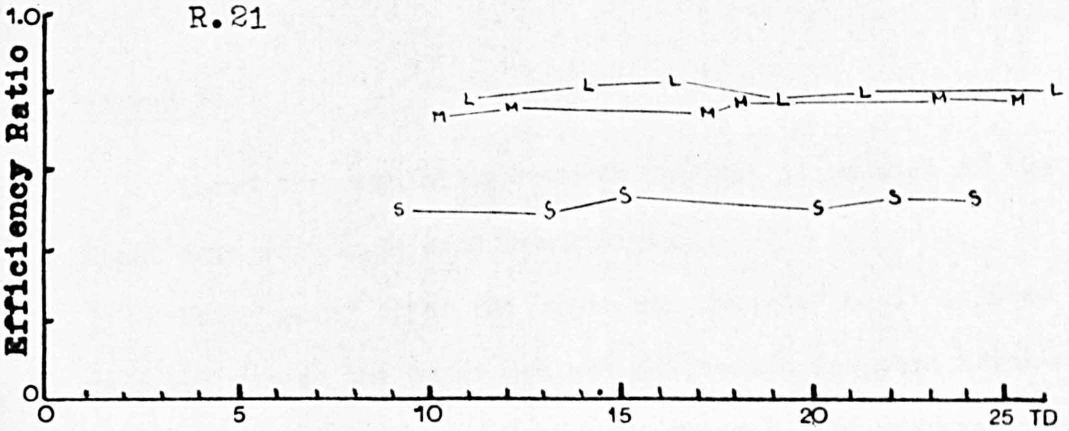
FIGURE 38

Shows the stability of DRL 18 sec. performance of each subject for the 15 days prior to the three test days (final days for each of the 3 sizes of wood block).

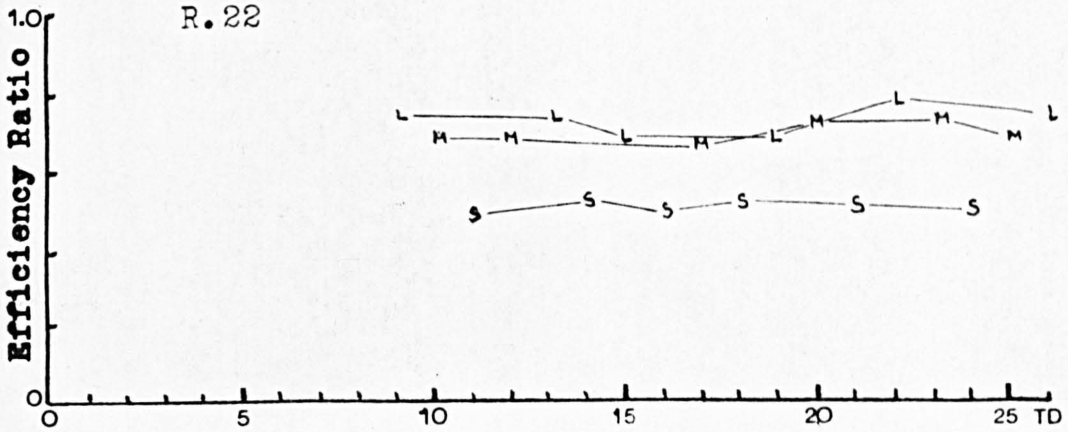
The stability is represented as efficiency ratios calculated by dividing the total number of reinforced lever press responses in a session by the total number of lever press responses for that session.

The sessions which contained the same size of wood block are joined together. In the final 3 days the order of presentation was the same for each subject, first day (day 24 on graph) s = small woodblock: second day (day 25 on graph) M = medium wood block: third and final day, L = large woodblock.

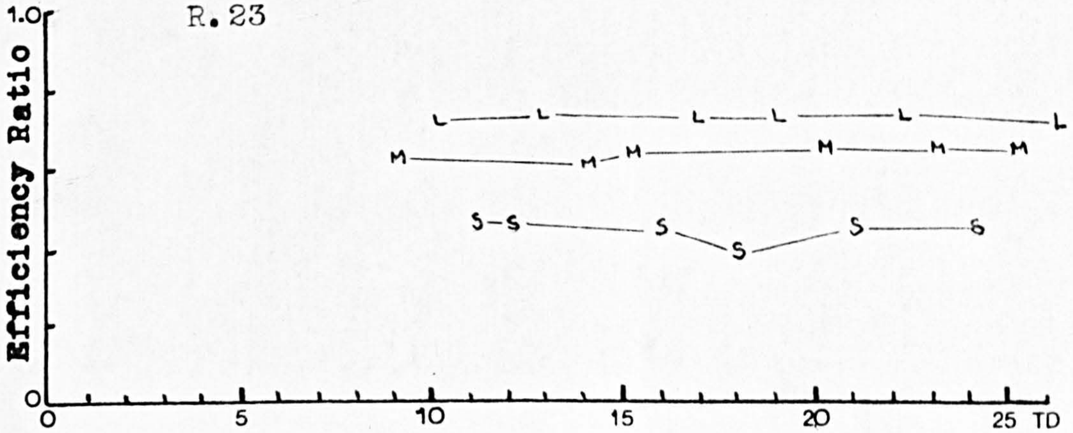
Expt. 4 Rats 21-23 Figure 38



Stability of DRL behaviour, last 25 days before Test Day (TD)



Stability of DRL behaviour, last 25 days before Test Day (TD)



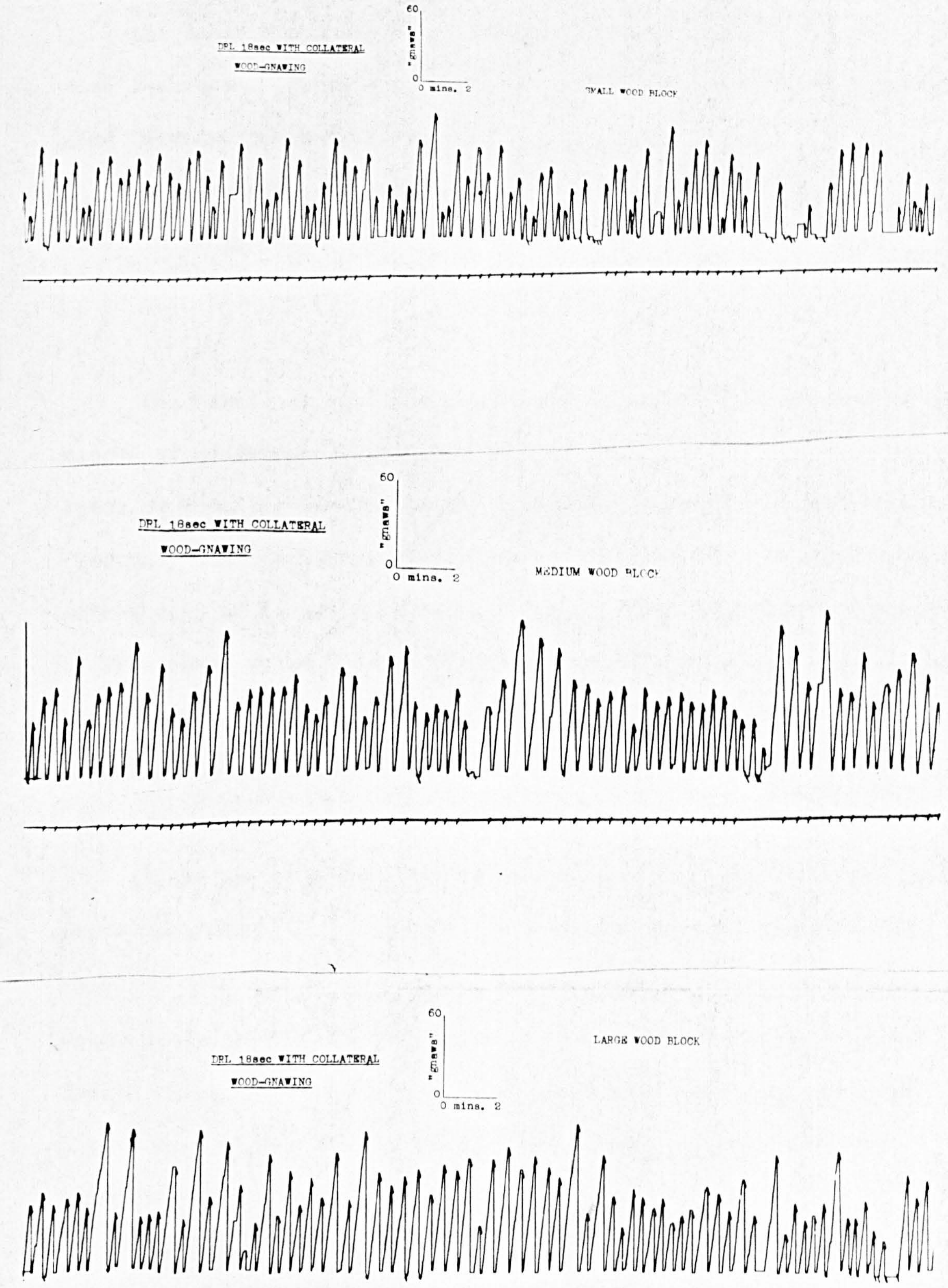
Stability of DRL behaviour, last 25 days before Test Day (TD)

FIGURE 39

Shows the cumulative records for Rat 22 on each of the three final days with each wood block size.

Each "gnaw" steps the upper pen upwards once. A lever press response resets the upper pen and delivers a downward "hatch-mark" of that pen. A reinforced response is indicated by a downward "hatch-mark" of the lower pen.

Expt. 4 Rat22 **Figure 39**



subjects. It is noticeable even from these records that

the behaviour looks more stereotyped or regular as the wood block size increases. There are fewer IRTs with no recorded behaviour and also fewer response "bursts".

The analysis of woodgnawing for each length of woodblock is shown in Tables XXII - XXX.

The result of giving the subjects an opportunity to gnaw at wood blocks of different lengths and thereby at different distances from the lever is seen in the IRT and IRI (amount of gnawing per IRI) relative frequency distributions. There was a uniform shift to longer IRTs with access to longer woodblocks. The relative frequency distributions of IRIs shows no consistent change in the distribution of woodgnawing within IRIs, except that with increasing size of woodblock there is a reduction in the number of IRIs containing fewer than 10 "gnaws" (Figures 40 - 42).

There was a marked difference between the total number of lever press responses for the three test sessions for each subject. The response rate dropped by at least a third between sessions with short woodblocks and the sessions with the longer lengths of wood (Table XXXI). That this was also the case in the previous five groups of 3 sessions is seen from the efficiency ratios of these sessions (Figure 38).

The tooth mark patterns on each woodblock size for the final 9 days are shown in Figure 43. The exaggerated shape to which the woodblocks had been gnawed is shown under 'A' where each woodblock had been present for two sessions of that woodblock size. Rats 21 and 22

FIGURES 40 - 42

Shows the relative frequency distributions of IRT/sec. and IRI/ amount of gnawing for each subject and each condition of wood block size.

The IRI analysis is in decades (or 10s) of "gnaws" per IRI category. Total number of "gnaws" for each condition are given at top right.

Figure 40

Expt. 4 Rat 21

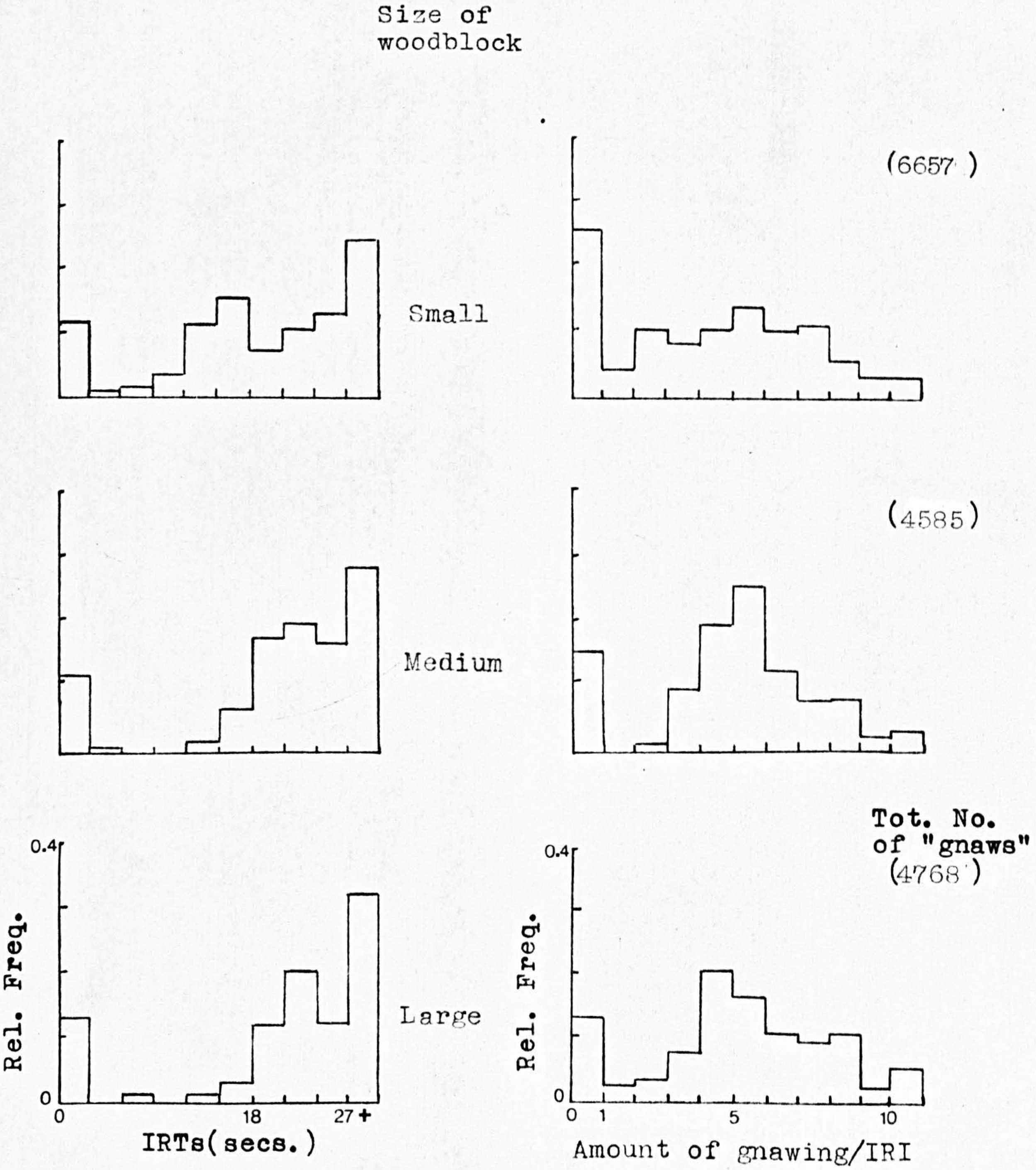


Figure 41

Expt. 4 Rat 22

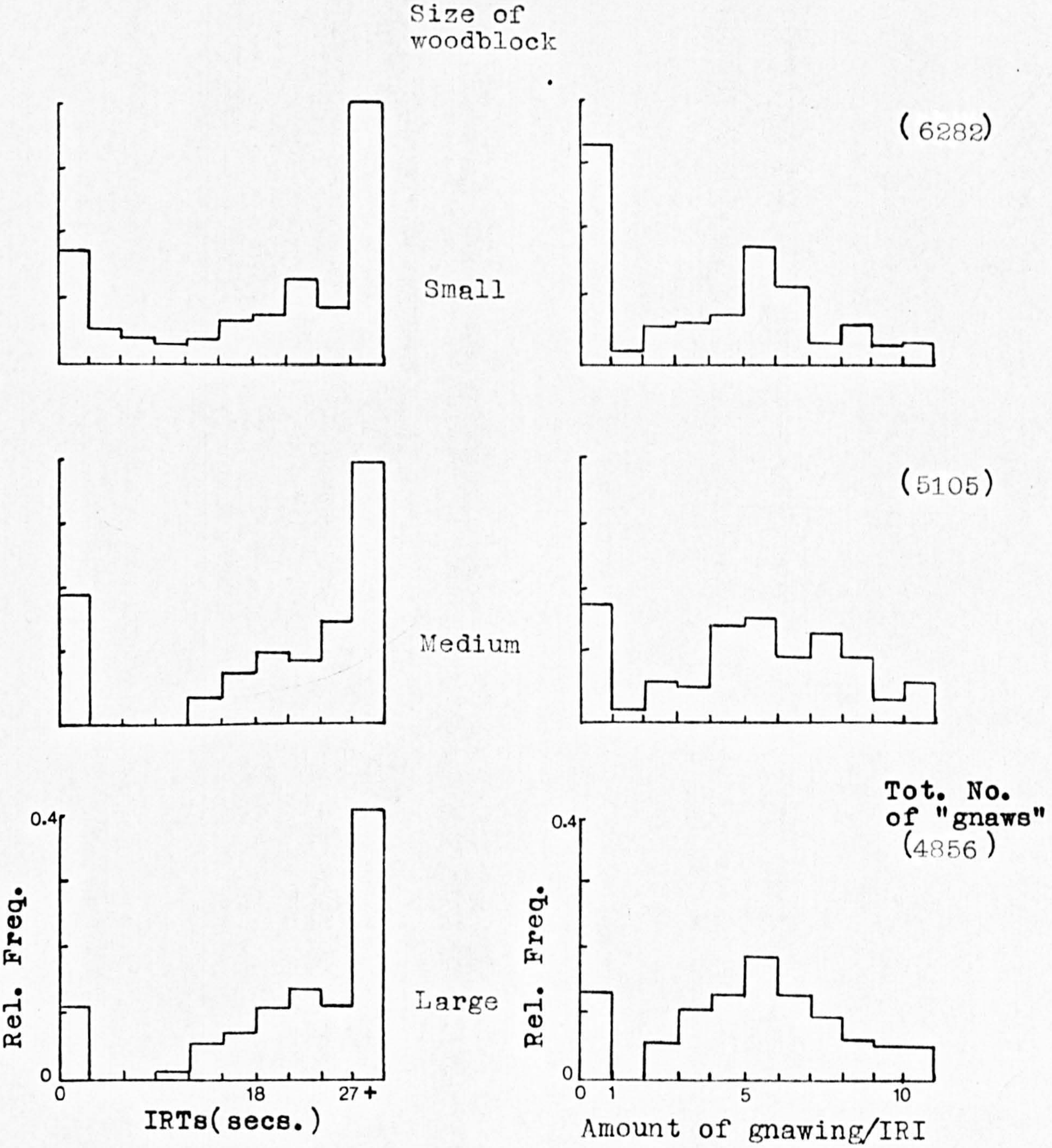
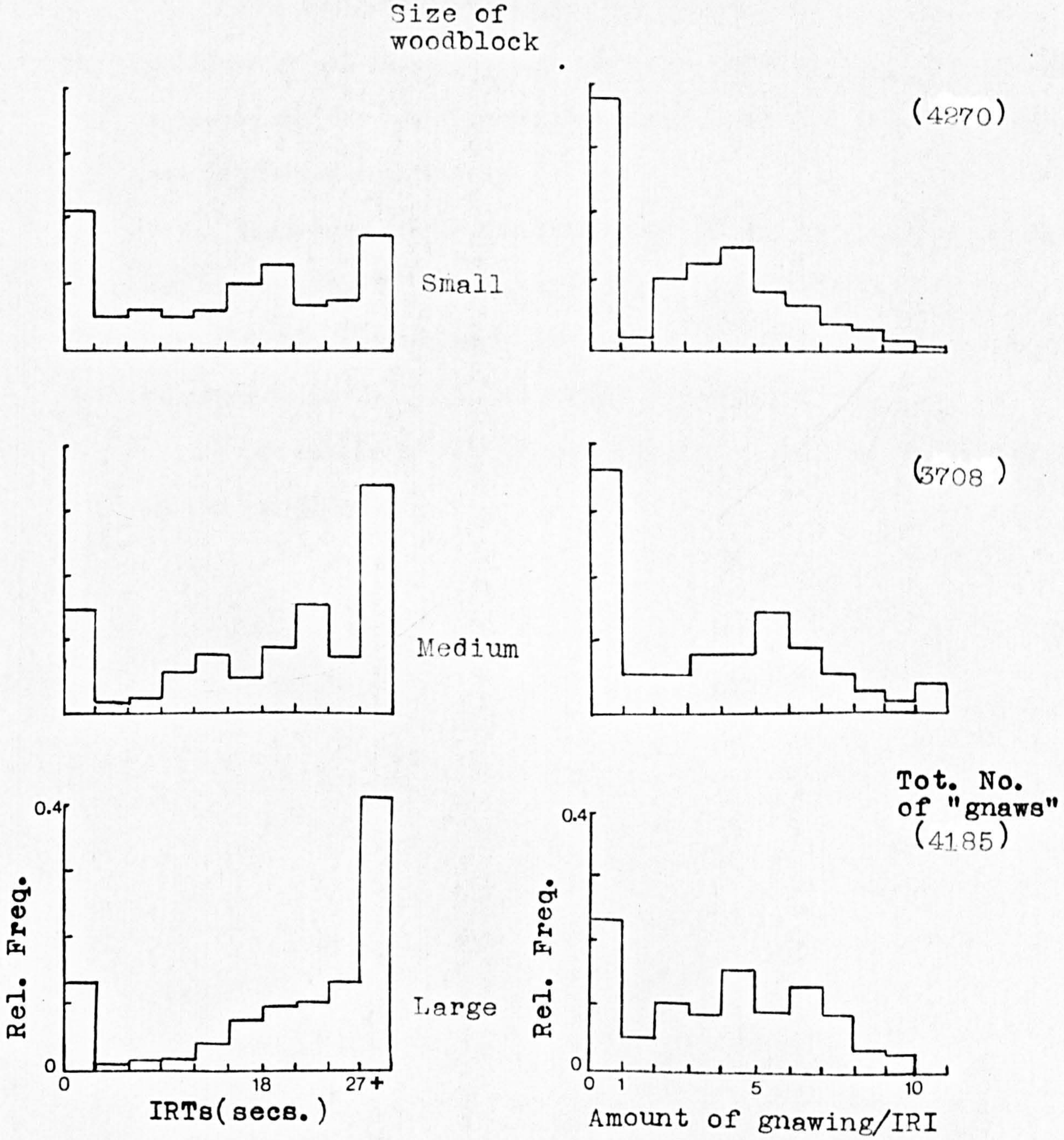


Figure 42

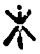
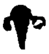
Expt. 4 Rat 23



TABLES XXII - XXX

Show the woodgnawing analysis for each subject on the DRL 18 sec. schedule with a different size of woodblock available in each session.

The table is divided into two matrices, The upper one is an analysis of all inter-response intervals which followed a reinforced response, and the lower , a similar analysis of IRIs which followed a non-reinforced response.

Each cell within a matrix shows  the mean time to complete ten "gnaws", and  the variance of the times which make up that mean time, for all instances of a decade occurring at that ordinal position in an IRI with that amount of gnawing.

The number of IRIs in any category is given by the "n" value on the extreme right.

Table XXII

Expt. 4 Rat 21

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.8 * 5.3 †										3
2	11.6 128.1	2.7 0.2									10
3	7.5 4.7	3.1 0.5	3.3 0.3								9
4	8.8 7.3	3.1 1.0	3.0 0.2	3.0 0.5							7
5	8.0 7.5	3.0 0.6	3.2 0.4	3.2 0.3	3.2 0.5						19
6	7.1 2.0	2.7 0.2	3.1 0.1	2.9 0.2	2.9 0.1	3.3 0.1					9
7	8.6 5.8	2.9 1.0	3.0 0.2	3.1 0.2	3.7 2.6	3.0 0.2	3.1 0.3				14
8	7.3 3.7	2.4 0.1	2.8 0.2	6.7 72.4	2.7 0.1	2.7 0.2	3.4 0.5	3.1 0.2			5
9	6.1 0.5	2.8 0.1	2.6 0.1	2.9 0.1	3.6 0.01	3.0 0.2	3.0 0.2	3.0 0.3	3.5 0.7		3
10	6.9 2.8	3.1 0.5	2.9 0.4	3.5 2.7	3.1 0.3	2.6 0.1	3.4 0.7	3.0 0.4	3.6 0.7	3.1 0.1	3

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	10.8 10.4										3
2	8.3 5.2	3.2 0.3									6
3	6.0 1.7	3.4 0.6	3.2 0.8								4
4	7.8 21.1	2.9 0.03	2.5 0.2	2.5 0.5							9
5	7.7 0.8	3.2 0.07	2.5 0.03	2.5 0.2	2.6 0.2						3
6	4.4 3.1	3.4 4.2	2.8 0.1	2.7 0.3	2.9 0.2	2.9 0.2					6
7	5.6 2.4	3.2 0.7	2.7 0.8	3.0 0.02	2.6 0.02	2.9 0.01	2.6 0.2				3
8	7.0 5.5	3.6 0.2	2.9 0.03	2.9 0.2	2.5 0.06	3.1 0.1	3.4 0.2	2.8 0.3			3
9	6.4 –	3.9 –	2.4 –	3.0 –	2.5 –	2.8 –	2.8 –	2.8 –	2.8 –		1
10	2.0 –	2.7 –	2.5 –	2.5 –	2.9 –	2.3 –	3.2 –	2.8 –	3.1 –	3.0 –	1

DRL 18 sec. with SMALL wood block

Table XXIII

Expt. 4 Rat21

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	– – –	* †									
2	– – –	– –									
3	6.9 2.2	3.3 0.7	3.4 0.5								8
4	7.1 1.3	3.4 0.4	3.2 0.3	3.5 0.2							17
5	7.0 3.3	3.2 0.2	3.2 0.3	3.3 0.4	3.3 0.5						24
6	6.9 1.3	3.2 0.3	3.1 0.3	3.0 0.3	3.4 0.5	3.0 0.1					9
7	6.8 6.4	3.3 0.3	3.0 0.3	3.5 0.2	3.1 0.04	3.3 0:2	3.6 0.1				6
8	5.8 1.6	2.9 0.4	3.0 0.1	4.1 2.1	3.2 0.2	3.3 0.5	3.2 0.4	3.1 0.08			6
9	6.0 –	3.5 –	2.7 –	3.2 –	3.6 –	3.1 –	2.6 –	3.2 –	3.1 –		1
10	5.9 2.8	3.0 0.3	3.2 0.4	3.2 0.3	3.9 3.1	3.5 0.5	2.5 0.01	2.8 0.02	2.8 0.4	4.1 0.6	2

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	– – –										
2	5.2 –	2.9 –									1
3	6.2 –	3.1 –	2.7 –								1
4	5.5 1.1	2.4 0.07	3.1 0.8	3.1 0.04							2
5	12.3 –	3.2 –	4.2 –	3.8 –	3.4 –						1
6	4.4 5.8	3.7 0.06	2.9 0.2	2.7 0.3	3.3 0.3	3.8 1.6					3
7	6.7 –	2.6 –	3.4 –	3.5 –	3.3 –	4.7 –	2.9 –				1
8	6.7 –	3.1 –	2.6 –	2.6 –	2.3 –	3.0 –	3.1 –	2.9 –			1
9	4.6 –	2.5 –	2.5 –	3.5 –	8.1 –	2.7 –	3.1 –	3.1 –	2.7 –		1
10	15.4 –	2.1 –	2.6 –	3.5 –	8.1 –	2.7 –	3.1 –	3.1 –	2.7 –	3.0 –	1

DRL 18 sec. with MEDIUM wood block

Table XXIV

Expt. 4 Rat 21

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	6.0 * – †										1
2	9.2	– –									
3	9.2 4.1	3.5 0.6	3.3 0.3								7
4	7.4 1.3	3.6 0.8	3.2 0.4	3.3 0.6							16
5	8.3 7.2	3.0 0.3	3.4 0.4	3.5 0.5	3.2 0.1						13
6	7.3 5.3	3.3 0.2	3.7 0.9	3.9 3.9	3.1 0.2	3.0 0.3					8
7	6.6 2.8	3.0 0.08	3.0 0.3	3.5 0.6	3.5 0.7	3.3 0.1	3.0 0.07				8
8	8.8 53.1	3.1 0.09	3.2 0.2	3.5 0.4	3.3 0.4	3.4 0.6	3.0 0.04	3.3 0.1			8
9	9.0 5.6	2.6 0.4	2.6 0.01	3.3 0.09	3.6 0.4	2.6 0.06	3.4 0.06	4.1 2.1	2.0 0.4		2
10	7.4 1.0	2.9 0.01	2.7 0.1	3.0 0.04	3.1 0.04	3.0 1.3	3.3 0.06	2.9 0.5	3.5 0.5	3.2 0.2	4

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	26.8 –										1
2	5.1 –	4.2 –									1
3	– – –	– – –	– – –								
4	7.3 13.9	2.7 0.06	3.1 0.2	2.9 0.1							3
5	6.7 5.4	2.9 0.04	2.9 1.2	2.9 0.5	2.8 0.4						2
6	5.4 7.0	3.4 0.01	3.2 0.05	3.3 0.03	3.3 0.9	3.2 0.1					2
7	7.8 –	3.1 –	3.4 –	3.2 –	2.3 –	2.9 –	2.8 –				1
8	7.2 1.5	3.1 0.01	4.4 3.2	2.8 0.4	3.1 0.7	3.2 0.9	2.7 0.3	3.1 0.4			2
9	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	

DRL 18 sec. with LARGE wood block

Expt. 4 Rat22

Table XXV

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.4 * 0.9 †										2
2	6.9 0.4	3.2 0.2									8
3	6.7 0.9	4.0 0.7	3.4 1.7								7
4	6.8 1.4	3.8 1.8	3.3 1.0	3.1 0.2							10
5	6.7 1.2	3.6 1.5	3.0 0.3	3.1 0.6	3.7 2.5						20
6	6.5 3.0	3.1 0.3	3.7 0.9	4.0 1.9	3.4 0.9	3.2 0.6					19
7	6.8 1.8	3.0 0.5	2.8 0.3	4.6 2.9	3.1 0.05	3.3 0.3	2.8 0.2				4
8	6.1 0.8	3.4 0.4	3.4 1.4	3.8 1.0	3.0 0.3	3.3 0.3	3.6 0.4	3.6 1.9			9
9	5.5 0.07	2.9 0.1	2.8 0.6	3.0 0.2	5.1 4.1	3.9 2.7	3.3 0.5	3.1 0.6	4.0 0.9		3
10	5.5 0.05	3.2 0.05	3.3 0.4	3.5 1.5	3.1 0.1	3.3 0.05	3.4 0.2	3.7 0.1	3.3 0.4	3.8 0.2	2

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	7.1 28.4										2
2	7.4 3.8	3.1 0.1									2
3	7.9 7.9	2.9 0.1	3.4 0.5								4
4	4.4 3.1	3.5 0.03	3.0 0.01	3.7 1.7							3
5	5.7 2.1	2.9 0.1	3.5 0.6	3.5 1.5	3.2 0.4						12
6	3.4 6.3	3.2 0.1	3.3 0.9	2.8 0.5	2.9 0.03	3.3 0.2					2
7	4.8 2.7	2.9 0.01	3.2 0.02	3.4 0.5	3.1 0.1	5.0 2.2	3.7 1.5				2
8	7.5 –	4.6 –	3.0 –	3.0 –	3.0 –	3.3 –	2.6 –	3.8 –			1
9	4.7 1.1	2.7 0.1	3.4 0.3	3.0 0.01	2.7 0.01	2.9 0.1	3.5 0.06	2.8 0.3	2.8 0.3		2
10	– – –	– –	– – –	– –	– – –	– –	– – –	– –	– – –	– –	

DRL 18 sec. with SMALL wood block

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	- - -	* †									
2	7.3 2.2	3.6 1.2									4
3	6.6 1.0	3.0 0.6	2.9 0.2								3
4	6.6 0.7	3.4 0.2	3.2 0.1	3.2 0.5							9
5	6.8 0.9	3.0 0.2	3.9 1.7	3.4 0.6	3.1 0.1						12
6	6.9 1.9	3.5 0.4	3.4 0.3	3.5 0.6	3.2 0.1	3.1 0.3					7
7	6.4 2.4	3.2 0.05	3.4 1.8	3.6 1.5	3.3 1.8	3.1 0.08	3.7 1.6				11
8	6.5 0.4	3.1 0.2	3.2 0.2	3.0 0.2	3.6 1.7	3.4 0.1	3.3 0.3	3.1 0.2			9
9	5.8 0.7	4.1 0.04	2.9 0.3	3.1 0.4	2.6 0.01	4.7 7.0	3.9 0.3	3.7 0.5	3.2 0.07		2
10	6.9 1.2	3.0 0.3	3.2 0.1	4.4 4.5	3.1 0.07	3.1 0.05	3.6 1.3	3.9 4.2	2.7 0.2	3.3 0.3	3

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.8 -										1
2	6.0 34.6	3.1 1.1									2
3	4.3 0.8	2.8 0.3	2.9 0.6								2
4	4.2 1.4	3.1 0.4	2.9 0.02	2.9 0.2							6
5	4.8 3.6	3.3 0.2	3.3 0.1	3.2 0.4	3.3 1.0						5
6	3.3 3.4	2.4 0.07	2.9 0.04	2.5 0.06	4.6 1.2	3.1 0.3					3
7	5.7 12.4	2.9 0.3	4.1 3.5	3.0 0.1	4.4 6.3	3.3 0.1	3.4 0.5				3
8	5.9 -	3.4 -	3.3 -	3.3 -	3.3 -	2.8 -	3.2 -	2.6 -			1
9	4.3 -	2.7 -	2.7 -	5.9 -	2.4 -	2.4 -	2.8 -	3.3 -	2.8 -		1
10	- - -	- -	- - -	- -	- - -	- -	- - -	- -	- - -	- -	

DRL 18 sec. with MEDIUM wood block

Expt. 4 Rat 22 Table XXVII

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	---	* †									
2	6.8 1.8	3.8 0.7									3
3	8.1 4.8	3.3 0.2	3.5 0.5								8
4	7.0 1.4	4.0 0.5	3.7 1.2	3.5 0.4							10
5	6.9 1.3	3.7 0.5	3.8 1.1	3.9 0.6	3.6 0.5						16
6	7.2 3.1	4.0 0.8	3.9 0.9	3.7 1.1	3.8 1.4	3.5 0.01					9
7	7.7 1.6	4.1 2.1	3.8 0.4	3.4 0.4	3.5 0.2	3.7 0.08	3.4 0.2				8
8	7.6 6.4	3.3 0.1	3.6 0.2	3.5 0.1	3.8 0.1	4.0 0.4	3.6 0.01	3.3 0.1			3
9	6.4 0.5	3.6 0.1	4.2 0.6	3.5 0.4	5.3 6.8	2.9 0.1	4.4 3.9	3.4 0.3	3.3 0.2		5
10	4.9 -	3.0 -	4.0 -	3.5 -	9.9 -	3.4 -	3.8 -	3.1 -	3.3 -	4.0 -	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	5.8 1.5	3.3 0.3									3
3	5.2 3.2	3.8 0.6	3.7 1.4								3
4	3.8 4.5	3.5 0.1	3.4 0.04	3.5 0.01							3
5	4.9 8.6	3.6 0.3	3.5 0.9	3.0 0.08	3.5 0.9						3
6	4.6 1.9	3.4 0.4	3.2 0.5	3.2 0.4	3.4 0.3	3.6 0.05					4
7	8.1 0.5	2.8 0.3	2.7 0.4	5.2 3.9	3.4 0.08	4.1 0.06	4.6 1.3				2
8	5.0 6.2	3.0 0.2	3.6 0.5	3.4 0.06	3.8 0.9	5.3 7.4	5.8 11.9	3.2 0.2			3
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. with LARGE wood block

Expt. 4 Rat 23

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.4 * – †										1
2	6.4 2.4	3.3 0.3									8
3	6.6 0.3	3.4 0.4	3.7 0.5								11
4	6.8 2.1	3.4 0.5	3.5 0.2	3.6 0.5							17
5	6.3 1.4	3.4 0.3	3.3 0.2	3.6 1.2	4.2 2.2						9
6	6.9 3.3	3.8 0.8	4.9 4.9	4.0 2.0	3.7 0.3	3.5 0.3					9
7	5.9 0.4	3.2 0.03	3.9 1.0	3.4 0.02	3.2 0.6	5.6 3.0	7.0 30.9				2
8	8.3 5.8	3.1 0.9	4.3 1.4	3.3 0.02	5.1 11.3	4.3 0.05	3.6 0.2	5.0 2.0			2
9	7.0 –	3.3 –	7.0 –	5.3 –	3.0 –	3.2 –	3.2 –	4.0 –	3.0 –		1
10	6.3 –	4.3 –	2.4 –	5.9 –	2.6 –	4.0 –	3.1 –	3.1 –	2.5 –	2.6 –	1

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.2 0.5										4
2	5.9 10.3	3.3 0.3									7
3	3.6 1.7	3.2 0.6	3.3 0.2								6
4	4.0 1.7	3.9 0.7	3.4 0.8	3.2 0.4							5
5	5.6 2.5	3.9 0.1	4.5 3.7	3.6 0.2	3.1 0.2						3
6	– – –	– – –	– – –	– – –	– – –	– –					
7	3.9 2.5	3.1 1.1	4.5 12.1	2.7 0.07	3.0 0.1	2.9 0.3	3.7 1.4				3
8	4.0 0.03	4.0 0.06	2.7 0.6	3.2 0.9	3.1 0.5	3.9 0.8	4.6 0.4	4.4 0.01			2
9	2.8 –	2.8 –	3.4 –	3.6 –	3.0 –	3.2 –	3.7 –	3.9 –	3.2 –		1
10	– – –	– – –	– – –	– – –	– – –	– –	– – –	– –	– – –	– –	

DRL 18 sec. with SMALL wood block

TableXXIX

Expt. 4 Rat 23

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	30.0 * 126.4 †										2
2	14.1 272.5	3.5 0.2									4
3	6.0 1.5	3.8 0.7	4.8 5.2								6
4	6.2 0.7	3.8 1.6	3.8 0.3	4.3 0.6							5
5	6.4 1.7	4.0 2.7	3.8 0.8	4.5 2.9	4.5 2.8						13
6	6.6 1.4	3.6 2.3	3.6 0.6	3.9 1.2	3.9 0.8	4.0 1.4					10
7	6.0 0.7	3.4 0.6	3.8 0.5	4.6 3.3	4.2 4.1	4.9 2.6	6.2 3.0				6
8	5.5 -	3.0 -	3.5 -	3.6 -	3.9 -	3.4 -	3.6 -	5.9 -			1
9	8.8 7.2	4.3 0.01	3.8 0.04	3.8 0.1	3.2 0.01	3.6 0.2	3.9 0.1	3.9 0.01	3.6 1.2		2
10	6.7 7.1	3.7 0.1	3.6 0.06	3.5 0.3	4.1 0.2	4.7 7.0	6.4 2.1	3.9 1.9	3.4 1.0	3.8 0.1	3

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.9 67.1										4
2	10.2 20.4	2.2 0.4									2
3	6.6 3.1	3.0 0.3	3.3 0.4								3
4	7.1 0.8	3.8 1.4	3.9 0.2	4.2 0.8							4
5	4.2 2.3	3.4 0.01	3.8 0.7	6.1 4.0	3.0 0.1						3
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	5.4 0.1	4.2 2.4	3.9 0.4	5.8 0.08	3.9 0.2	3.7 0.06	3.9 0.3	5.4 7.1			2
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

DRL 18 sec. with MEDIUM wood block

Table XXX

Expt. 4 Rat 23

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.6 * 13.1 †										2
2	11.2 28.9	4.2 6.9									8
3	9.2 12.2	3.6 0.1	4.8 2.6								6
4	7.6 3.3	4.0 0.7	3.8 0.7	3.9 1.6							15
5	6.8 2.3	4.1 5.9	3.6 0.3	5.5 15.7	4.1 3.5						7
6	7.8 12.0	3.9 0.4	4.2 3.1	3.9 2.0	3.9 0.2	4.7 3.3					8
7	7.4 0.9	3.6 0.7	5.2 6.0	3.6 0.3	4.7 1.1	4.0 0.4	3.9 0.5				7
8	7.1 2.3	3.8 0.1	3.6 0.8	3.8 0.1	4.1 4.1	3.9 0.2	4.3 3.7	3.6 0.3			4
9	10.1 14.4	3.9 0.02	3.4 0.02	6.0 5.9	4.3 0.01	3.0 0.01	3.2 0.2	3.9 1.8	4.0 0.5		2
10	- - -	- -	- - -	- -	- - -	- -	- - -	- -	- - -	- -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	6.3 9.9										3
2	8.1 0.3	3.4 0.6									3
3	7.9 5.0	3.5 1.2	4.1 0.4								3
4	4.9 0.6	3.4 0.5	6.1 7.3	4.0 0.9							2
5	7.7 14.2	3.4 0.4	4.2 1.5	3.0 0.6	4.8 0.1						3
6	5.8 2.6	3.6 0.5	3.4 0.5	4.3 2.8	4.2 2.4	4.2 1.8					6
7	4.9 3.6	2.6 0.9	4.1 0.1	3.1 0.3	2.7 0.1	3.3 0.01	3.7 0.01				2
8	- - -	- -	- - -	- -	- - -	- -	- - -	- -			
9	1.9 -	3.1 -	2.9 -	3.1 -	2.4 -	3.3 -	7.5 -	2.9 -	4.0 -		1
10	- - -	- -	- - -	- -	- - -	- -	- - -	- -	- - -	- -	

DRL 18 sec. with LARGE wood block

appeared to have gnawed more at the end of the woodblocks which was nearest the lever and intelligence panel but a considerable amount of gnawing has taken place further along the woodblock (The shadows cast by the photographic lights may give some idea of overall shapes). Rat 23 appears to have gnawed more often at the end of the woodblock furthest from the lever.

The woodblocks from the final three sessions under 'B' show the same shapes but they are less marked due to the lesser amount of gnawing (one session as against two). The standard block sizes are shown on the extreme right for comparison.

Discussion:

The result of giving the subjects the opportunity to emit the gnawing behaviour further away from the lever was a consistent drop in lever press response rates and an increase in efficiency ratios.

However observations of the gnawed woodblock suggest that, if the amount of wood removed by gnawing was reasonably constant, then only in one case (Rat 23) did the subject actually gnaw more at the end of the larger woodblocks that were furthest from the lever. The other two subjects, Rats 21 and 22 appear to have distributed gnawing along the length of the woodblocks but gnawed most often at the end nearest the lever. If the hypothesis that distance from the lever is a variable controlling the response rate were correct, there ought to be a clear difference in IRT distributions between Rat 23 data and the data for Rats 21 and 22. There does not appear to be such a difference. One suggestion which might resolve the apparent contradictions in these results, is that woodgnawing nearer to the lever involved removal of more wood from the woodblock than did woodgnawing further away. Were this the case it would be an interesting result

TABLE XXXI

Shows the total amount of lever press responses in each of the three final sessions on a DRL 18 sec. schedule with one of three sizes of wood block,

	SIZE OF WOOD BLOCK		
	Small	Medium	Large
R21	161	100	94
R22	191	108	102
R23	147	112	107

Total number of lever-press responses in each session.

Performance of three rats on a DRL 18 sec. with one of three sizes of wood block.

FIGURE 43

Shows pattern of teeth marks on gnawed wood blocks for the final 3 sessions for each rat on each size of wood block.

A: shows, for each subject, the gnawing on each size of wood block. Each woodblock was in place for two, 30 minute, sessions.

B: shows, for each subject, the gnawing on each size of wood block for the final three sessions.

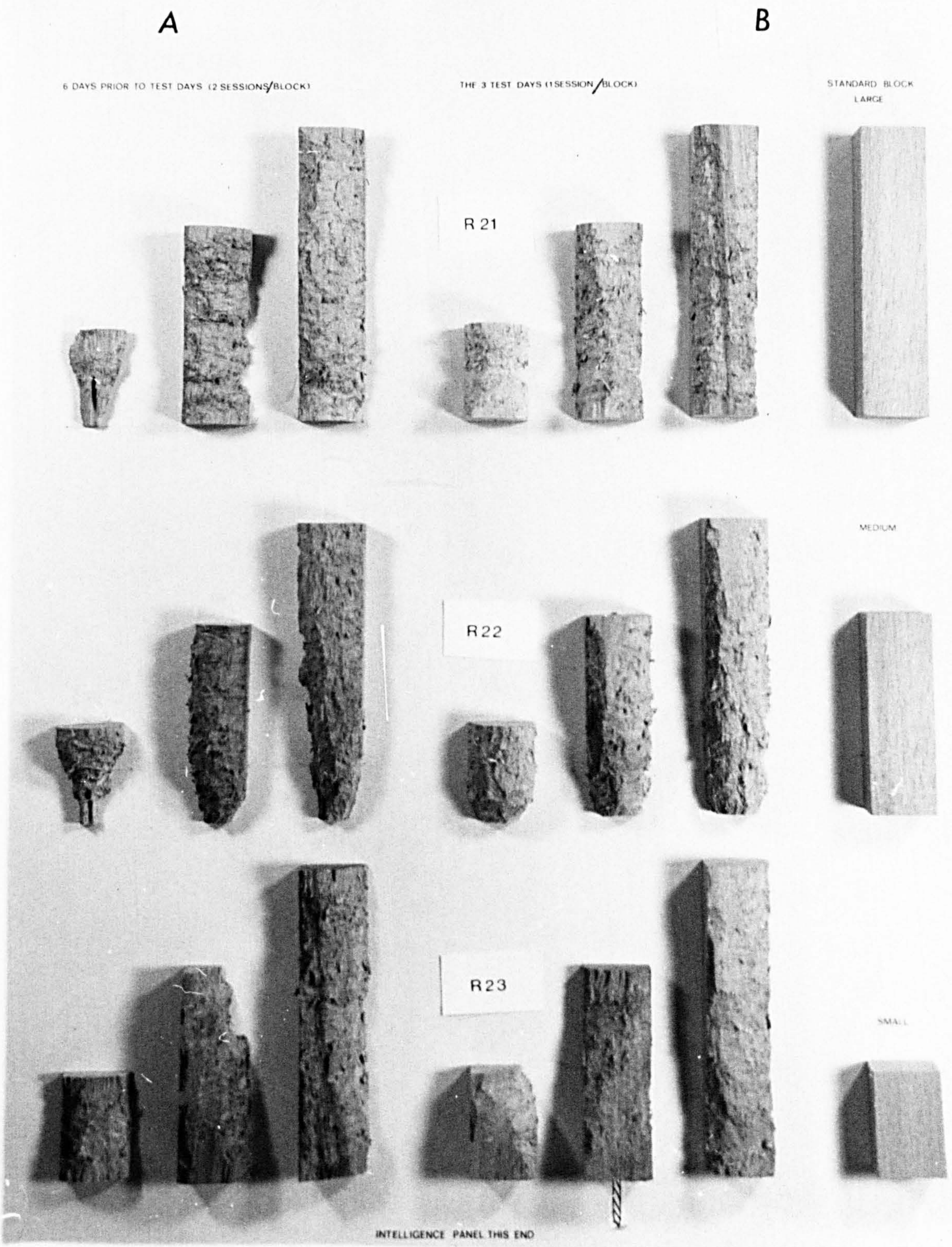
On the extreme right are examples of the original ungnawed size of each block.

The small woodblock is 4 cm. long.

The medium woodblock is 8 cm. long.

The large woodblock is 12 cm. long.

Figure 43


A
B
6 DAYS PRIOR TO TEST DAYS (2 SESSIONS/BLOCK)
THE 3 TEST DAYS (1 SESSION/BLOCK)
STANDARD BLOCK
LARGE
R 21
MEDIUM
R22
R23
SMALL
INTELLIGENCE PANEL THIS END

viewed from an ethological perspective. The nearer to the source of the conflict inducing stimuli, the greater the intensity of displaced or redirected behaviour.

However, in the absence of corroborating evidence on the amount of wood removed per "gnaw", it is clear that this explanation of the results of this experiment must remain hypothetical.

Another aspect of these results which is puzzling is the large range and low amplitude of the bimodal distributions of IRTs. While the larger range in the longer sizes of woodblock obviously must be associated with the drop in response rate, it is not clear why similar low amplitude bimodal distributions should be obtained from the sessions where the small woodblock was used. In these sessions this atypical distribution is shifted to the left towards shorter IRTs but there is no clear modal IRT category. It is possible that the technique of presenting all three woodblock sizes in daily sessions close together may have caused some generalization of responding which resulted is a wider range of IRTs in the small woodblock condition than might otherwise be expected.

SUMMARY OF EXPERIMENTS 2, 3, 4

SUMMARY

The three experiments reported in this chapter attempted to manipulate the collateral woodgnawing behaviour while maintaining the DRL schedule requirements.

Experiment 2 looked at the effect of withdrawing the woodblock from the situation described and analysed in Experiment 1. When the opportunity to emit the collateral woodgnawing behaviour was with:drawn, the results from five subjects who had been previously emitting stable DRL performance with collateral woodgnawing was as follows:-

(1) Removing the wood resulted in higher lever press response rates and a decrease in DRL performance efficiency.

(2) Despite the wood removal there was evidence that all subjects continued to space their lever press responding differentially with respect to time.

(3) Those subjects who,prior to wood removal,had produced the larger number of long IRTs and most collateral woodgnawing,emitted the higher lever press response rates in the first 8 minutes following wood removal.

(4) This experiment suggested that while collateral behaviour of this type is not necessary for "timing" behaviour, it probably serves some response inhibitory function in removing the subject from the vicinity of the lever,and it's attendant situational stimuli for responding.

Experiment 3 studied the effect of three different topographies of collateral behaviour on the distribution of lever press responses in time on a DRL 12 sec.schedule.

It was observed that amount of collateral behaviour in a session and the efficiency ratio for that session were positively related in the performance of all four subjects.

The detailed analysis of the licking collateral behaviour gave additional and substantial support to the observation from Experiment 1 that the post response "pause" may be a predictor of the subsequent amount of gnawing in, or where the collateral behaviour occurs at a uniform rate, the duration of, the inter response interval in which it occurs.

Experiment 4 demonstrated that giving three subjects on a DRL 18 sec. schedule the opportunity to emit the gnawing collateral behaviour at different distances from the lever, pellet chute and intelligence panel, resulted in a decrease in response rates and an increase in efficiency ratios.

However, direct observations of the positions on woodblocks (of different size) where the gnawing took place, suggested that either this result was a artifact produced by some other unidentified variable in the situation, or that the amount of wood removed per "gnaw" increased towards the end of the woodblock nearest the lever.

CHAPTER VI

EXPERIMENTS 5, 6 and 7

MANIPULATIONS OF THE DRL SCHEDULE REQUIREMENTS TO STUDY THE EFFECT ON THE COLLATERAL BEHAVIOUR

EXPERIMENT 5

Introduction

This was the first of three experiments which attempted to manipulate the DRL contingencies in order to study differential effects on the woodgnawing collateral behaviour. The aim of this first experiment was to replicate the extinction experiments of Laties et al., (1969). They observed that, "gnawing ceased before lever pressing.... demonstrating.....the status of collateral behaviour as a member of a hetemgeneous chain". As painted out previously in the present thesis, this analysis of woodgnawing is inconsistent with the findings of Zimmerman (1959) and Miller (1951). They both showed that a chain extinguishes from the terminal link to the initial link (rather than vice versa, as Laties et al. suggest). This finding has been supported by Bruning, Becker and Tucker (1965), Becker and Bruning (1966) and to a certain extent by Mansfield and Rachlin (1970). In this latter experiment the results indicated that "as complete response chains decrease in rate, whether by punishment, extinction or satiation, the initial and terminal elements of the chain decrease together". However there is some doubt as to whether the response chain which Mansfield and Rachlin used was in fact a chain in the sense that Zimmerman's, Miller's and Bruning's were. Mansfield and Rachlin point out that their chain, consisting as it does of right key pecks followed by left key pecks, could be regarded as a behavioural unit.

Where the initial and terminal links are topographically distinct as in the Zimmerman, Miller and Bruning experiments the consensus appears to be that such chains deteriorate from the terminal link backwards.

Method

Subjects: Five Rats (Laboratory Numbers 7, 8, 9, 10 and 11) previously used in Experiments 1 and 2. They were maintained as in Experiments 1 and 2.

Apparatus: As previously described in the General Method section.

Procedure: Following Experiment 2 the subjects were maintained at 85% of free feeding body weight for a further 21 days, after which they were reintroduced to the DRL 18 sec. schedule of reinforcement. Sessions were 60 minutes rather than 30 minutes long. All subjects were run for 15 daily sessions prior to the test day. On that day all subjects were run for 15 minutes on the DRL 18 sec. schedule, following which reinforcement of lever press responses which fulfilled the schedule requirements was discontinued. The test sessions ended when subjects ceased to emit either woodgnawing or leverpress responding for a period equal to, or longer than, 3 minutes in duration.

Results

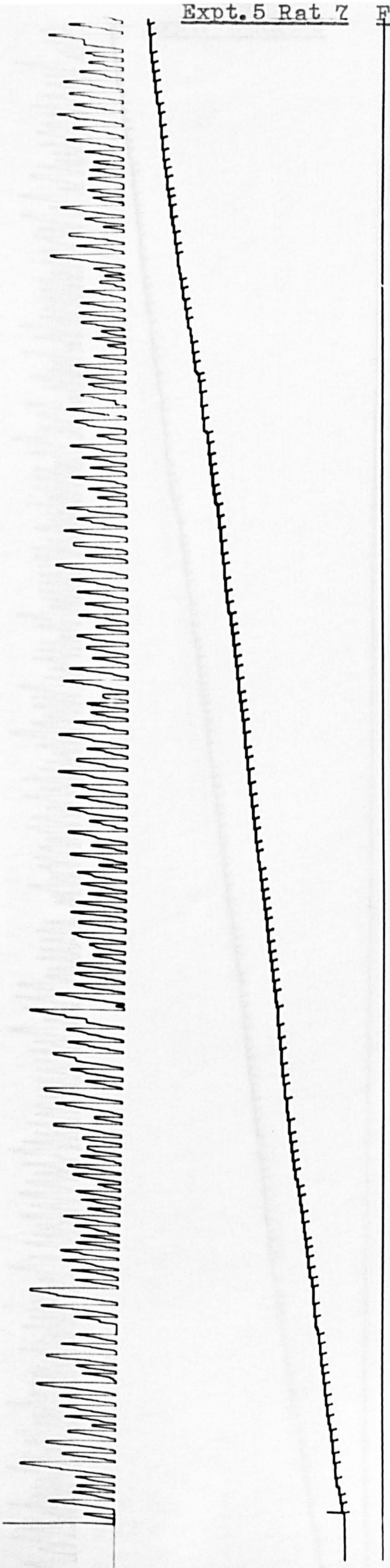
Due to the increased length of sessions the DRL performances prior to the test day were less efficient than comparable behaviour in Experiments 1 and 2. This inefficiency was not evident throughout the session but only in the second 30 minutes. Figures 44-48 show the cumulative records for the day preceding the test day. Unfortunately, as an illustration of the breakdown in the second half of the experiment they are not very persuasive. The efficiency ratios for this day were uniformly relatively high so that the breakdown later in the session, characteristic of performances in earlier sessions are not seen clearly except in the cumulative records for Rat 9 and 11. However as these were the records nearest in time to the test day they are perhaps more appropriate illustrations of the behaviour than records from earlier sessions. Four days before the test session all

FIGURES 44 - 48

Show the cumulative records of the 60 minute session on the day prior to the test day, for each subject.

The format is as for similar records in Experiments 1 and 2. The upper record shows the gnawing behaviour, each "gnaw" stepping the pen upwards once, a lever press response resets the pen. The lower record shows the lever press responding; each lever press stepped the pen upwards once while a downward "hatchmark" indicates that the response was reinforced. This lower record for Rat 11 is incomplete due to the pen running out of ink in mid-session.

Expt. 5 Rat 7 Figure 44



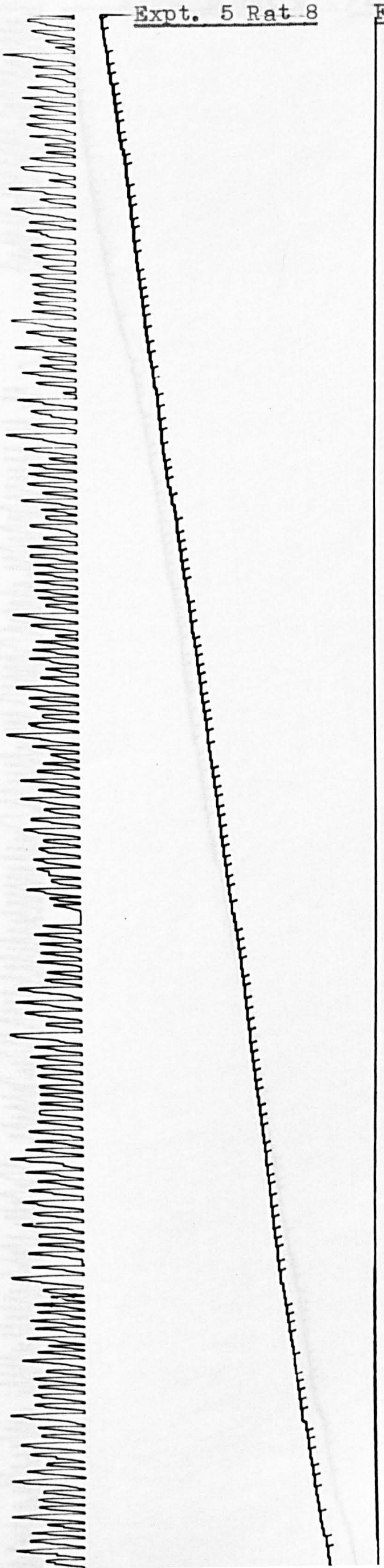
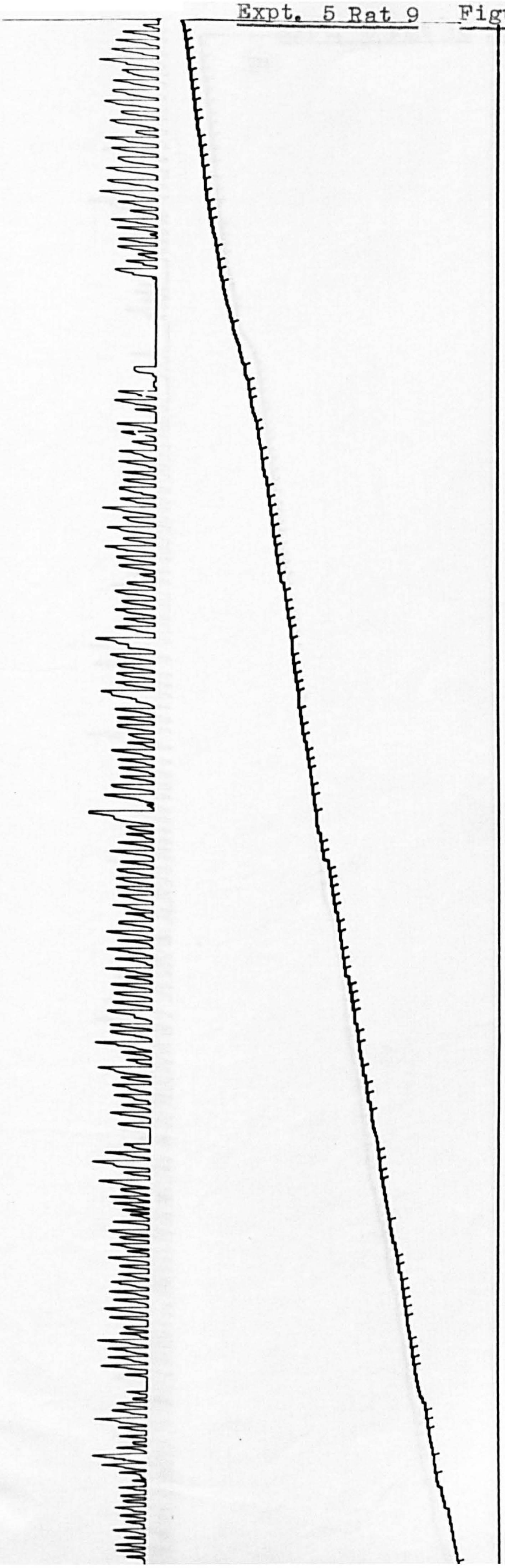
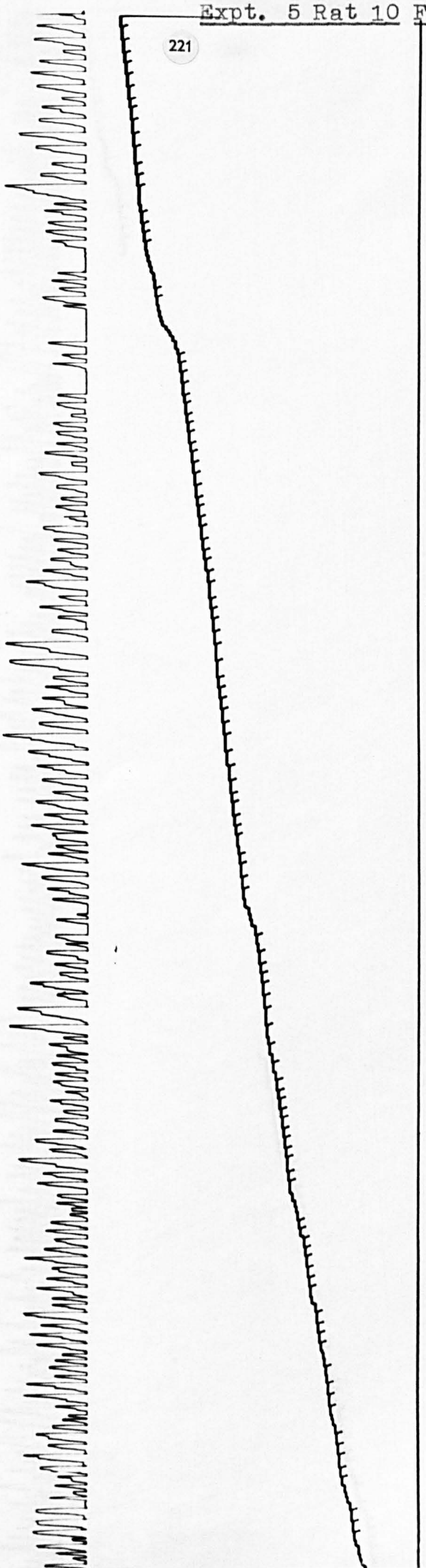


Figure 45

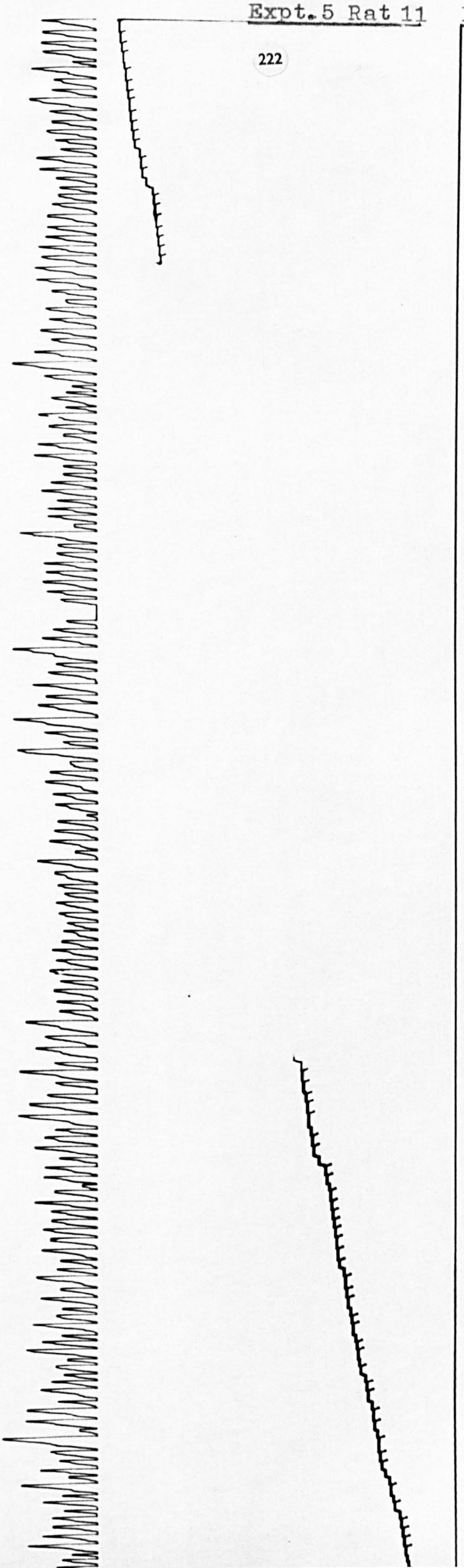
Expt. 5 Rat 9 Figure 46



Expt. 5 Rat 10 Figure 47



Expt. 5 Rat 11 Figure 48



subjects produced poor performances during that session. This was attributed to a marked drop in ambient temperature in the home cage, the result of an equipment failure. The efficiency ratios for the 15 days prior to the extinction trials are shown in Figures 49-53 :a.

The result of the extinction procedure was consistent for all 5 subjects. After extinction was introduced responding became gradually more variable and finally stopped altogether for the 3 minutes which constituted the extinction criterion. The order in which the two behaviours ceased to be emitted was clearly and consistently - woodgnawing followed by lever press responding. This is illustrated by the cumulative records for each subject on the test day (Figures 49-53:b: not all of the session is shown due to excessive length)

The data reported in this figure is from Rats 8, 9, 10 and 11 only. Due to an experimenter error, the computer punch tape of this test session for Rat 7 contained many character errors and these could not be corrected with sufficient certainty. This data is therefore omitted.

The relative frequency distributions of IRTs show the shift towards shorter IRTs in extinction (interrupted lines) as opposed to the distributions for the DRL 18 sec. performance of the 15 minutes prior to the introduction of extinction (solid lines).(Figures 49-53:c)

The woodgnawing analysis (Figures 49-53:d, Tables XXXII-XXXIX) confirm that the DRL 18 sec. performances of the four subjects whose performance could be analysed were similar in the first 15 minutes of the session prior to extinction to the previous DRL 18 sec. schedule performance of these subjects (Experiments 1 and 2). Apart from the

FIGURES 49 - 53

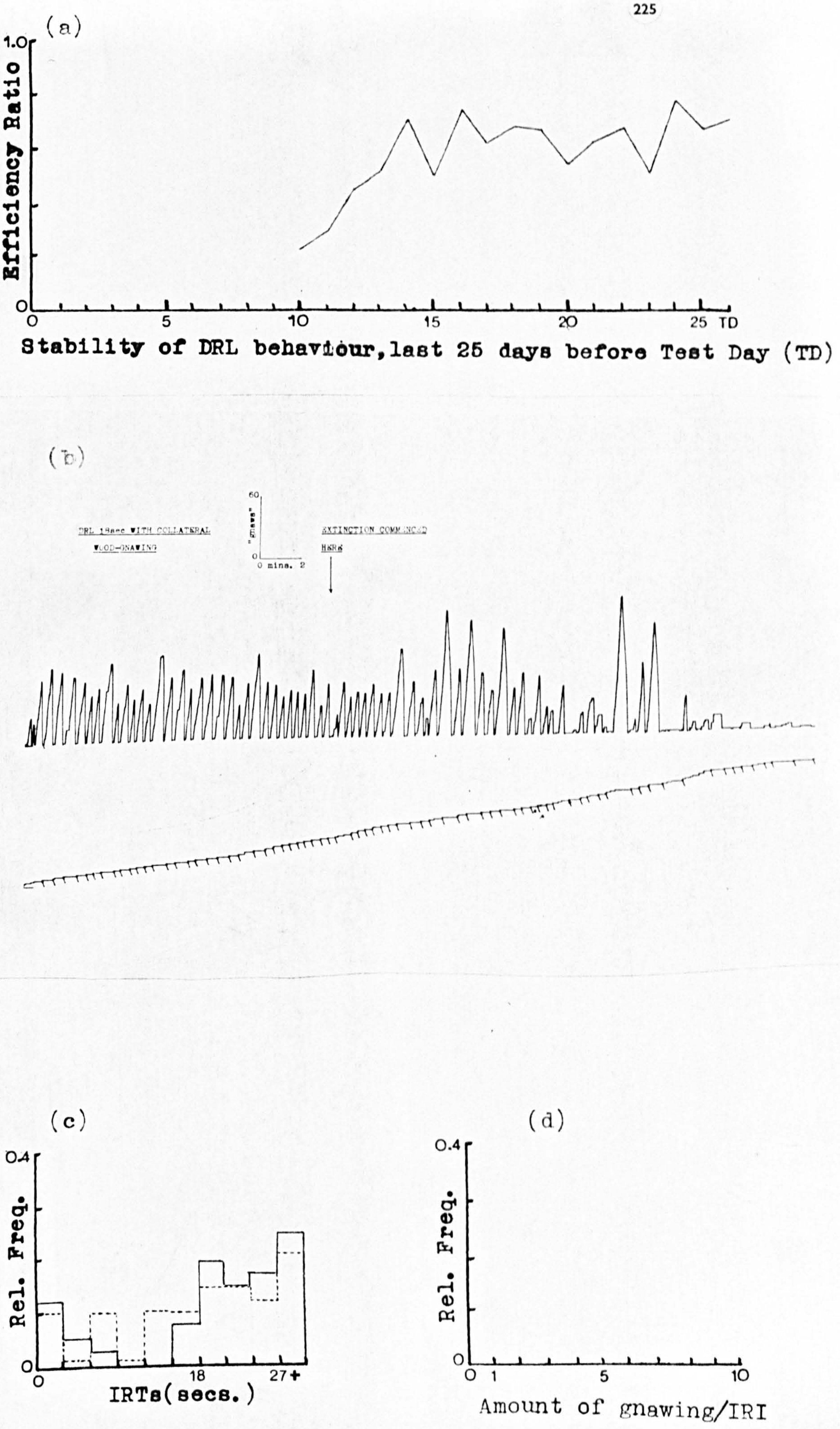
a) Shows the efficiency ratio of each daily session in the 15 days prior to the final (test) day on the DRL 18 sec. schedule. The efficiency ratio is calculated as described in Experiment 1.

b) Shows the cumulative record of the subjects final day performance both prior to and during extinction of the DRL 18 sec. schedule performance. See legend to Figs. 44 - 48.

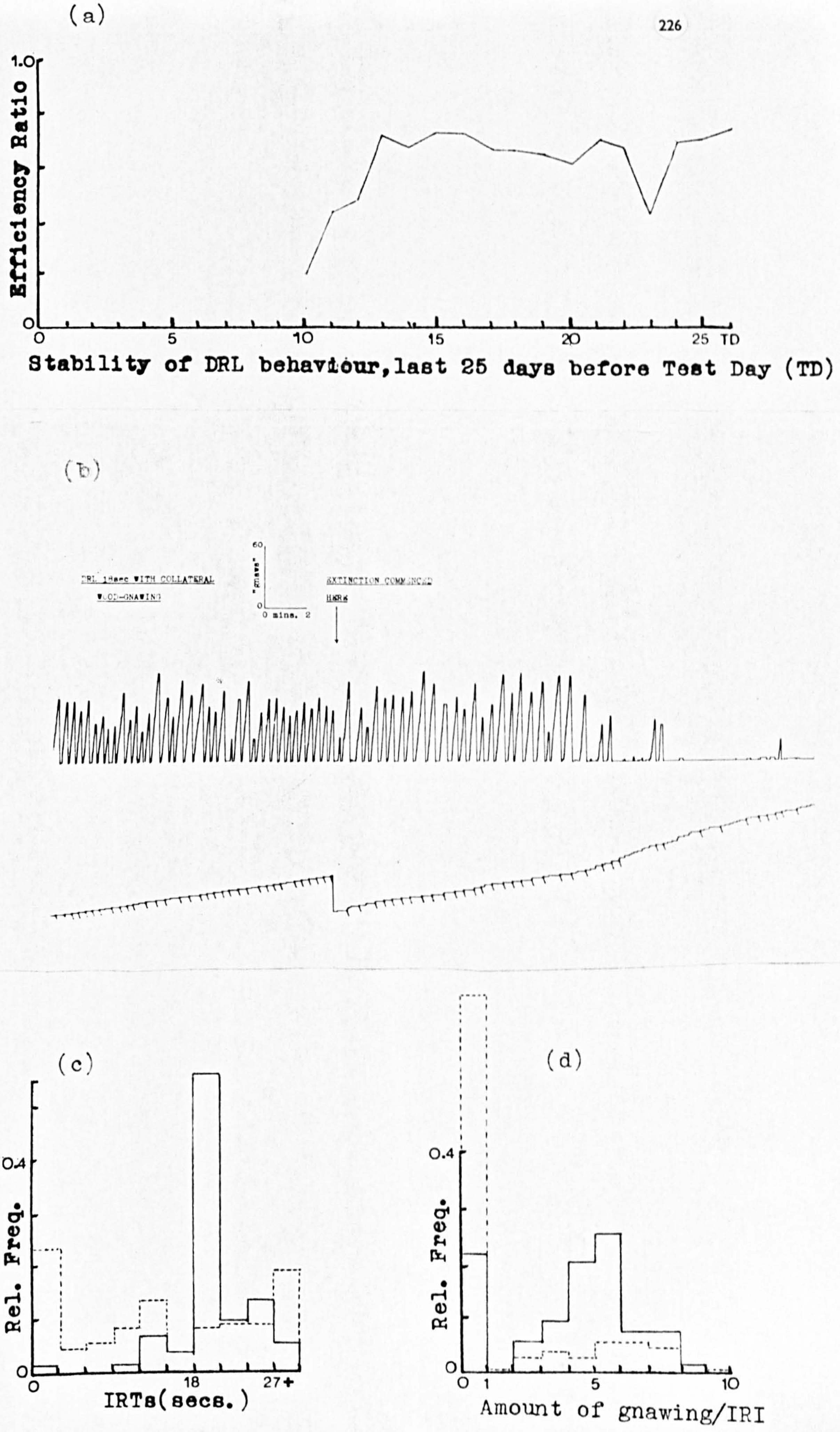
c) Shows the relative frequency distribution of interresponse times in seconds (IRT/secs) both during DRL 18 sec. schedule (solid lines) and during extinction (interrupted lines).

d) Shows (with the exception of Rat 7) the relative frequency distribution of interresponse intervals (IRIs) measured by amount of gnawing in the IRI. IRI occurring during DRL 18 sec schedule are shown as solid lines, those occurring during extinction as interrupted lines.

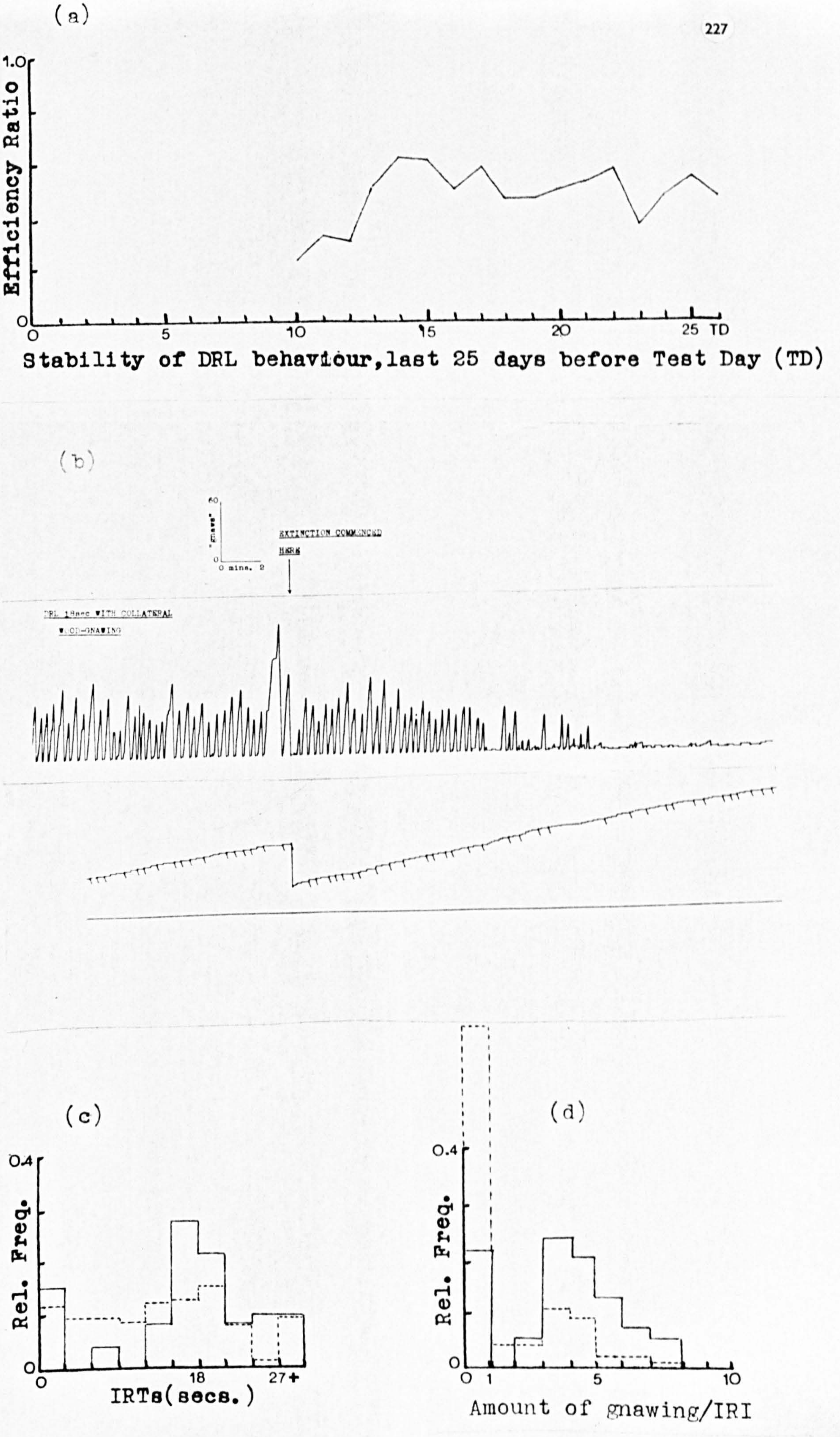
Expt.5 Rat 7 **Figure 49**



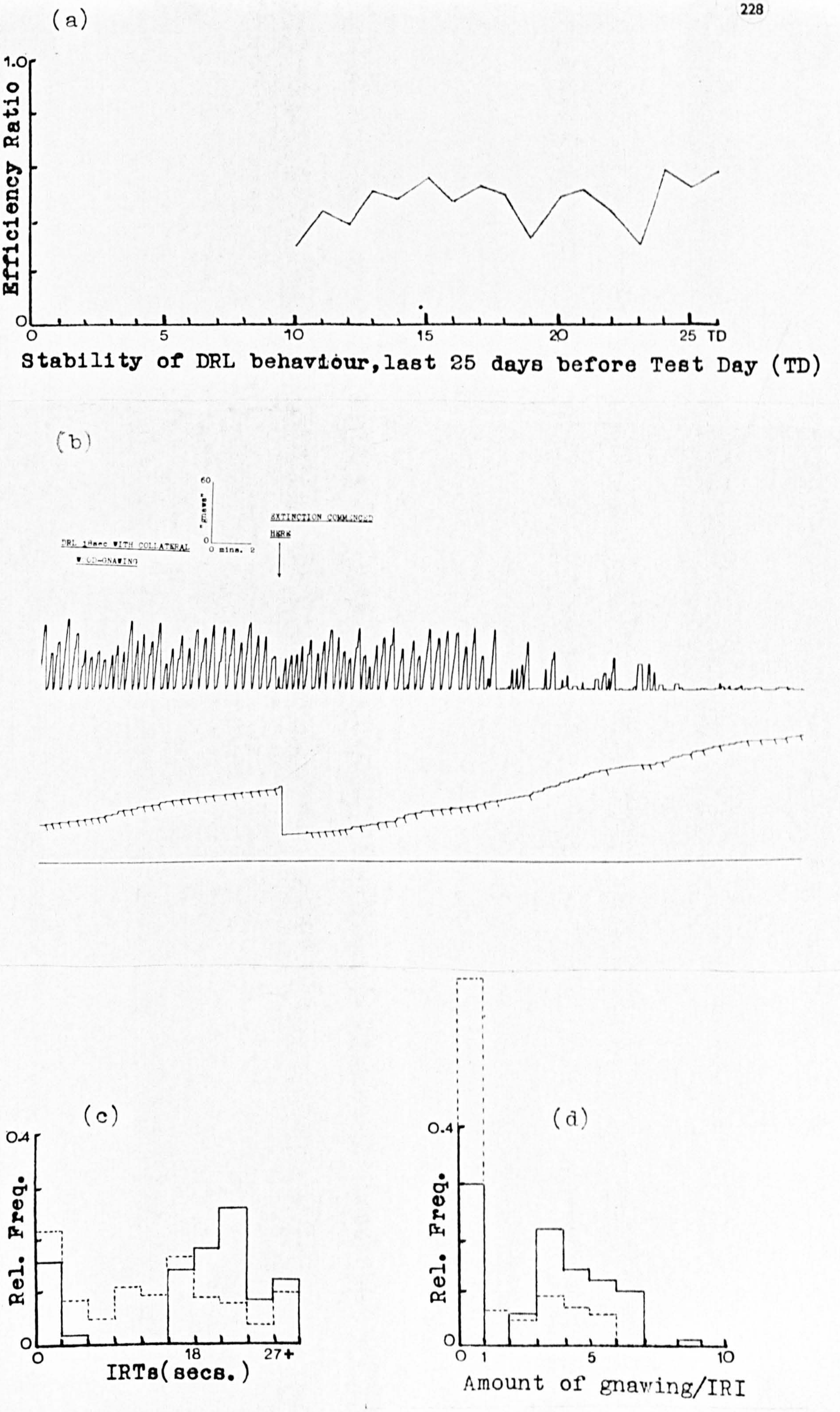
Expt. 5 Rat 8 **Figure 50**



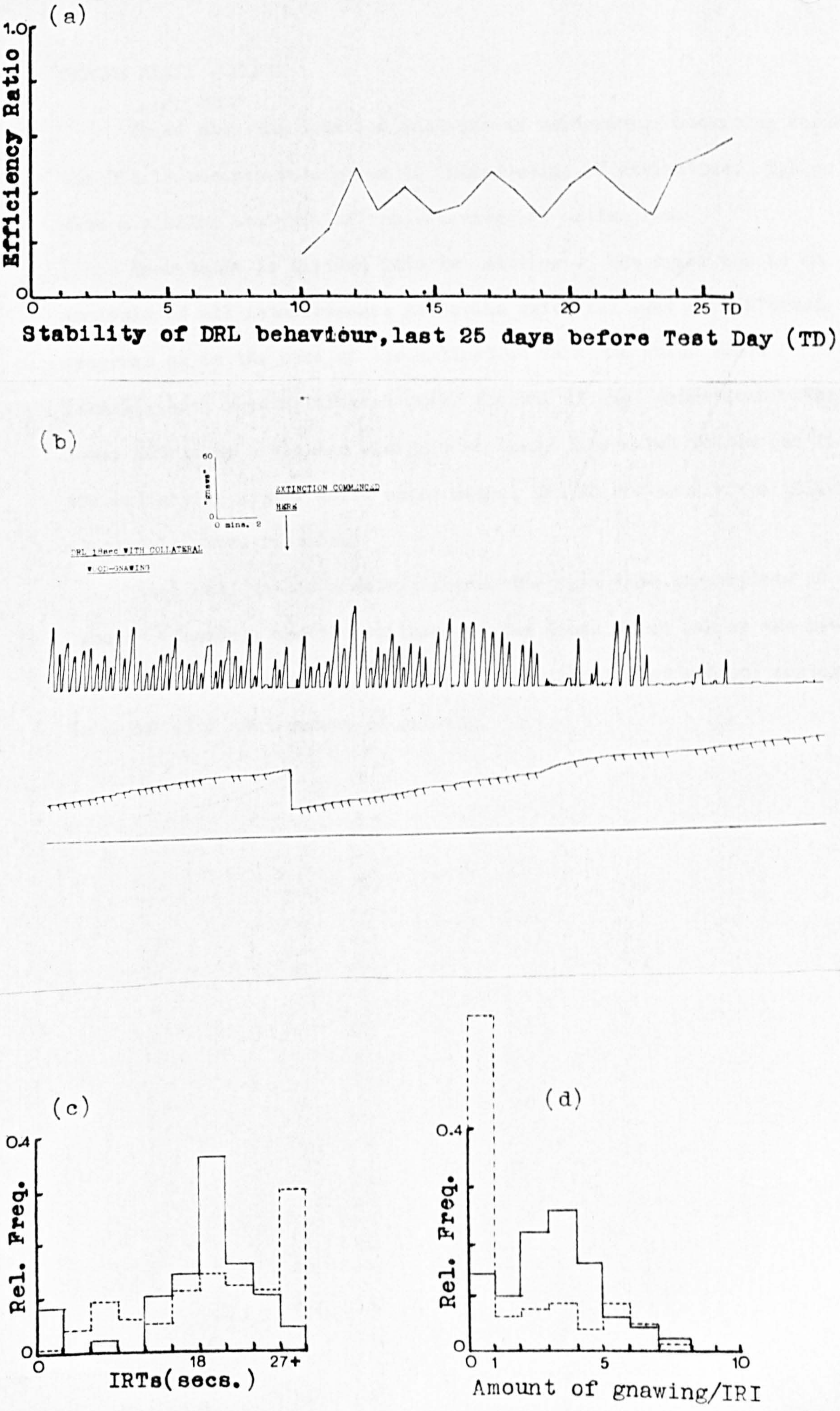
Expt.5 Rat 9 **Figure 51**



Expt. 5 Rat 10 **Figure 52**



Expt. 5 Rat 11 **Figure 53**



TABLES XXXII - XXXIX

" XXXII - XXXV

These show the detailed analysis of woodgnawing occurring during the DRL 18 sec. schedule prior to introduction of extinction. Tables XXXVI-XXXIX show a similar analysis of the behaviour in extinction.

Each table is divided into two matrices. The upper one is an analysis of all interresponse intervals which followed a reinforced response or in the case of the extinction data one which would normally have been reinforced under the DRL 18 sec. conditions. The lower matrix is a similar analysis of those IRIs which follow (or in the extinction matrix would under normal DRL 18 sec. conditions follow) a non-reinforced response.

Each cell within a matrix shows, the mean time to complete 10 "gnaws" (decade), and the variance of the times which make up the mean time, for all instances of a decade occurring at that ordinal number in a IRI with that amount of gnawing.

POST REINFORCEMENT IRIs

IRIs(decades of gnawing/IRI)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	- - -	✱ †									
2	10.5 28.2	2.9 0.08									3
3	7.4 1.3	3.4 0.2	3.3 0.3								4
4	6.6 0.7	3.0 0.4	2.7 0.3	3.2 0.3							7
5	7.1 0.6	2.8 0.2	2.8 0.2	3.0 0.1	2.6 0.1						14
6	6.4 0.7	3.6 0.1	2.8 0.2	3.0 0.05	3.6 0.1	2.6 0.3					4
7	6.2 0.2	3.1 0.8	3.3 0.1	3.7 0.2	2.9 0.2	2.9 0.4	2.8 0.02				3
8	6.3 -	2.6 -	3.0 -	3.3 -	2.0 -	2.7 -	2.9 -	2.9 -			1
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

✱ Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	- - -										
2	- - -	- - -									
3	12.9 -	2.5 -	2.7 -								1
4	7.2 1.1	2.6 0.02	3.2 0.1	2.9 0.1							4
5	- - -	- - -	- - -	- - -	- - -						
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	6.7 -	2.8 -	2.4 -	2.9 -	3.0 -	3.1 -	2.8 -				1
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

DRL 18 sec. with wood block(prior to extinction)15min. session

Table XXXIII

Expt. 5 Rat 9

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	---	* †									
2	8.7 –	2.7 –									1
3	7.9 1.5	3.0 0.2	3.0 0.2								7
4	7.8 0.2	3.4 0.5	3.7 1.3	3.0 0.2							7
5	9.5 0.05	2.5 0.07	2.8 0.02	3.1 0.1	3.0 0.2						3
6	7.4 0.1	3.5 0.6	3.2 0.4	4.4 4.6	3.2 0.8	3.0 0.08					2
7	7.2 6.7	2.9 0.3	2.7 0.02	3.1 0.5	2.9 0.4	2.9 0.3	3.1 0.1				2
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	9.2 1.8	2.7 0.04									2
3	8.0 0.7	2.8 0.4	2.7 0.01								6
4	8.0 4.1	2.7 0.02	2.9 0.1	3.2 0.4							4
5	6.3 1.7	3.3 0.02	2.8 0.3	3.5 0.9	3.2 0.6						4
6	8.2 7.0	2.6 0.08	2.4 0.01	3.5 0.06	2.5 0.05	3.2 0.05					2
7	4.7 –	3.0 –	3.0 –	3.1 –	9.2 –	3.9 –	3.6 –				1
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. with wood block(prior to extinction)15min. session.

Expt. 5 Rat 10

Table XXXIV

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10		n
1	---	* †										
2	7.1 –	4.4 –										1
3	8.5 2.0	3.1 0.1	4.0 3.8									8
4	7.0 1.8	2.8 0.4	2.6 0.06	4.2 3.1								4
5	6.9 2.9	2.8 0.2	4.3 3.2	3.2 1.3	3.4 2.3							5
6	5.7 2.1	2.7 0.07	2.9 0.1	2.7 0.2	2.9 0.07	2.9 0.3						4
7	---	---	---	---	---	---	---					
8	6.7 –	3.3 –	2.3 –	6.5 –	2.6 –	2.8 –	2.8 –	2.8 –				1
9	---	---	---	---	---	---	---	---	---			
10	---	---	---	---	---	---	---	---	---	---		

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10		n
1	---											
2	6.2 0.4	3.6 0.3										2
3	5.9 2.3	3.4 0.4	3.4 0.1									3
4	6.7 4.3	2.5 0.3	2.3 0.2	3.3 2.7								3
5	4.8 –	2.4 –	3.1 –	3.4 –	2.6 –							1
6	3.7 –	2.7 –	2.2 –	2.6 –	2.8 –	2.8 –						1
7	---	---	---	---	---	---	---					
8	---	---	---	---	---	---	---	---				
9	---	---	---	---	---	---	---	---	---			
10	---	---	---	---	---	---	---	---	---	---		

DRL 18 sec. with wood block(prior to extinction)15min. session.

Expt. 5 Rat 11

Table XXXV

POST REINFORCEMENT IRIs

IRIs(decades of gnawing/IRI)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	10.9* 2.5†										4
2	9.8 1.1	3.6 1.2									8
3	9.0 3.2	3.2 0.4	3.2 0.7								12
4	9.0 2.8	2.8 0.3	2.7 0.03	3.4 1.7							4
5	---	---	---	---	---						
6	9.7 -	2.5 -	2.9 -	2.7 -	3.2 -	1.9 -					1
7	10.3 -	2.4 -	6.1 -	2.2 -	3.3 -	2.6 -	2.3 -				1
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	8.0 -										1
2	6.9 2.9	3.6 1.2									3
3	8.3 -	3.5 -	3.8 -								1
4	4.7 0.3	3.3 0.1	3.8 2.1	3.8 2.7							4
5	7.3 6.3	3.1 0.2	2.9 0.5	2.5 0.1	2.7 0.1						3
6	6.2 -	3.3 -	3.3 -	2.6 -	2.1 -	3.0 -					1
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. with wood block(prior to extinction)15min. session

Expt. 5 Rat 8

TableXXXVI

POST REINFORCEMENT IRIs

IRIs(decades of gnawing/IRI)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	--- * †										
2	9.3 5.5	3.1 0.8									2
3	9.8 3.0	2.7 0.01	2.6 0.01								2
4	9.4 -	2.6 -	2.7 -	2.1 -							1
5	12.8 2.7	3.2 0.01	2.9 0.5	2.7 0.1	2.5 0.01						2
6	8.8 2.9	3.2 0.07	3.1 0.3	2.4 0.1	3.4 0.4	2.6 0.06					4
7	10.0 2.4	2.6 0.4	2.8 0.08	2.9 0.2	3.4 0.4	3.2 0.7	2.7 0.3				3
8	6.9 3.4	2.3 0.01	3.1 0.1	3.0 0.08	3.1 0.01	2.6 0.09	2.8 0.03	3.1 0.3			2
9	9.5 -	3.5 -	2.7 -	3.2 -	2.7 -	2.6 -	3.1 -	2.3 -	2.7 -		1
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	13.9 -										1
2	9.6 -	1.9 -									1
3	7.8 1.4	4.6 1.7	2.2 0.1								2
4	8.9 0.04	3.1 0.2	2.5 0.01	2.5 0.01							2
5	9.3 7.8	2.8 0.2	3.0 0.5	2.9 0.1	2.9 0.2						4
6	6.8 1.3	2.6 0.01	3.1 0.01	3.1 0.7	2.5 0.01	2.5 0.1					2
7	9.0 5.6	2.9 0.05	3.5 1.2	2.4 0.06	2.8 0.3	3.1 0.9	2.6 0.01				2
8	7.9 -	2.5 -	3.0 -,	3.9 -	3.4 -	2.7 -	3.4 -	6.0 -			1
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

'DRL 18 sec. with wood'behaviour in extinction.

Table XXXVII

Expt. 5 Rat 9

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	9.4 -	* †									1
2	47.9 3041	19.2 565									2
3	13.3 165	10.3 249	6.5 46.8								5
4	6.7 2.7	3.6 3.0	3.4 1.1	3.3 3.5							4
5	6.5 -	2.7 -	2.8 -	3.1 -	3.4 -						1
6	10.0 -	3.3 -	2.4 -	3.1 -	4.3 -	3.0 -					1
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	12.8 33.5										4
2	9.0 4.5	3.2 0.2									3
3	9.2 12.1	3.4 0.1	3.1 0.5								8
4	6.8 3.4	3.2 0.3	3.2 0.1	3.3 0.7							7
5	7.6 0.7	2.6 0.02	2.9 0.1	3.2 0.2	3.6 0.02						2
6	5.6 2.3	3.4 3.1	3.8 0.4	2.9 0.4	2.8 0.05	3.0 0.2					2
7	5.6 -	2.9 -	2.5 -	2.9 -	2.8 -	3.0 -	3.8 -				1
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

'DRL 18 sec. with wood' behaviour in extinction.

Expt. 5 Rat 10

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	9.3 * 1.5 †										2
2	16.3 -	2.7 -									1
3	6.8 6.1	3.2 0.3	4.0 3.0								5
4	7.6 7.0	3.1 0.01	3.7 0.1	3.9 1.0							3
5	7.4 2.6	3.6 0.4	3.3 0.8	2.8 0.01	4.4 3.0						5
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

IRIs(decades of gnawing/IRI)

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	9.1 8.1										7
2	7.6 5.5	3.3 0.1									5
3	6.8 4.4	3.4 0.7	4.1 3.1								8
4	6.7 13.5	10.5 367	4.9 16.3	3.8 2.0							7
5	6.1 3.2	3.1 0.7	3.7 0.2	4.4 3.0	3.3 0.3						3
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

'DRL 18 sec. with wood' behaviour in extinction.

Table XXXIX

Expt. 5 Rat 11

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	12.3 * 42.5 †										5
2	11.4 3.9	4.3 2.7									5
3	7.3 0.3	3.9 1.7	2.9 0.3								5
4	9.9 7.9	3.1 0.08	3.1 0.6	3.6 0.2							3
5	9.0 2.3	3.9 0.6	3.2 0.1	4.0 3.4	3.1 0.5						5
6	8.0 3.1	3.6 0.7	3.2 0.2	3.2 0.2	3.4 0.7	3.1 0.8					5
7	8.4 -	2.7 -	3.0 -	3.3 -	2.4 -	3.0 -	3.2 -				1
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	25.6 -										1
2	15.9 186	4.4 9.4									2
3	11.3 21.2	3.1 0.1	2.8 0.01								3
4	5.0 -	2.3 -	2.8 -	2.2 -							1
5	12.6 107	2.9 0.7	3.2 0.3	3.0 0.5	3.2 0.8						3
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

'DRL 18 sec. with wood'behaviour in extinction.

increased range of the IRI/amount of gnawing distributions there did not appear to be any consistent difference in "rates" of woodgnawing between IRIs prior to extinction and those occurring in extinction.

Discussion

These results support the Laties et al. (1969) results on the effect of extinction on DRL 18 sec. performance with collateral woodgnawing behaviour. The wood gnawing was the first behaviour to extinguish followed by the lever press responding. Considered with the Zimmerman, (1959): Miller (1951); Becker and Bruning (1966); Bruning Becker and Tucker (1965) results on the direction of extinction of heterogeneous chains, the present results indicate that the chain hypothesis cannot explain the maintenance of DRL performance which includes stereotyped collateral woodgnawing behaviour.

The empirical evidence does suggest that the order in which initial and terminal links of a chain extinguish may depend on the topography of links in the chain. However there does not appear to be any reported evidence that the initial link extinguishes before the terminal link. The Mansfield and Rachlin (1970) results suggest that if indeed their lever press response sequence is a chain, and not a single operant, then in such homogeneous chains the initial and terminal link extinguish together.

However it is clear that to definitely remove the chain hypothesis from the list of possible interpretations of DRL performance with stereotyped collateral behaviour it may be necessary to construct an experiment where woodgnawing is part of a formally defined chain with brief stimuli signalling the end of each link and paired both with reinforcement and a topographically distinct terminal link. Extinction of this chain should, if previous evidence is considered, shew that the terminal link extinguishes first followed by the initial link.

In comparison with the efficiency ratios for these subjects in previous experiments, the efficiency ratios for these extended sessions were low. This might suggest that the results are not representative. However it was the case that early on in most sessions the DRL behaviour efficiency ratio was comparable with the efficiency ratios in the two previous experiments (Experiments 1 and 2). Indeed the cumulative records for the first 15 minutes in the test session show behaviour typical of the first two experiments. The reduced efficiency ratios in the sessions prior to the test day were due to increased lever press responding in the second 30 minutes of the sessions. In retrospect it might have been better to run the pre-test sessions for only 30 minutes as usual, or possibly 45 minutes. The reason longer sessions were used in this experiment was to control for the possible extended period of extinction. Previously these subjects had been run for 30 minutes each session. In this experiment extinction was begun 15 minutes after the beginning of the final session. Assuming that the subjects took more than 15 minutes to reach the extinction criterion they would then have been exposed to the experimental conditions for longer than usual. Consequently it was decided to run the subjects for 60 minutes in the sessions prior to the test day.

It is interesting to note that except for a few IRIs the stereo-:typed collateral behaviour was either evident throughout IRIs in extinction or it was not. This suggests that whatever maintains such behaviour on DRL schedules probably effects the entire inter response interval collateral behaviour rather than discrete units of such behaviour. This point will be taken up in the general discussion of how stereotyped collateral behaviours on DRL schedules are maintained and the predictions one might make based on a "superstition", or adventitious reinforcement, interpretation of such behaviour.

EXPERIMENT 6

Introduction

From the detailed analysis of woodgnawing in Experiment 1 (and later experiments) it was apparent that there was no consistent significant difference between the woodgnawing "rates" and variances following a reinforced lever press response and corresponding woodgnawing data following a non-reinforced lever press response.

One of the possibilities that arise from a functional interpretation of the stereotyped collateral behaviour on DRL schedules, particularly a "counting" hypothesis, is that following a sequence of collateral behaviour which ends in a non-reinforced lever press response, the collateral behaviour in the next IRI may in some manner be different. In the absence of a limited hold contingency the duration of an IRI following a non-reinforced lever press fesponse on DRL schedules must be greater than the duration of the previous IRI, for reinforcement to occur. This requirement does not hold following a reinforced response. It does not appear to be unreasonable to suppose that collateral behaviour following a nonreinforced response might, in the interests of efficiency of performance, be different from collateral behaviour following a reinforced response.

This is particularly so since Lowe and Harzem (1973) using a two component DRL schedule have illustrated the discriminative effects of reinforcement and non-reinforcement. Their schedule required that the introduction of the second component was contingent on a non-reinforced lever press response. When this second criterion IRT value was half the duration of the first, Lowe and Harzem found that instead of alternating between the two components by emitting a response "burst" immediately after reinforcement, which would have resulted in the highest frequency of reinforcement, the subjects spent most time in the longer criterion IRT component and nearly all "bursts" occurred after non-reinforced lever press responses. Apparently the effects of reinforcement and non reinforcement were sufficient to control different IRT relative frequency distributions (Lowe and Harzem reported two separate IRT distributions, one for each component). The present author considered it possible that similar control of the collateral behaviour in the two criterion DRL schedule might occur. It was therefore proposed to use this two criterion DRL schedule to study the effects of two reinforcement requirements on the collateral woodgnawing behaviour.

Method:

Subjects: 3 Rats (Laboratory Numbers 26, 29 and 30) maintained as described in the General Method.

Apparatus: As described in the General Method section.

Procedure: The subjects were pre-trained as described in the General Method section. Prior to the final day (test day) each subject was run for 50 daily sessions. Each daily session lasted 45 minutes. The reinforcement requirements were such that following a reinforced response, DRL 18 sec. schedule requirements were operative; following a non-reinforced response, DRL 9 sec. schedule requirements were in operation. Technically this schedule could be called a two criterion DRL 18 sec/9 sec.

Following the final day several attempts were made to film the behaviour of each subject. This proved impossible using conventional floodlighting and closed circuit television (recorded a video tape). The light intensity caused the subjects to turn their backs to the lights thus obscuring the wood gnawing behaviour on the woodblock. Finally the experimenter obtained the use of an infra-red television camera for one day. Filming was concentrated on Rat 29 who produced most behaviour facing the camera. Rat 29 was adapted to an infra-red lamp shining into the opened experimental space for four sessions prior to the filming day. The session was recorded on conventional videotape.

Results:

Despite what might be regarded as demanding reinforcement requirements a high degree of stability was achieved by all subjects in the 25 days prior to the final (test) day. (Figures 55 - 57:a).

The woodgnawing collateral behaviour occurred both between lever press responses in the DRL 18 sec. and the DRL 9 sec. components (Figures 55 - 57:b) For two of the three subjects (Rats 29 and 30) there was a clear difference between the relative frequency distributions, of both IRTs and IRIs, in the DRL 18 sec. and DRL 9 sec. components. In the case of Rat 26 there appeared to be ~~s~~more homogeneous distribution of both IRTs and IRIs under the two conditions, with long IRTs in the DRL 9 sec. component and no clear distinction between IRIs in the two components (Figures 55 - 57:c and d).

The detailed analysis of woodgnawing shows that there was no significant difference between mean woodgnawing "rates" in either DRL component. The mean time to complete 10 "gnaws" in similarly located ordinal decades in each matrix were compared using a "t" test.* The mean times used for this comparison were those occurring in IRI catagories which had a double figure "n" value in either component (or matrix). This meant that for Rats 29 and 30 comparisons were ~~/~~made

* Figure 54

FIGURE 56

't' tests for differences between "rate" measures in post-reinforced response IRIs and post-non reinforced response IRIs.

In the 't' tests on the next page 't' was calculated given the means and standard deviations:-

$$t = \frac{\overline{x}_1 - \overline{x}_2}{p\sqrt{\frac{1}{N_1} + \frac{1}{N_2}}}$$

$$\text{where } p = \sqrt{\frac{(N_1-1)\sigma_1^2 + (N_2-1)\sigma_2^2}{N_1 + N_2 - 2}}$$

where $\overline{x}_1$ and $\overline{x}_2$ are the means, σ_1 and σ_2 are the standard deviations, and N_1 and N_2 are the number of values in each sample.

't' values which are underlined are significant:-

$\underline{x}.\underline{x}$ sig. at 0.05 level

$\underline{x.x}$ sig. at 0.01 level

(The results overleaf support the contention that there was no significant difference between mean decade times in post reinforced response IRIs and post non-reinforced response IRIs.)

't' test values for similarly placed 'mean decade times in post-reinforced and post non-reinforced matrices.

Inter-response Interval (Decades of gnawing/IRI)

Expt 6	Ordinal decade number						
Rat 26	2	3	4	5	6	7	8
2	2.8						
3	1.8	0.0					
4	0.3	-0.6	1.6				
5	-0.5	0.8	0.2	0.2			
6	0.5	-1.9	-0.2	-1.6	-1.3		
Rat 29							
2	0.7						
3	1.8	1.4					
4	1.5	-1.0	0.8				
5	0.5	-0.1	1.3	0.5			
Rat 30							
2	1.3						
3	0.2	0.7					
4	2.3	0.5	0.2				
5	1.0	0.7	-1.2	-0.2			

FIGURE 54

FIGURES 55 - 57

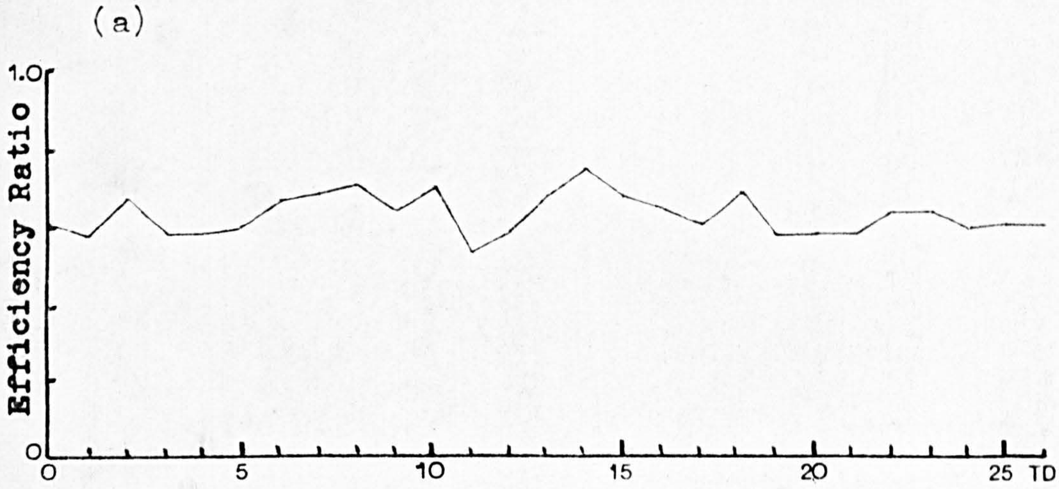
a) Shows the efficiency ratio for each daily session for that subject in the 25 sessions prior to the final (test)day. The schedule in operation is the DRL 18/9 sec. schedule. The efficiency ratio is calculated as in Experiment 1.

b) Shows the cumulative record of that subject's performance on the final (test) day on the DRL 18/9 sec. schedule.

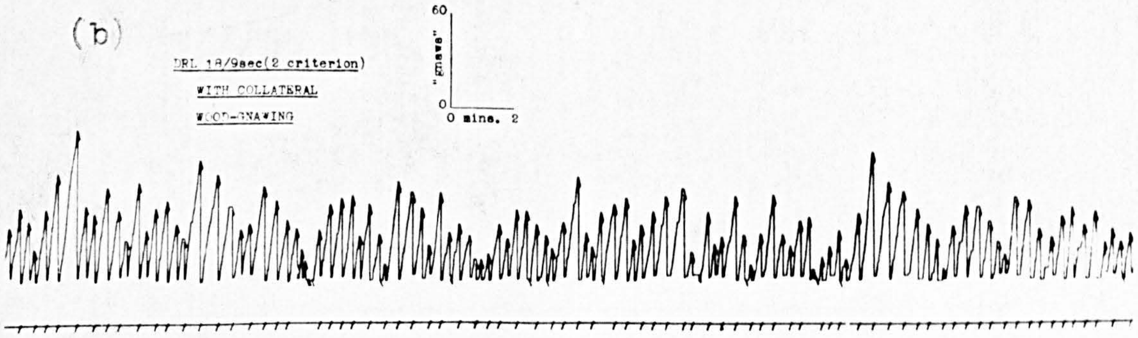
c) Shows the relative frequency distribution of interresponse times in seconds (IRTs/secs) IRTs in the DRL 18 sec. component are shown in solid lines, IRTs in the DRL 9 sec. component are shown in interrupted lines. The relative frequency of any IRT category is expressed as a fraction of the total number of IRTs in the session.

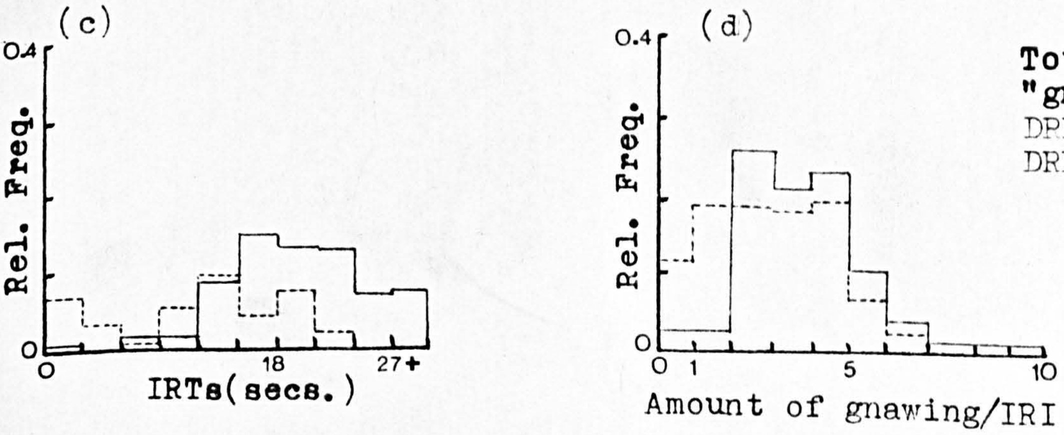
d) Shows the relative frequency of interresponse intervals categorised by the amount of gnawing in each IRI. Amounts of gnawing are expressed in decades (10s) of "gnaws". The relative frequency of any IRI category is expressed as a fraction of the number of IRIs in that component of the schedule.. IRIs in the DRL 18 sec. component are shown in solid lines those in the DRL 9 sec. component in interrupted lines. Total number of gnaws in the session are recorded in top right of this figure.

Expt.6 Rat 26 Figure 55



Stability of DRL behaviour, last 25 days before Test Day (TD)

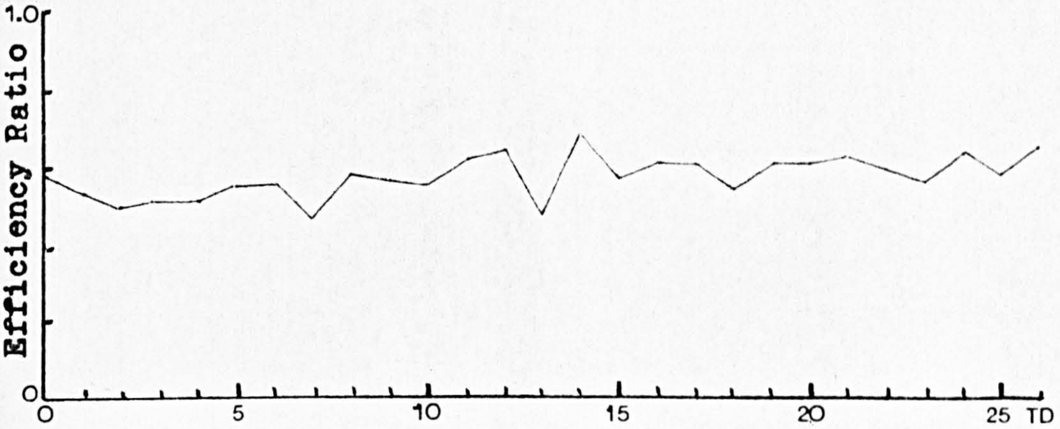




Tot.No. of "gnaws"

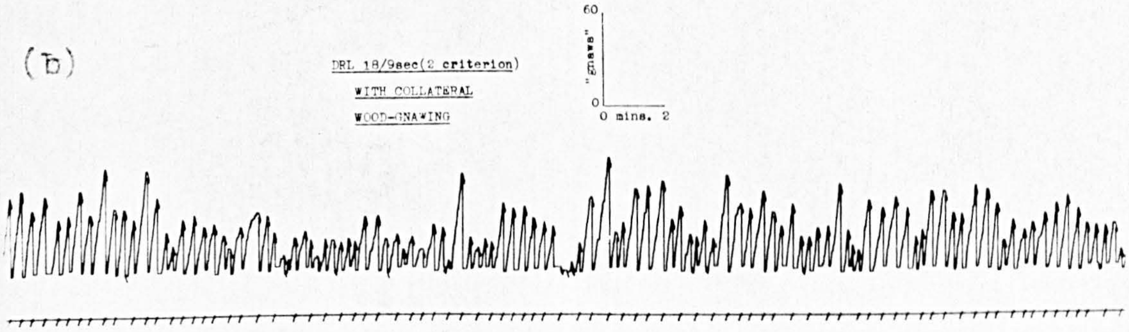
DRL	18"	2250
DRL	9"	2340

(a)

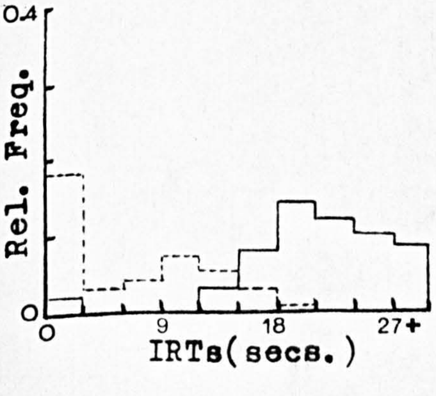


Stability of DRL behaviour, last 25 days before Test Day (TD)

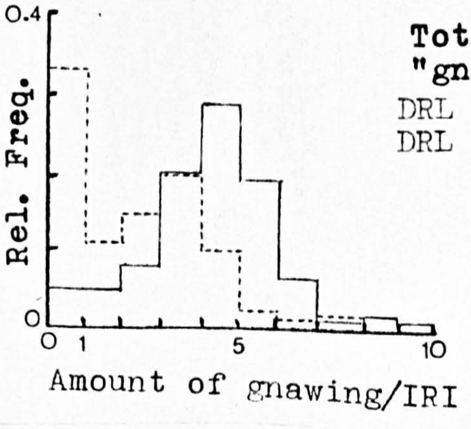
(b)



(c)

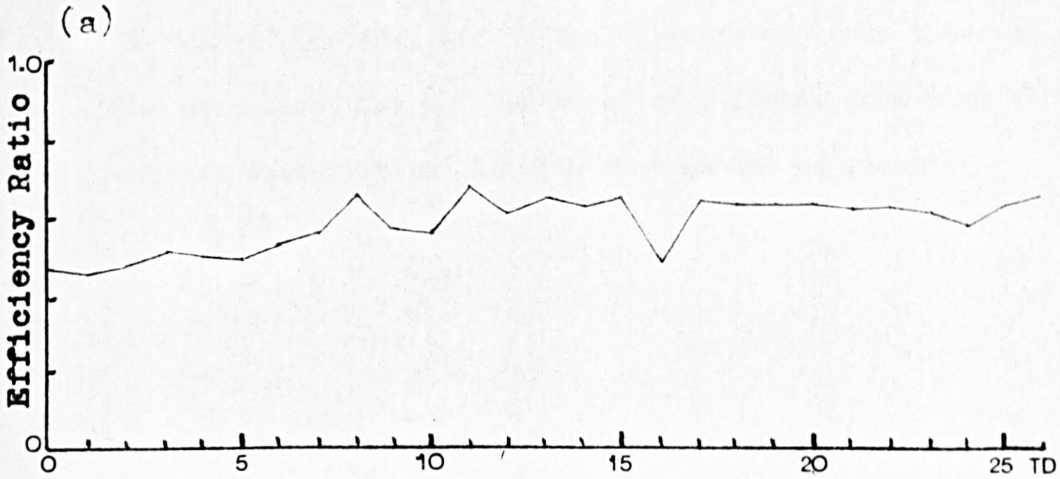


(d)

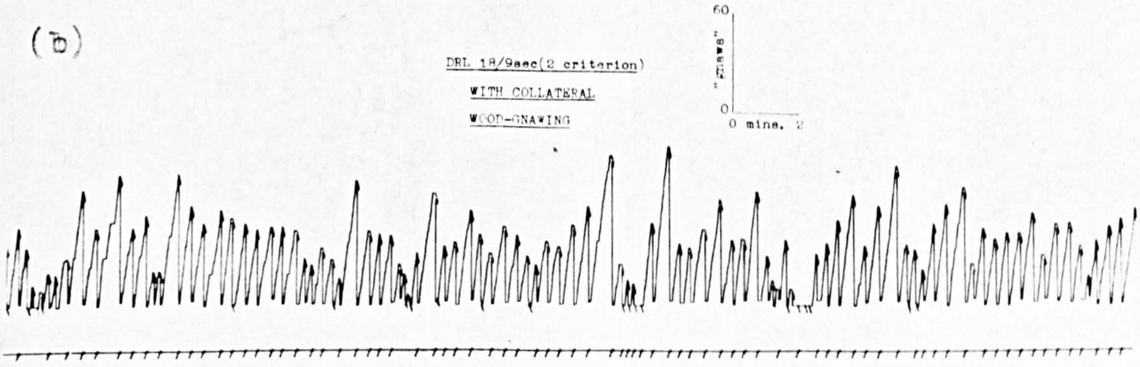


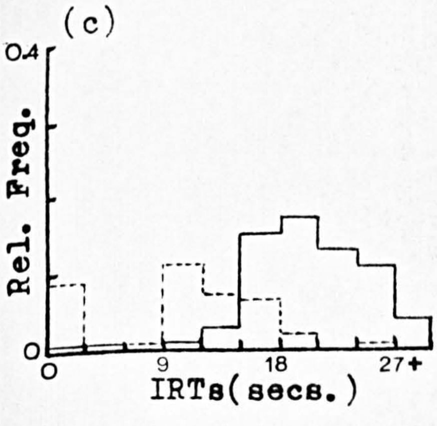
Tot.No. of "gnaws"
DRL 18" 2760
DRL 9" 1760

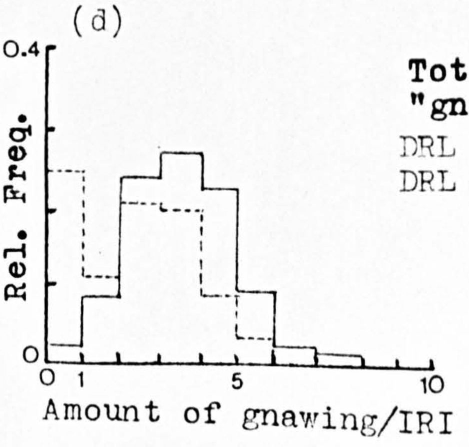
Expt. 6 **Rat** 30 **Figure** 57



Stability of DRL behaviour, last 25 days before Test Day (TD)







Tot.No. of "gnaws"

DRL	18"	2150
DRL	9"	1810

TABLES XL - XLII

The table is divided into two matrices. The upper one is an analysis of all interresponse intervals which occured in the DRL 18 sec. component of the 2 criterion DRL 18/9 schedule. The lower matrix shows the IRIs in the DRL 9 sec component.

Each cell within a matrix shows * the mean time to complete 10 "gnaws" (decade, and † the variance of those times which make up the mean time, for all instances of a decade occurring at that ordinal number in an IRI with that amount of gnawing.

Expt. 6 Rat 26

POST REINFORCEMENT IRIs (DRL 18 sec.)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	8.1 0.4	* †									2
2	8.3 6.3	4.2 1.1									17
3	7.8 5.4	4.7 2.8	3.9 0.6								14
4	7.1 1.3	4.0 1.4	3.6 1.2	3.7 1.4							15
5	7.4 4.0	3.6 1.4	3.9 1.4	4.0 1.2	3.8 0.6						7
6	5.0 0.3	3.9 3.5	2.7 0.5	3.5 0.1	3.0 0.1	2.9 0.01					3
7	4.8 –	2.7 –	3.5 –	4.7 –	4.3 –	3.8 –	3.7 –				1
8	5.9 –	4.1 –	2.9 –	2.8 –	2.5 –	3.8 –	2.7 –	3.0 –			1
9	6.6 –	4.1 –	3.3 –	2.1 –	2.6 –	4.0 –	4.0 –	4.5 –	2.9 –		1
10	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– – –	– –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

(decades of gnawing/IRI)

POST NON-REINFORCED RESPONSE IRIs (DRL 9 sec.)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	7.0 9.7										18
2	6.9 10.3	3.4 0.4									18
3	5.3 3.0	3.8 1.3	3.9 1.0								17
4	5.8 4.0	3.9 1.0	3.8 0.9	3.2 0.3							19
5	5.9 4.4	3.9 1.0	3.5 0.5	3.9 0.7	3.7 2.1						7
6	4.9 8.0	3.3 0.6	3.7 0.3	3.7 3.5	4.1 1.3	3.5 0.6					3
7	– – –	– – –	– – –	– – –	– – –	– –	– – –				
8	– – –	– – –	– – –	– – –	– – –	– –	– – –	– –			
9	– – –	– – –	– – –	– – –	– – –	– –	– – –	– – –	– – –		
10	– – –	– – –	– – –	– – –	– – –	– –	– – –	– – –	– – –	– –	

2 criterion DRL 18/9 sec.

Expt. 6 Rat 29

POST REINFORCEMENT IRIs (DRL 18 sec.)

ORDINAL DECADE NUMBER

(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	8.9 * 6.0 †										3
2	8.4 1.6	4.2 1.4									6
3	7.5 1.7	4.1 1.6	3.9 1.2								15
4	7.0 1.7	4.1 1.4	4.0 0.8	3.6 0.6							21
5	6.9 1.4	3.9 2.0	4.3 1.1	3.9 0.8	3.8 0.4						14
6	6.2 0.7	3.2 0.5	3.8 1.0	3.7 1.4	4.0 0.5	3.4 0.05					5
7	6.3 –	2.6 –	9.1 –	3.4 –	10.2 –	2.9 –	3.2 –				1
8	6.6 0.2	3.4 0.01	3.7 0.01	4.6 3.9	3.3 0.2	3.6 0.9	3.4 0.4	4,4 1.1			2
9	5.8 –	1.8 –	2.4 –	2.0 –	3.6 –	3.3 –	2.7 –	4.0 –	2.9 –		1
10	– – –	– –	– – –	– –	– – –	– –	– – –	– –	– – –	– –	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs (DRL 9 sec.)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	4.9 2.1										11
2	5.5 4.8	3.9 0.6									15
3	6.2 8.9	3.4 1.0	3.5 0.4								20
4	6.6 0.6	3.5 0.2	4.4 1.6	3.3 1.6							10
5	5.7 1.2	3.5 0.3	4.4 3.8	3.2 0.1	3.6 0.2						3
6	6.0 –	4.3 –	3.8 –	3.4 –	4.6 –	3.6 –					1
7	6.0 0.3	3.2 0.01	3.4 0.08	5.6 2.3	3.7 0.8	3.2 0.2	3.3 0.01				2
8	– – –	– –	– – –	– –	– – –	– –	– – –	– –			
9	– – –	– –	– – –	– –	– – –	– –	– – –	– –	– – –		
10	– – –	– –	– – –	– –	– – –	– –	– – –	– –	– – –	– –	

2 criterion DRL 18/9 sec.

Expt. 6 Rat 30

Table XLII

POST REINFORCEMENT IRIs (DRL 18 sec.)

ORDINAL DECADE NUMBER

(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	12.5 * 21.5 †										6
2	9.1 2.6	4.5 3.0									17
3	8.5 5.3	4.0 1.9	4.0 0.7								19
4	8.5 2.3	3.9 0.9	3.7 1.4	3.7 2.0							16
5	7.4 2.3	4.1 2.0	3.5 1.1	4.0 0.6	3.0 0.6						7
6	6.5 0.03	3.4 0.3	3.4 0.01	3.8 0.3	2.9 1.2	2.5 0.03					2
7	6.9 -	6.5 -	2.4 -	3.4 -	5.0 -	3.7 -	2.7 -				1
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs (DRL 9 sec.)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	7.5 4.2										11
2	6.3 4.5	3.9 2.0									31
3	6.2 3.0	3.9 2.7	3.8 0.9								19
4	6.9 4.4	3.1 0.4	3.5 0.6	3.6 0.6							9
5	5.7 9.4	3.2 0.4	3.0 0.8	4.7 1.0	3.1 0.2						3
6	- - -	- - -	- - -	- - -	- - -	- -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- -	

2 criterion DRL 18/9 sec.

between mean times in IRI categories containing 3 and 4 decades of woodgnawing and for Rat 26 in IRI categories containing 2, 3 and 4 decades of woodgnawing.

The mean times for all IRI categories are compared in Figures 58-60 where the "rates" for woodgnawing in the DRL 18 sec. component are in solid lines and those for DRL 9 sec. in interrupted lines.

Observation of the infra-red video film for Rat 29 showed that the subject had a distinctive pattern of woodgnawing in the sections of the video record when the subject was facing the camera. This is illustrated in Figure 61. Unfortunately insufficient evidence of this kind was gathered to enable statistical evaluation of the behaviour using ethological observer/recorder methods of analysis.

Rat 29 was observed to gnaw at the end of the woodblock furthest from the lever following a reinforced lever press response. Runs of reinforced lever press responding were observed to be mediated by gnawing at this end of the woodblock. When a non-reinforced response occurred it was usually due, either to drifting of gnawing along the block towards the lever, or interruption of gnawing ~~due~~ apparently to irritation of the nose, presumably by wood dust. Following a non-reinforced response (which changed the reinforcement requirements to a DRL 9 sec.) the rat produced "agitated" gnawing of the wood block at the end nearest the lever. If the subsequent response was not reinforced the subject returned to the end of the woodblock nearest the lever, if it was reinforced the subject returned to the far end of the woodblock associated with the DRL 18 sec. component which would then be in operation.

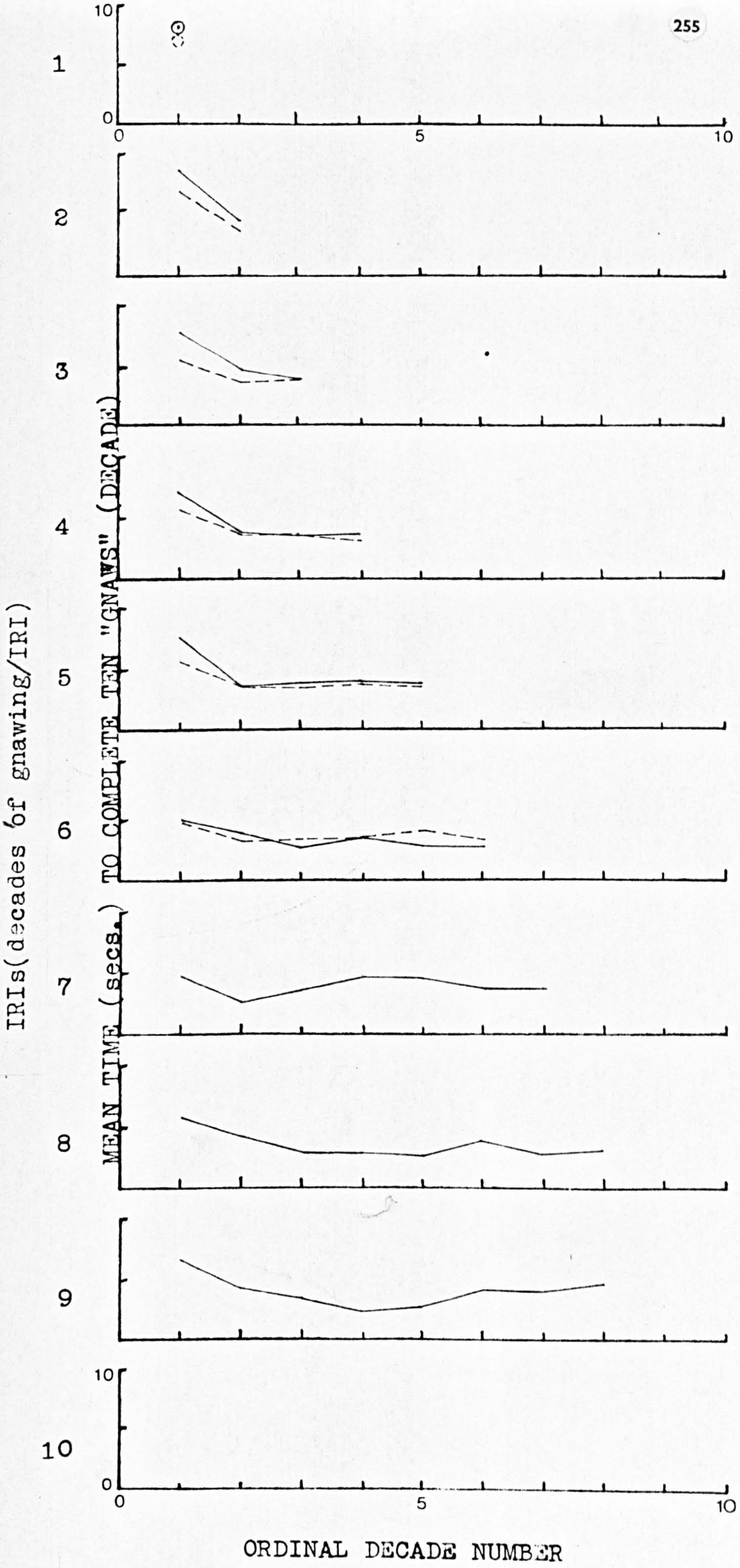
Figure 62 shows the development of this pattern of woodgnawing over a session. By removing woodblocks from the subject a different

FIGURES 58 - 60

Shows the "rate" data from Tables XL - XLII expressed as a graph. Mean times of decades in IRIs during the DRL 18 sec. component of the 2 criterion DRL 18/9 sec. schedule are shown as solid lines. Data from the DRL 9 sec. component is shown in interrupted lines.

Figure 58

Expt. 6 Rat 26



Expt.6 Rat 29

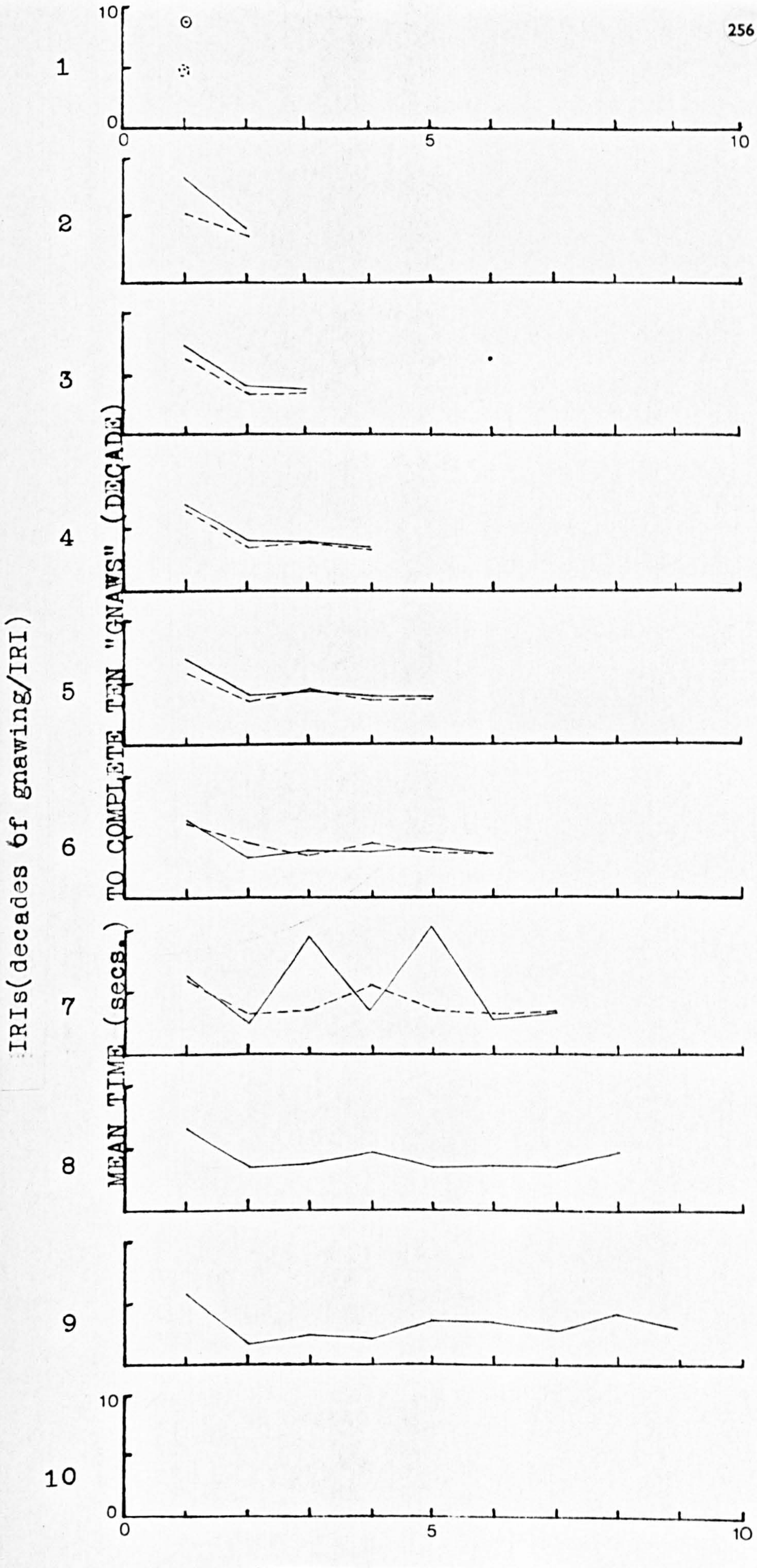

10
0
0
5
10
1
2
3
4
5
6
7
8
9
10
IRIs(decades of gnawing/IRI)
MEAN TIME (secs.) TO COMPLETE TEN "GNAWS" (DECADE)
10
0
0
5
10
ORDINAL DECADE NUMBER

Figure 60

Expt. 6 Rat30

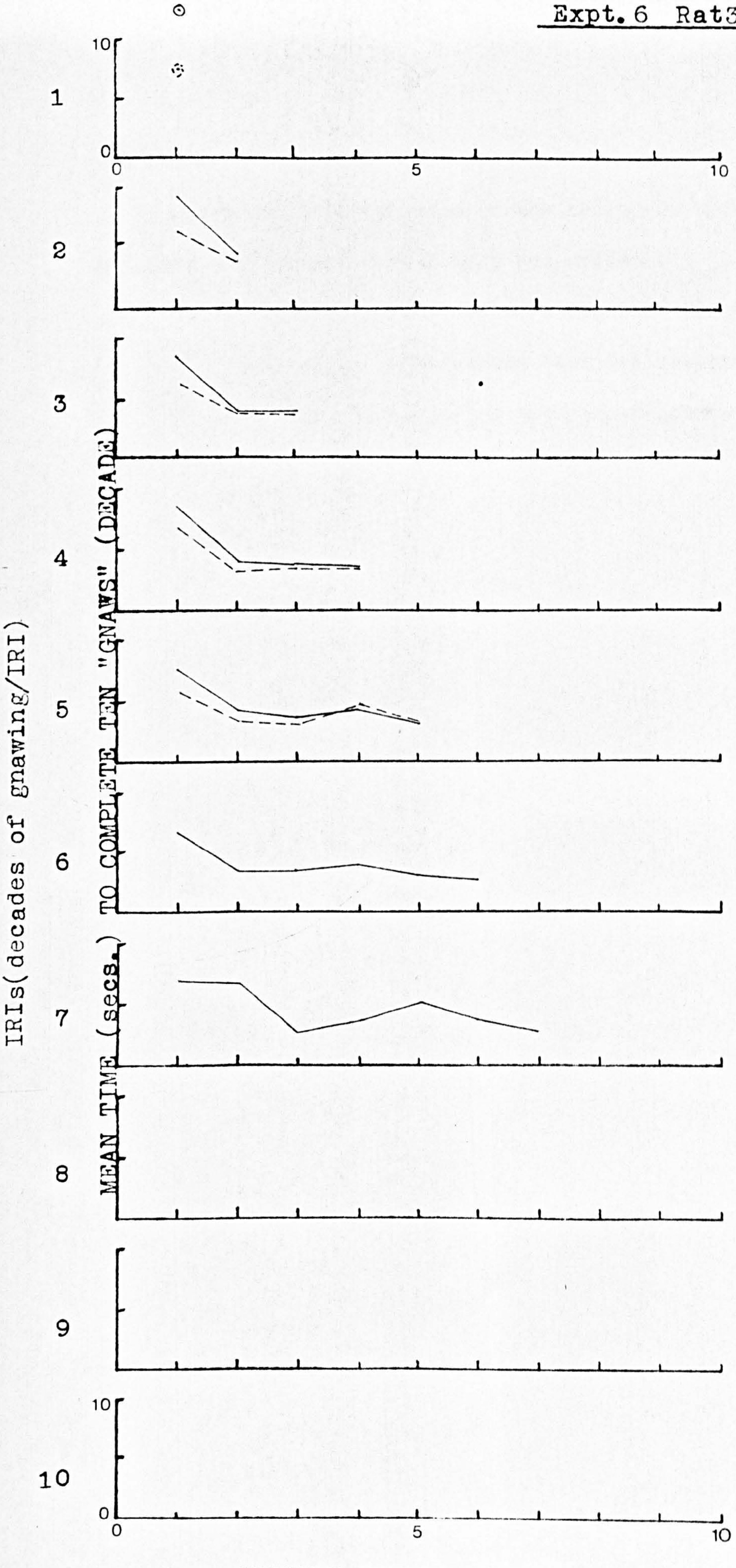


FIGURE 61

Shows still photographs of the infra-red video tape taken of Rat 29's performance on DRL 18/9 sec. schedule.

It illustratesthe pattern of responding alluded to in the tent.

S^r this light bulb flashed when the response was reinforced.

$\overline{S^r}$ this light bulb flashed when the response was not reinforced.

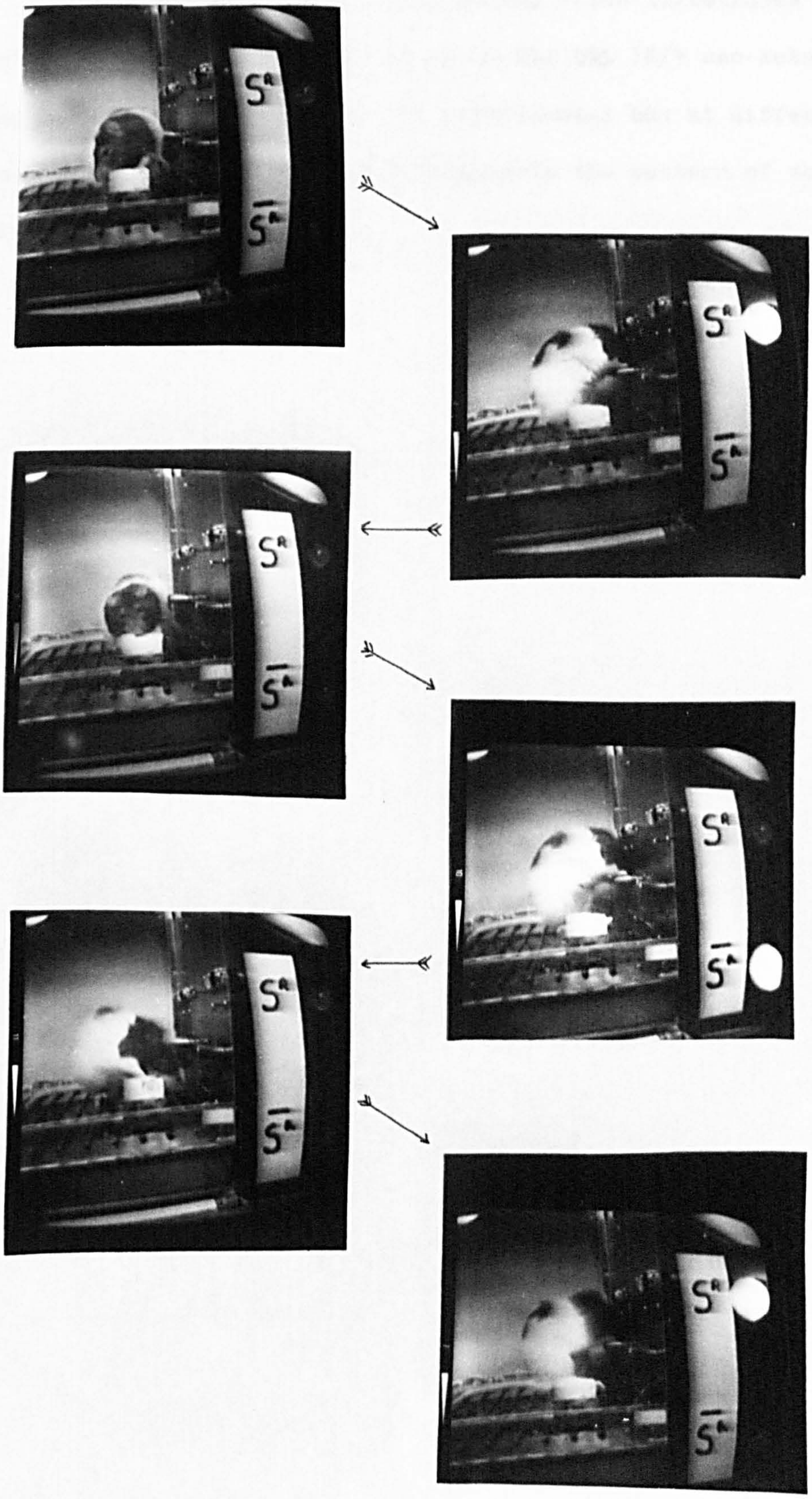
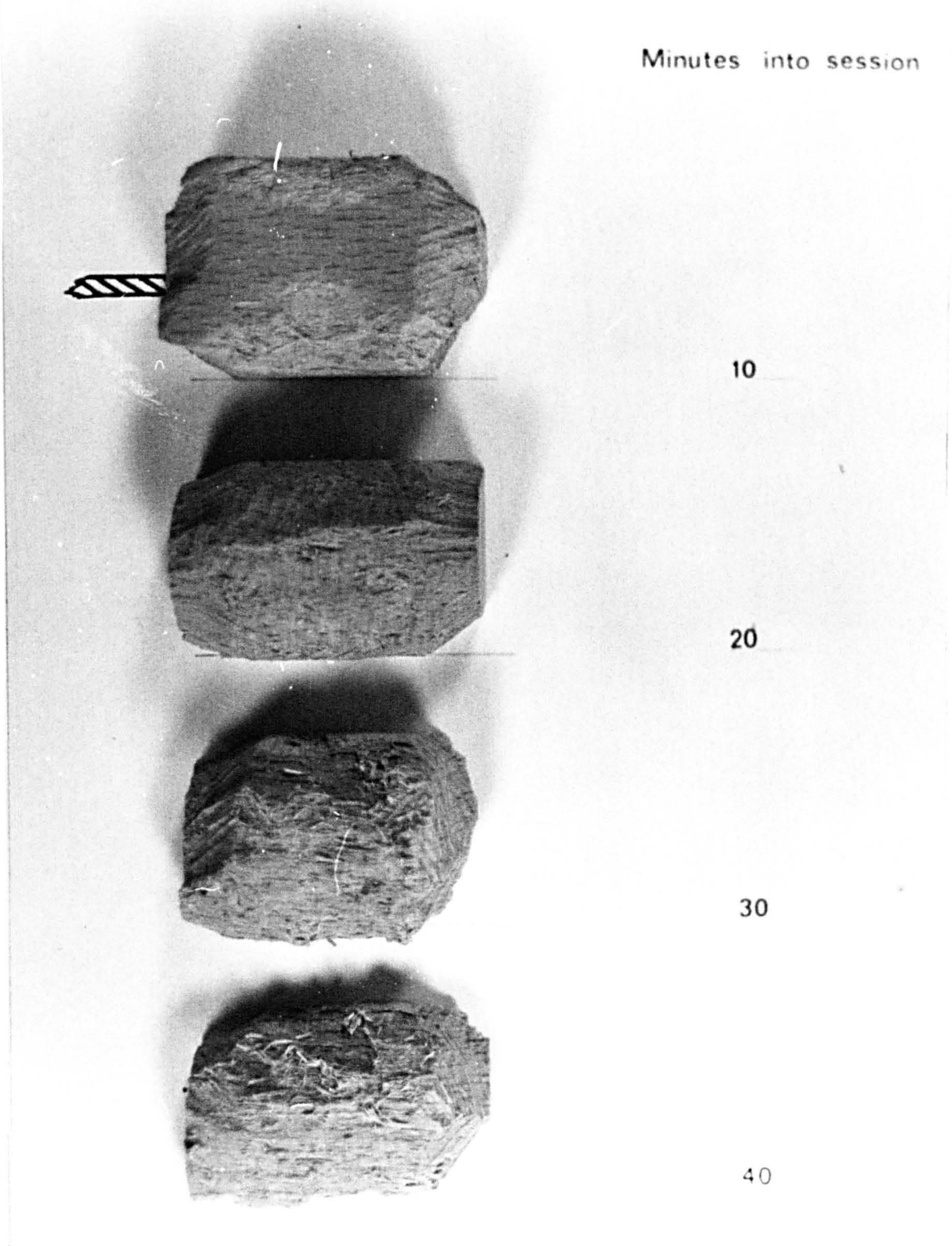

SR
S̄R

FIGURE 62

Shows the pattern of tooth marks, which illustrates the pattern of woodgnawing, of Rat 29 on the DRL 18/9 sec·schedule. Wood blocks were taken from the experimental box at different times in successive sessions. They illustrate the pattern of wood gnawing discussed in the text.

RAT 29 Development of gnawing pattern through session

Figure 62


Minutes into session
10
20
30
40

points in the session over several sessions it was possible to show that this pattern of gnawing at either end of the woodblock appeared to remain consistent throughout the session.

This pattern of gnawing at either end of the woodblock was similar to the pattern of woodgnawing developed by Rat 30 but different from that produced by Rat 26 which gnawed at one end (nearest the lever) only.

Discussion:

In the introduction to this experiment it was mentioned that the results of Experiment 1 suggested that the woodgnawing "rate" analysis revealed no consistent significant difference between woodgnawing following a reinforced response and that following a non-reinforced response.

The present experiment suggests that in the two criterion situation there was a similar lack of evidence for a differential "rate" effect in the two conditions. However the infra-red observations suggested that the two criterion DRL schedule requirements did control two different woodgnawing topographies which, though appearing similar at a woodgnawing "rate", or quantitive , level of analysis, were different at the observational, or qualitative, level of analysis.

In the present experiment two out of the three subjects produced two distinct IRT distributions, one for each component of this mixed schedule. Both of these subjects also emitted woodgnawing which occurred in a different location for each of the two components. The third subject did not produce two distinct IRT distributions and woodgnawing appeared to be confined to one location on the woodblock. This latter subject's performance suggests that it did not come under the control of the two criterion DRL schedule requirements.

Unfortunately it is not possible to state unequivocally which of the two factors may have controlled these different woodgnawing topographies. This experiment confounds the two variables, reinforced or non-reinforced prior response, and duration of the criterion IRT. The fact that the one subject who did not produce two distinct woodgnawing topographies also produced a single undifferentiated IRT distribution (similar to that produced on a single value DRL schedule) gives slight support to the view that the controlling variable in this situation was the duration of the criterion IRT which followed a discriminable event. On this evidence it would be difficult to say that a similar topography shift might be responsible for a "successful" IRT in single value DRL performance following "unsuccessful" IRT behaviour, but the possibility cannot be ruled out.

This present experiment could in the experimenter's view, have profited from considerably more observational data than was in fact gathered. In particular a detailed analysis of the performance from video tape records would have been most interesting. Unfortunately this was not possible due to lack of access to the infra-red camera at the time. The type of study which is envisaged would be similar to that conducted by Stein, Hoffman and Stitt (1971), who observed stereotyped collateral behaviour on a VI 2 minute schedule. They arranged that several observer/recorders should report movements of the subject's head into different sections of the experimental space. This ethological procedure, used here to study a pigeons movements could be used to examine video tape records of the rat woodgnawing on DRL schedules.

The author has described the woodgnawing at the lever end of the woodblock in this present experiment as "agitated". It is possible that this observation supports the suggestion in the discussion of Experiment 4, that woodgnawing nearer the lever is different from woodgnawing further away from the lever. In Experiment 4 it was suggested that each "gnaw" at a point on the woodblock nearer the lever may remove more wood than a similar "gnaw" at a point further from the lever. The observations of Rat 29 behaviour in this experiment cannot support this directly, but does indicate that gnawing can look qualitatively different to an observer while not appearing quantit. ively different in a "rate" analysis.

EXPERIMENT 7

Introduction

Having reached this stage in the investigation of stereotyped collateral woodgnawing behaviour it was disappointing that no definite statement could be made about the necessity of such behaviour for efficient DRL schedule performance. Experiments 2 and 4 had tentatively suggested that such behaviour might fulfil a response inhibition role in DRL performance but the evidence of continued timing behaviour in the absence of wood in Experiment 2 suggested that stereotyped collateral behaviour was not necessary for such timing behaviour. Experiment 2 is open to the criticism that withdrawal of the wood block leaves a novel stimulus situation, in which case the disruptive factor in the wood removal situation may not be the removal of a necessary collateral manipulandum so much as the introduction of a novel stimulus (which are known to disrupt DRL performance, Contrucci et al. 1971).

Experiment 4 certainly suggested that variations in woodgnawing could effect DRL response rate but one cannot conclude from this that woodgnawing is therefore necessary for DRL performance.

Consequently, as a further experiment to determine whether stereotyped collateral behaviour of this type is necessary for efficient DRL schedule performance it was decided to use the technique of adding a stimulus to signal reinforcer availability on the DRL schedule and to observe the effect on the collateral behaviour of manipulating this stimulus. This technique may be regarded as removing the "temporal discrimination" aspect of DRL schedule performance while retaining the response inhibition requirement during the criterion IRT.

Since this present experiment was carried out a detailed study carried out by Marcucella (1974) has revealed that in fact the above statement is an oversimplification of the situation. Marcucella showed that if the criterion IRT on a signalled DRL schedule is greater than 30 seconds, very little, if any, lever press responses occur in the S2 condition when no stimulus is present and a response would not be reinforced. This finding is similar to that reported by Stevenson and Clayton (1970). They required that rats hold down a lever for 40 seconds after which a stimulus signalled reinforcement availability. Stevenson and Clayton reported no evidence that animals discriminated the 40 sec. duration on the basis of a temporal dimension. Instead they provided evidence that the holding down ofthe lever was under almost complete control of the signal.

Marcucella (1974) showed that if the criterion IRT was less than 30 seconds in duration, then premature responding occurred in the S2 (unsignalled) condition. The amount of premature responding was found to vary inversely with the duration of the criterion IRT. This is in accord with the findings of Shimp (1968) and Catania (1970) using signalled DRL schedules with < 30 sec. criterion IRT value.

Marcucella concludes: "It appears that time is a highly salient stimulus for rats. At short DRL values, time governed responding, i.e. the performance of rats on signalled DRL resembled that of rats on unsignalled DRL schedules, even though the use of the discriminative stimuli would have increased the rate of reinforcement. At long DRL values, where temporal discrimination is difficult and the potential drop in reinforcement rate is great, the rats shifted to the auditory localization dimension".

The present study investigated the effect on the collateral behaviour of removing the signal from the stable signalled DRL schedule performance and then reintroducing the signal once the un-

unsignalled behaviour had been studied.

This experiment differed from the other experiments in this investigation in that a steady state methodology was not used. A previous unreported experiment suggested that an irreversible change might occur as a result of removing the signal from the signalled DRL performance. This would mean that the baseline (signalled DRL) performance might not be recoverable on reintroduction of the signalled DRL schedule.

Revusky (1967) has said: "The conventional method of assessing the effects of such treatments by statistical means involves separate experimental and control groups. An alternative........is to administer the experimental treatment to each subject one subject at a time and in a random order; whenever any subject receives the experimental treatment, those subjects which have not yet received it receive a control treatment. This procedure permits results significant at the one-tailed 0.05 level to be obtained with four subjects". In the light of the results from the previous unreported experiment it was decided that Revusky's suggested methodology should be employed.

Method

Subjects: 4 Rats (Laboratory Numbers 72, 73, 74 and 75) maintained as described in the General Method section.

Apparatus: as described in the General Method section except that for this experiment the Sonalert tone generator was connected to the equipment programming the DRL schedule parameters.

Procedure: all subjects were pre-trained as described in the General Method section. They were then introduced to the signalled DRL 18 sec. schedule requirements (Condition A). The requirements were identical to normal unsignalled DRL 18 sec. schedule requirements except that 18 seconds after a response (and providing, of course, that no other response had occurred) an 85 db tone signal came on and stayed on until a response, which was always reinforced, occurred. After 21 daily 30 minute sessions Rat 73 was transferred to an unsignalled DRL 18 sec. schedule, as was Rat 74 four days later (Condition B). The other two subjects were transferred to the unsignalled condition eight days (Rat 72), and twelve days (Rat 75) after Rat 73 was transferred to this condition.

It was hoped that any effect of transfer from the signalled to the unsignalled DRL 18 sec. would occur within four days as a previous, unreported experiment suggested it might.

Each subject was returned to the signalled DRL 18 sec condition (Condition C) in the same order, and separated by four days from one another, after 27 daily, 30 minute sessions on the unsignalled DRL 18 sec. condition. Finally each subjects was run for 15 daily sessions on this original signalled DRL 18 sec. schedule. Data for each subject were gathered from the final day of each condition. Cumulative session to session data were also collected.

Results:

Comparing the types and degree of collateral behaviour during this experiment it can be seen that during the unsignalled condition there was a noticeable change in collateral behaviour in all four subjects (Figures 63-66) However the fact that these changes took more time to occur, by far, than the four days which had been allowed for in the design, meant that a statistical analysis on the lines suggested by Revusky (1967) was not possible.

Comparing the final day performances in each condition of the experiment resulted in the following observations:-

In the first signalled DRL 18 sec.condition (A) three rats out of four did not produce wood gnawing behaviour at all (Figures 67-70:A) but their relative frequency distributions of IRTs show a typical signalled DRL schedule distribution which compare well with the distributions reported by Marcucella (1974). A few short unreinforced IRTs occurred but the majority of IRTs occurred shortly after the signal onset. The amount of unreinforced responding was smallbut again corresponded well with the data reported by Marcucella (Figures 71-74) One of these three subjects (Rat 73) produced some recordable behaviour on the second unreinforced lever.. In the final session in condition A Rat 73 produced 341 responses on this lever or just over 3 collateral lever press responses for every one left (reinforced) lever press response. The unrecorded collateral behaviour of Rats 74 and 75 consisted of typically "superstititious" responding. Rat 74 stretched up to grasp and hang from the house light cover while Rat 75 walked round the experimental space in a repetitive manner.

The fourth subject (Rat 72) did produce woodgnawing during condition A, but it was very different in IRI distribution from the

FIGURES 63-66

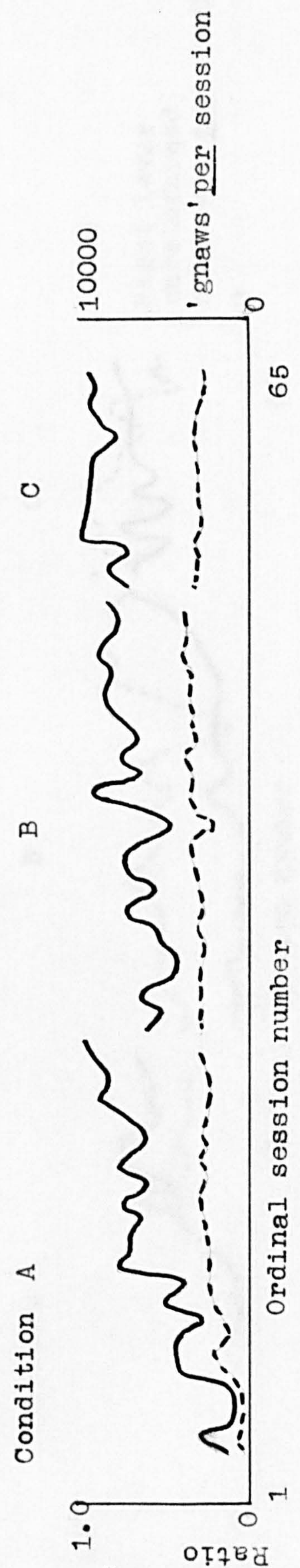
The daily efficiency ratios are plotted, for each animal, with the daily total amount of collateral behaviour. Note that while in Figure 64 the amounts of lever press responding on the left (reinforced) and right (collateral) levers are directly comparible, in the other graphs the amounts of woodgnawing are indicated by the right vertical axis.

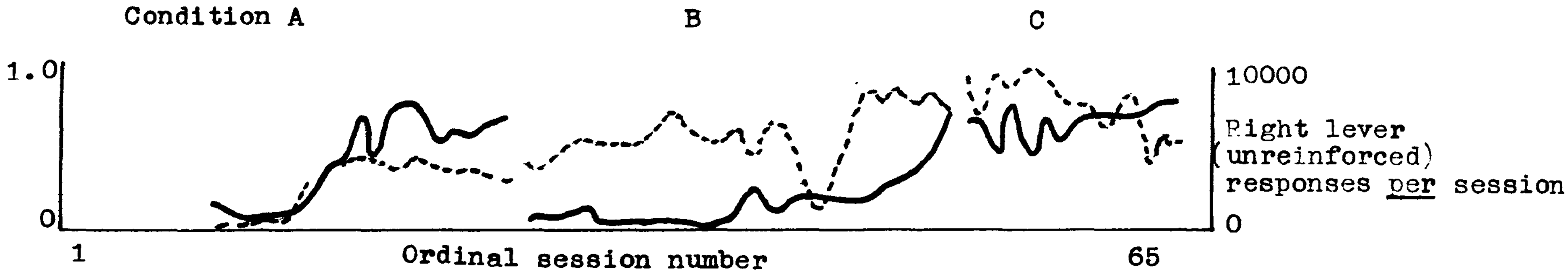
Condition A = first signalled DRL 18 sec. condition

Condition B = unsignalled DRL 18 sec. condition

Condition C = second signalled DRL 18 sec. condition.

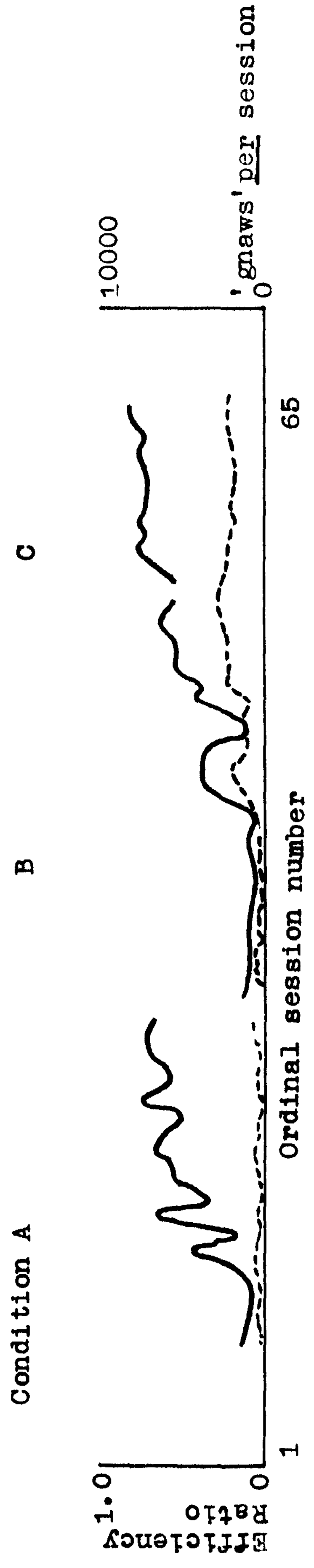
Expt. 7 Rat 72 Figure 63



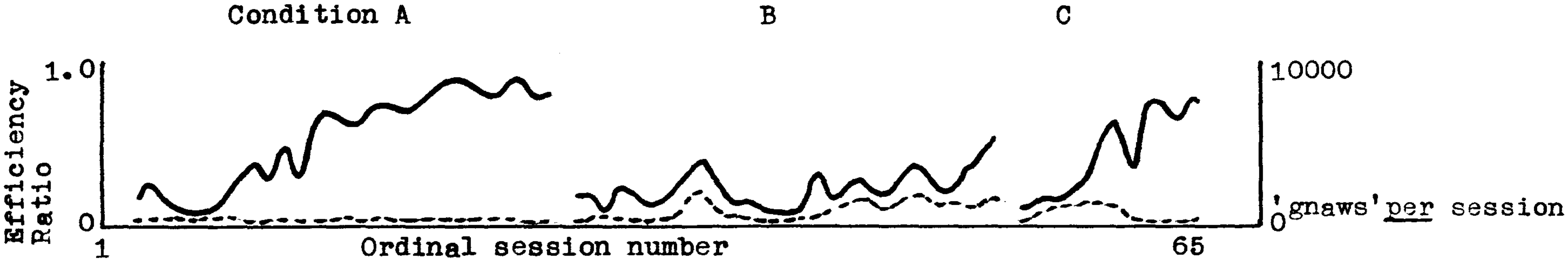


Expt. 7 Rat 73 Figure 64

Expt. 7 Rat 74 Figure 65



Expt. 7 Rat 75 Figure 66



FIGURES 67 - 70

A) Shows the cumulative record of the final day performance on the signalled DRL 18 sec. schedule. The upper pen is stepped upwards once by each "gnaw", resets and "hatchmarks" each response. A reinforced response produces a "hatchmark" on the lower record.

B) Shows the cumulative record of the final day performance on the unsignalled DRL 18 sec. schedule. Format the same as (A) above.

C) Shows the cumulative record of the final day performance on the reintroduction of the signalled DRL 18 sec. schedule. Format as (A) above.

Figure 67

Expt. 7 Rat 72

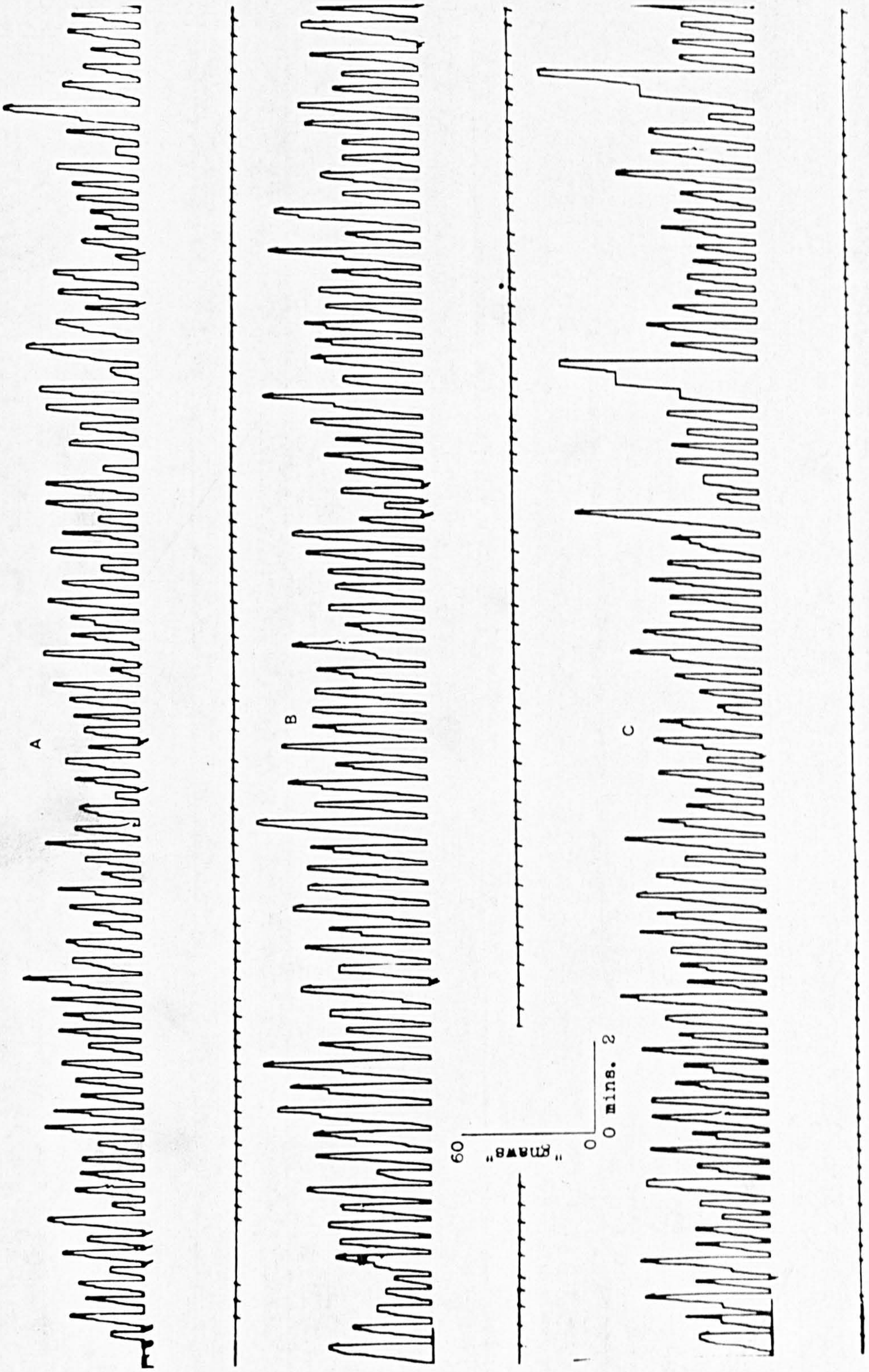


Figure 68

Expt. 7 Rat 73

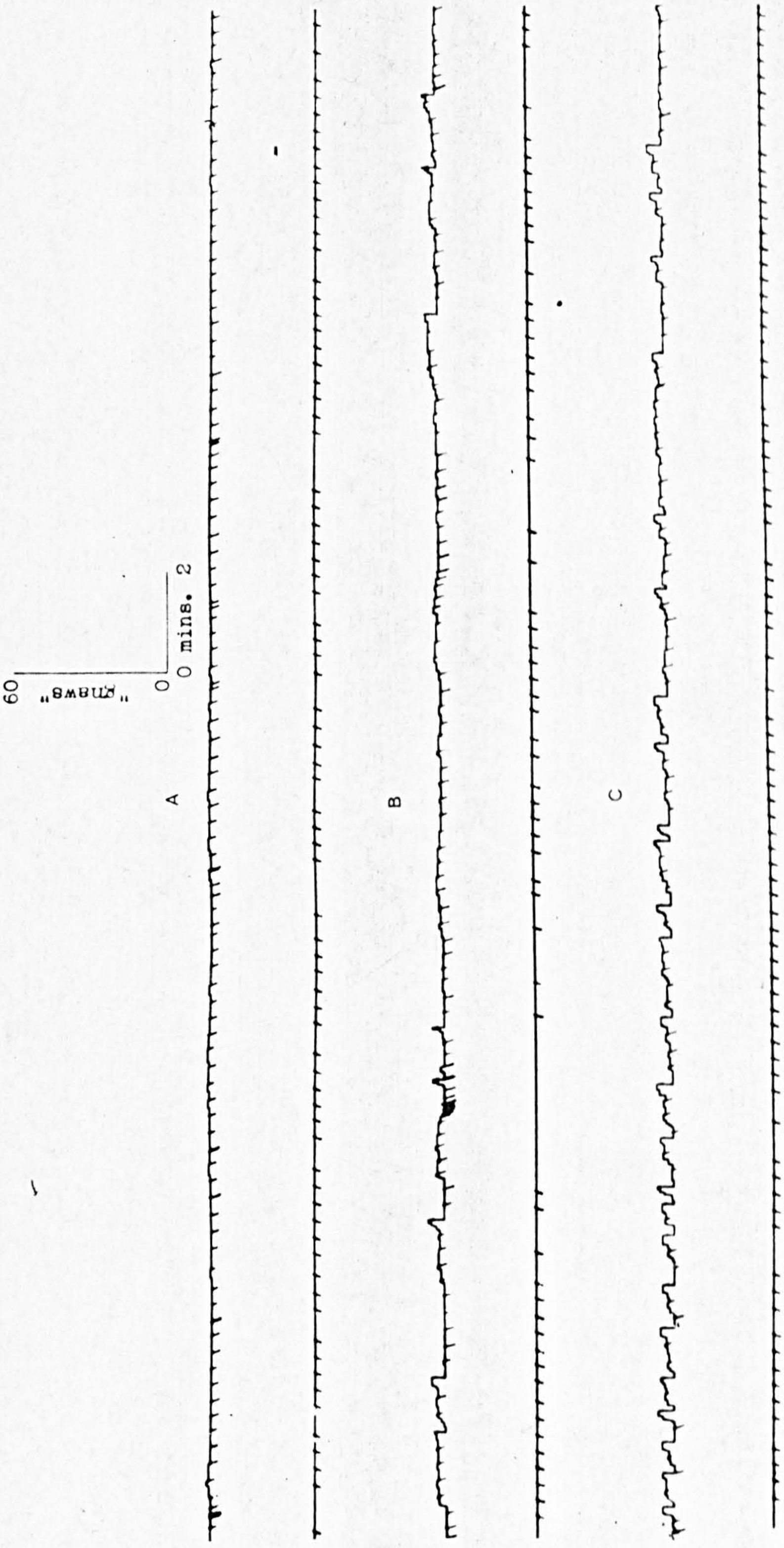


Figure 69

Expt. 7 Rat 74

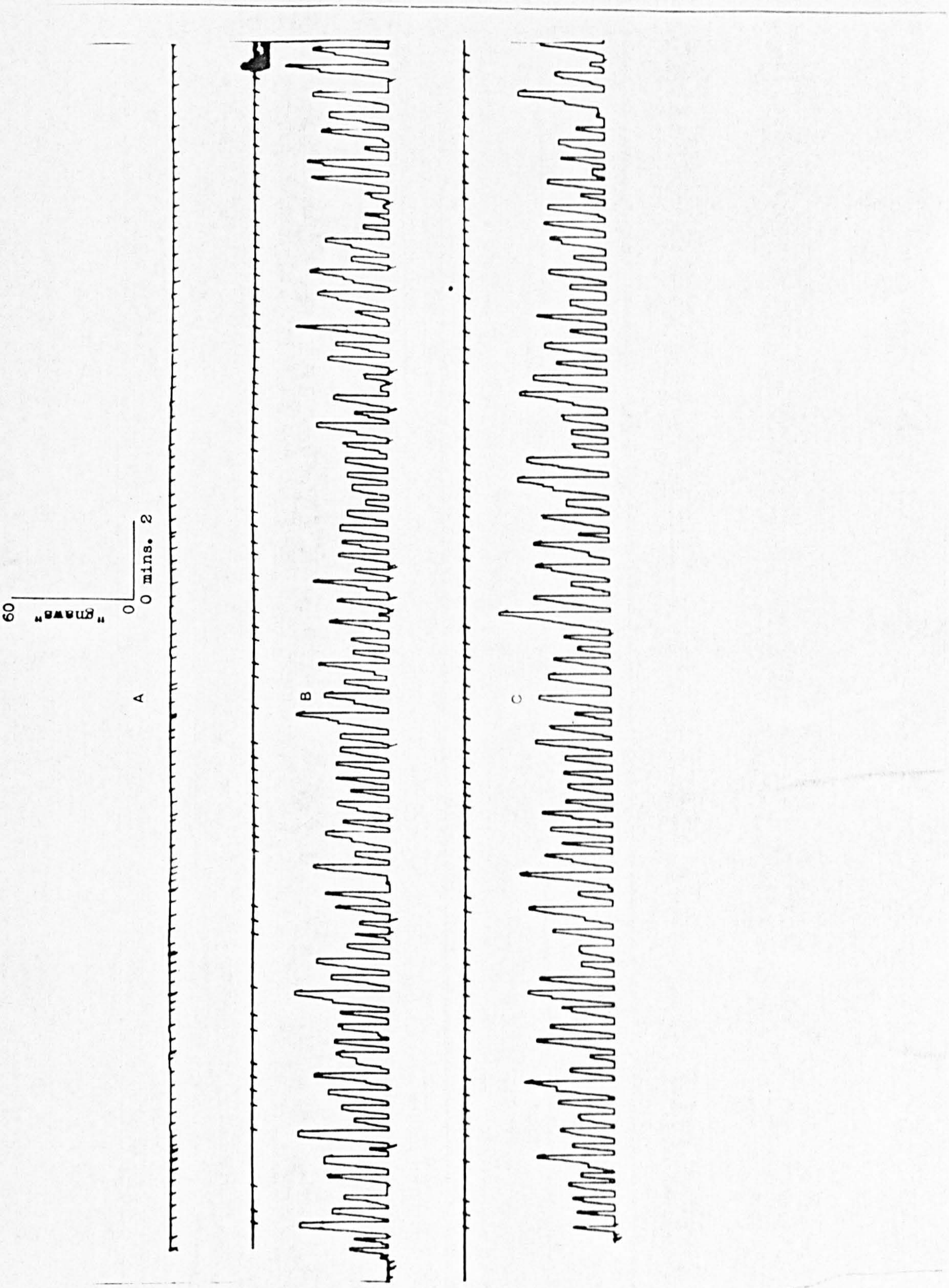
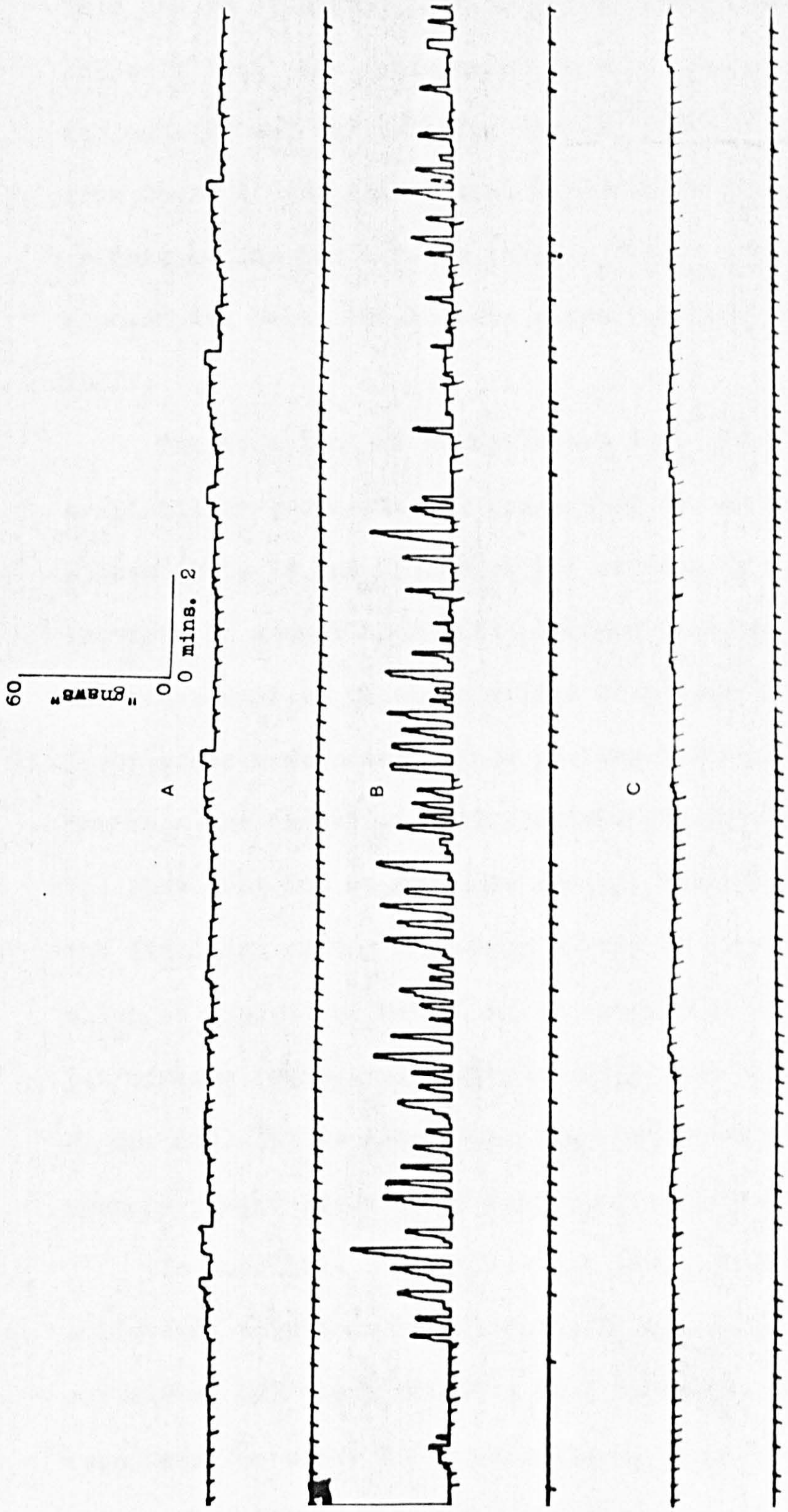


Figure 70

Expt. 7 Rat 75



type of behaviour reported in Experiment 1 and subsequent experiments. This can be seen from the cumulative record (Figure 67A) of this subject's final day performance in this condition. However this subject's IRT and IRI relative frequency distributions were different from those of the other three subjects in being more typical of unsignalled DRL performance (Figure 71A). A detailed analysis of Rat 72 woodgnawing behaviour in this signalled condition is shown in Table XLIII.

The effect of withdrawing the tone which signalled reinforcer availability (condition B) was marked for all subjects. The two subjects (Rats 74 and 75) which had emitted no recorded collateral behaviour in condition B both produced woodgnawing collateral behaviour the appearance of which coincided with increased efficiency of DRL lever press responding in this unsignalled condition (Figures 65 and 66). The relative frequency distributions of IRTs and IRIs (Figures 73 and 74) show that Rat 74 produced typical behaviour for this schedule by the final day of the condition B. Rat 75 showed a pattern of behaviour which is typical of behaviour in transition from very inefficient DRL performance (as measured by the efficiency ratios for each session: Figure 66). It is clear from the cumulative record that most reinforced responses were preceded by sequences of inter response woodgnawing.

In condition B Rat 73, which had produced the lever pressing collateral behaviour in condition A, continued to produce this collateral behaviour, but at a much increased rate (7.5 collateral responses for every left, reinforced, lever press response). The topography of this behaviour changed, too. In condition A the lever press response was made with the forefeet, while in condition B these responses were the result of biting and gnawing of the lever both of which produced considerable marking of the metal lever. The relative frequency distribution of IRTs (Figure 72B) of this subject's behaviour show an almost uni-modal distribution round the criterion IRT value.

The behaviour of Rat 72 in condition B showed an increase in total number of "gnaws" per session and much less "pausing" in relation to the amount of gnawing. Comparisons of Table XLIII and Table XLIV showing Rat 72 woodgnawing in condition A and B respectively shows the change to longer and more uniform runs of woodgnawing within IRIs in condition B.

On reintroduction of the signalled DRL 18 sec. procedure (condition C) three Rats 72, 73 and 75 appeared to regain their baseline performance of condition A but with increased amounts of collateral behaviour.

Rat 74 appeared to disregard the reintroduction of the discriminative stimulus for reinforcer availability. The relative frequency distributions (Figure 73c) shows behaviour typical of unsignalled DRL schedule performance .

These rather complex results are summarised in Figures 63-66 which show the session to session changes in DRL efficiency ratios throughout the experiment and the corresponding changes in total amounts of collateral behaviour per session.

FIGURES 71 - 74

A) Shows the relative frequency of IRTs/sec and IRIs/amount of woodgnawing (in decades, 10s, of "gnaws") for the final day of signalled DRL 18 sec.schedule.

B) Shows the same relative frequency measures as (A) above for the final day of unsignalled DRL 18 sec.schedule.

C) Shows the same relative frequency measures as (A) above for the final day of the reintroduced signalled DRL 18 sec.schedule.

Figure 71

Expt. 7 Rat 72

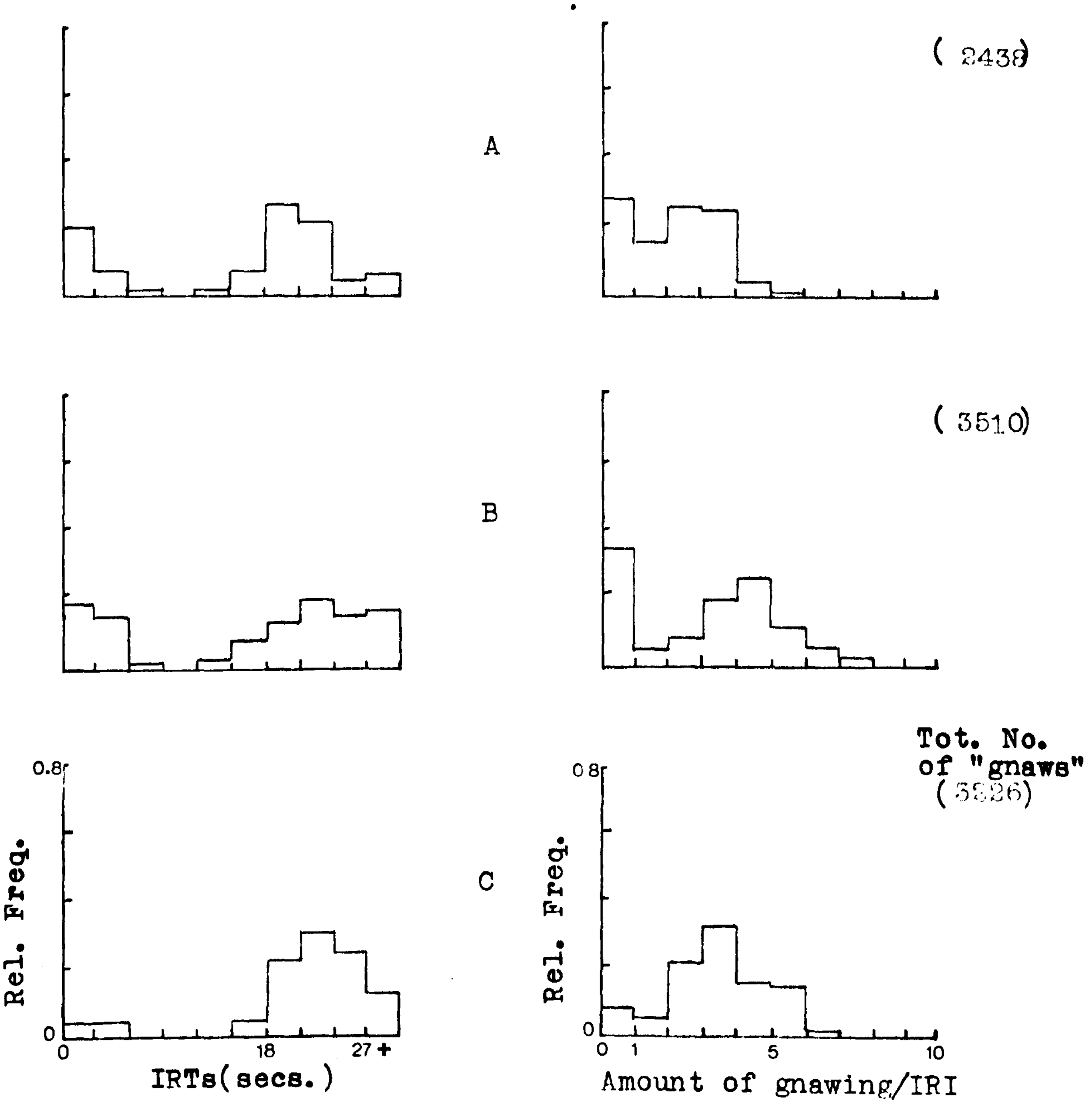


Figure 72

Expt. 7 Rat 73

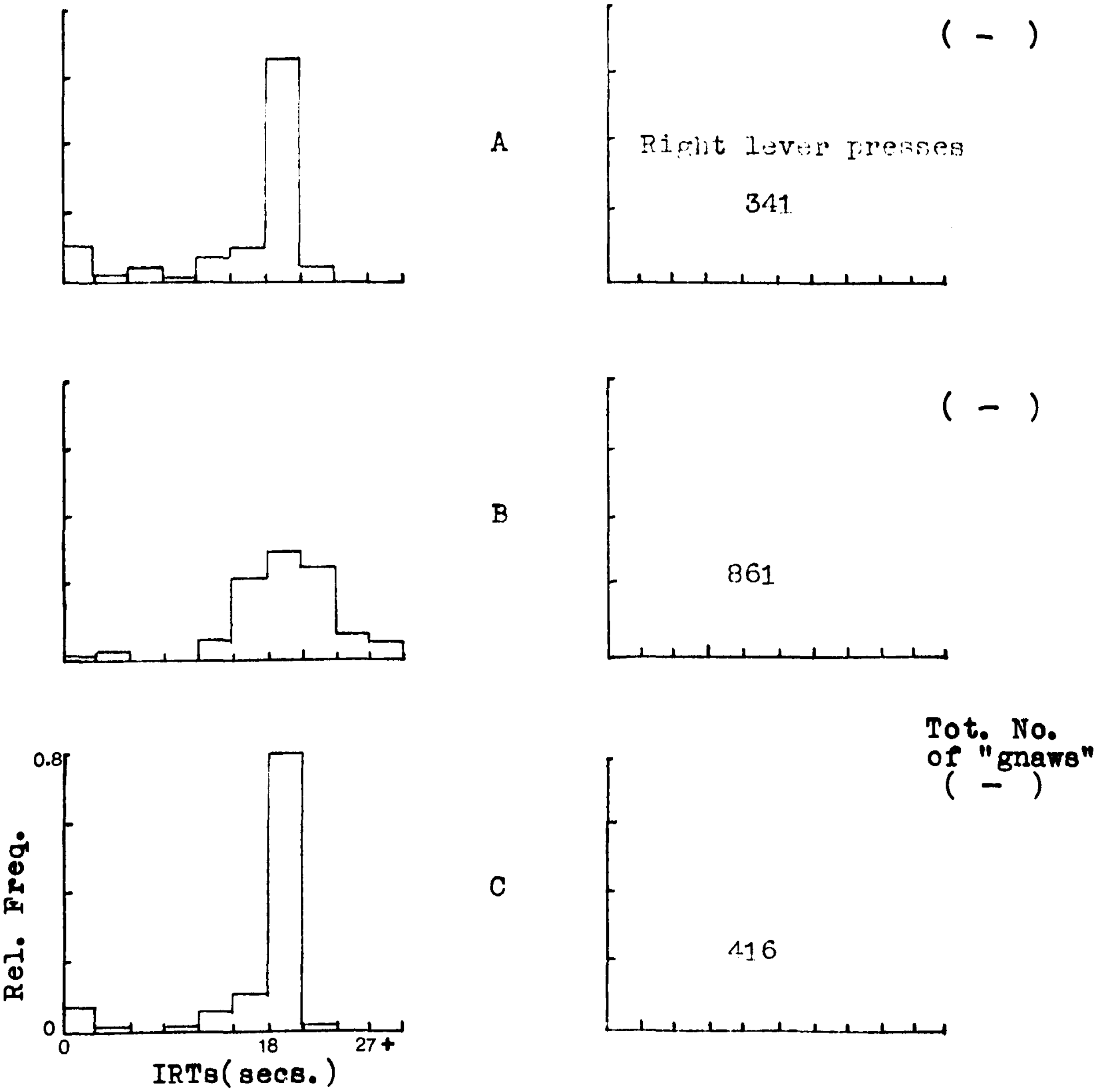


Figure 73

Expt. 7 Rat 74

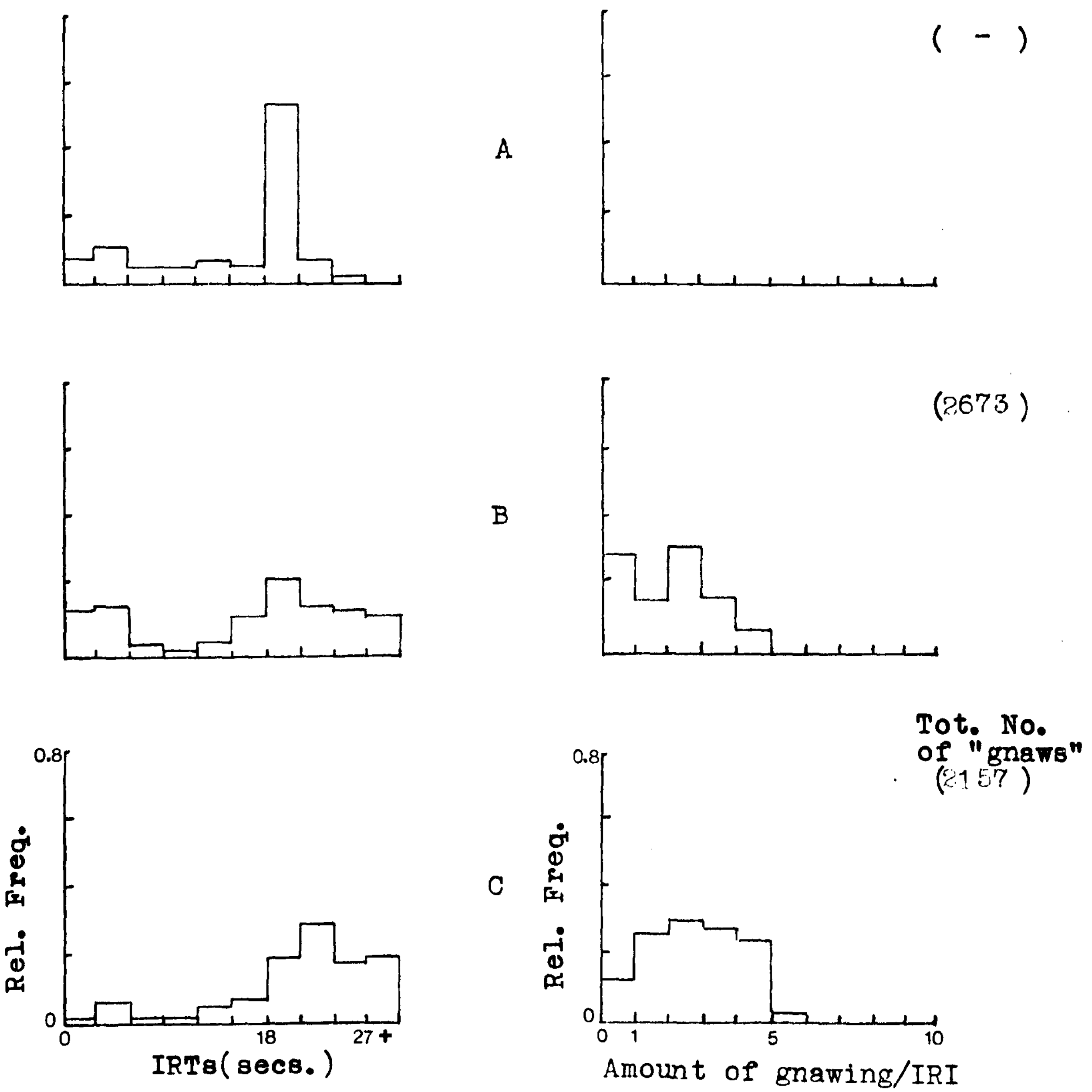
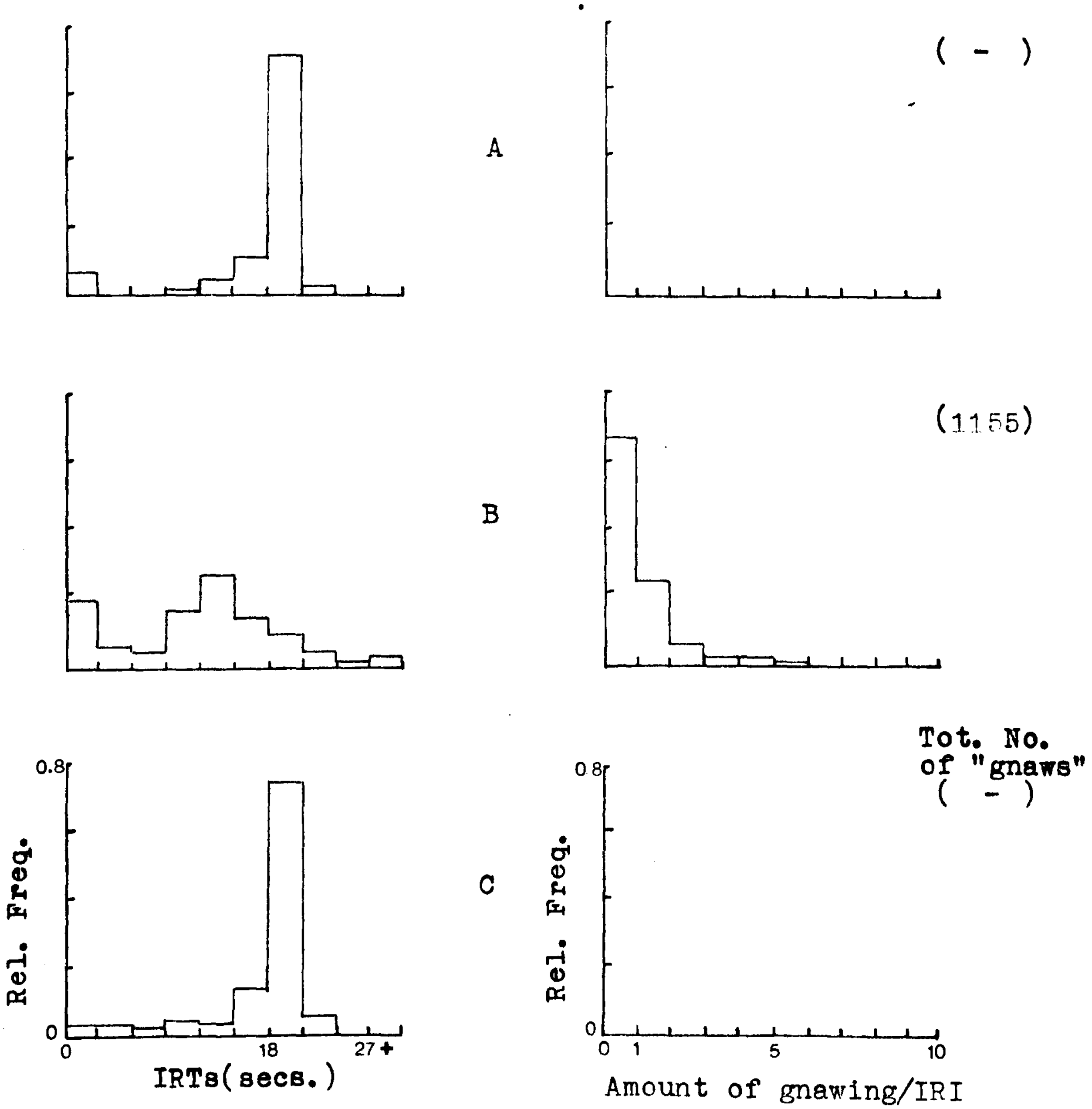


Figure 74

Expt. 7 Rat 75



TABLES XLIII - XLVIII

Each table is divided into two matrices. The upper one is an analyses of a interresponse intervals (IRIs) which occurred following a reinforced response, the lower one of IRIs following a non-reinforced response.

Each cell within a matrix shows (✱) the mean time to complete 10 "gnaws" (decade) and (†) the variance of those times which make up the mean time, for all instances of a decade occurring at that ordinal number in an IRI with that amount of gnawing.

The woodgnawing analysis applies, of course, only to those sessions in which wood gnawing did occur.

Table XLIII

Expt.7 Rat72

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	11.7 ✱ 7.9 †										12
2	10.7 5.7	4.6 2.7									23
3	9.4 3.1	4.6 2.3	4.3 2.8								25
4	8.3 0.2	4.0 2.9	5.8 6.7	4.7 10.2							3
5	8.3 -	2.3 -	7.1 -	2.5 -	3.0 -						1
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

✱ Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	8.4 9.2	5.9 4.3									8
3	6.9 0.4	5.0 3.7	2.8 0.1								3
4	2.4 -	2.9 -	3.0 -	5.1 -							1
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. with stimulus (A)

Expt. 7 Rat 72

Table XLIV

IRIs(decades of gnawing/IRI)

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	8.1 * 1.9 †										2
2	8.5 2.7	3.9 2.4									6
3	9.8 2.0	3.2 1.4	3.6 1.6								15
4	7.9 1.0	3.4 0.7	3.4 1.8	3.9 3.7							21
5	7.4 0.5	3.3 1.2	4.1 5.8	3.2 0.2	4.1 3.0						12
6	8.0 1.8	3.3 0.4	2.9 0.07	4.5 5.5	4.2 2.5	3.3 2.4					5
7	7.9 0.9	3.3 0.02	3.3 0.2	4.8 7.4	2.7 0.3	3.2 0.03	2.7 0.3				2
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	8.5 -										1
2	---	---									
3	7.1 4.1	3.1 1.8	5.2 5.8								3
4	6.7 11.7	4.3 2.9	4.0 0.5	2.5 1.4							3
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. without stimulus (B)

Table XLV

Expt. 7 Rat72

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs (decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	10.4 * 1.9 †										4
2	10.1 3.7	4.3 2.5									17
3	9.4 1.9	4.4 3.2	4.1 2.4								23
4	9.3 1.9	3.4 0.5	4.2 3.3	3.8 2.7							13
5	8.2 1.7	3.3 0.3	4.0 1.1	4.5 2.1	3.6 1.3						12
6	7.8 –	1.9 –	3.8 –	3.5 –	3.6 –	6.9 –					1
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)
† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	---										
2	---	---									
3	8.8 1.8	3.8 1.0	4.5 4.4								3
4	---	---	---	---							
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. with stimulus (C)

Table XLVI

Expt.7 Rat74

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	9.9 * 3.2 †										7
2	9.9 5.5	4.0 1.3									22
3	9.5 3.3	4.2 1.3	4.0 0.7								15
4	9.1 2.3	3.6 0.2	4.0 0.6	3.3 0.3							5
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

IRIs(decades of gnawing/IRI)	1	2	3	4	5	6	7	8	9	10	n
1	7.6 3.1										12
2	8.3 10.9	4.0 0.6									15
3	7.5 1.8	4.0 0.3	3.8 0.6								6
4	6.3 0.8	6.7 17.9	4.9 1.3	4.1 0.2							2
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. without stimulus (B)

Expt. 7 Rat 74

POST REINFORCEMENT IRIs

IRIs(decades of gnawing/IRI)

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	11.7 * 4.5 †										19
2	11.8 3.3	4.4 2.5									21
3	10.4 5.0	4.3 1.5	4.4 1.5								18
4	10.8 5.5	5.8 9.8	5.5 9.6	4.7 7.5							5
5	- - -	- - -	- - -	- - -	- - -						
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	11.1 30.9										2
2	10.2 0.5	3.5 0.2									3
3	10.1 9.9	5.3 6.4	3.9 0.4								4
4	- - -	- - -	- - -	- - -							
5	9.7 -	4.4 -	5.4 -	3.7 -	4.1 -						1
6	- - -	- - -	- - -	- - -	- - -	- - -					
7	- - -	- - -	- - -	- - -	- - -	- - -	- - -				
8	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -			
9	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -		
10	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	- - -	

DRL 18 sec. with stimulus (C)

Table XLVIII

Expt. 7 Rat 75

POST REINFORCEMENT IRIs

ORDINAL DECADE NUMBER

(decades of gnawing/IRI)

	1	2	3	4	5	6	7	8	9	10	n
1	12.6 * 1.9 †										9
2	11.9 -	4.1 -									1
3	10.8 -	4.4 -	3.7 -								1
4	---	---	---	---							
5	---	---	---	---	---						
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

* Mean time (secs.) to complete ten "gnaws" (DECADE)

† Variance (σ^2) of the above times.

POST NON-REINFORCED RESPONSE IRIs

ORDINAL DECADE NUMBER

	1	2	3	4	5	6	7	8	9	10	n
1	9.6 6.7										31
2	10.2 16.4	3.7 1.6									8
3	7.6 -	5.2 -	4.1 -								1
4	7.4 0.5	14.7 20.5	3.5 0.04	4.2 0.06							2
5	9.4 -	6.9 -	10.8 -	3.4 -	3.8 -						1
6	---	---	---	---	---	---					
7	---	---	---	---	---	---	---				
8	---	---	---	---	---	---	---	---			
9	---	---	---	---	---	---	---	---	---		
10	---	---	---	---	---	---	---	---	---	---	

DRL 18 sec. without stimulus (B)

Discussion

It was found that stereotyped collateral behaviour of an oral, gnawing, kind, was necessary for efficient DRL schedule performance in all 4 subjects in the unsignalled DRL condition. In 3 out of the 4 subjects the collateral behaviour emitted in the unsignalled condition was different in topography from that observed in the first signalled condition. For the fourth subject there was a change in the amount and distribution of the collateral (woodgnawing) behaviour between the two conditions A and B.

The effect of reintroduction of the signalled condition was to return 3 out of the subjects to baseline lever press response distributions with slightly increased amounts of stereotyped collateral behaviour over the earlier values. The fourth subject appeared unaffected by the reintroduction of the discriminative stimulus.

These results appear to be the strongest evidence yet obtained in support of the contention that stereotyped collateral behaviour of a particular kind and distribution is necessary for efficient DRL performance.

Although Marcucella (1974) did not report the incidence of collateral behaviour he has said "At short DRL values (5 and 10 sec) collateral behaviour occurred regardless of the presence or absence of the signal. Increasing the DRL value for signalled animals decreased the frequency of collateral behaviour such that in my experiment, at least, somebut not much collateral behaviour occurred at the 30 sec DRL value. At longer DRL values no systematic collateral behaviour occurred if the availability of the reinforcer was signalled.......This was in marked contrast to the behaviour observed in the unsignalled conditions. At all DRL values considerable collateral behaviour occurred" Marcucella (1975, personal communication).

Allowing for the fact that these are results of direct visual observations and that the topographies of the collateral behaviours are not specified, these results are consistent with the results of the present experiment.

A possible explanation for Marcucella's (1974) observation that in the signalled condition the amount of premature responding was inversely related to the duration of the criterion IRT, may be that, on a DRL 5 sec. schedule it is difficult, if not impossible, for the subject to remove itself from the lever spatially and still be able to respond in an efficient manner. The situational cues for responding are therefore present for most of the session. On longer DRL values the subject may remove itself from the area near the lever and still be able to respond efficiently (in terms of efficiency ratios).

The technique employed in the present experiment may be regarded as removing the "temporal discrimination" aspect of DRL schedule requirements while retaining the response inhibition requirement during the criterion IRT. The results clearly indicate that the oral, gnawing, kind of collateral behaviour was peculiar to the unsignalled condition where "temporal discrimination" of some kind was presumably necessary. This argues strongly for the contention that stereotyped collateral behaviours have a timing function in addition to their response competition or inhibition function.

SUMMARY OF EXPERIMENTS 5, 6, 7

SUMMARY

The three experiments reported in this chapter attempted to manipulate the DRL schedule requirements to observe the effects on the collateral woodgnawing.

Experiment 5 looked at the effect of extinction on behaviour previously maintained by a DRL 18 sec. schedule of reinforcement. It was noted that:-

(1) Wood gnawing extinguished before lever pressing, suggesting that the sequences cannot be conceptualised as a chain.

(2) Wood gnawing sequences tended to extinguish in such a way that they were either present in their entirety or were absent.

Experiment 6 demonstrated that in each component of a two criterion DRL schedule the schedule requirements of each component gained control over the topography of the collateral behaviour. Where no such control was evidenced a similar lack of control over the lever press distribution was also noted.

Experiment 7 showed that collateral behaviour emitted on an unsignalled DRL 18 sec. schedule differed markedly from that observed on a signalled DRL 18 sec. schedule. It was suggested that this result supports the contention that stereotyped collateral behaviour is necessary for efficient DRL performance.

CHAPTER VII

THE EFFECT OF REMOVING THE OPPORTUNITY TO EMIT COLLATERAL BEHAVIOUR ON THE DISTRIBUTION OF LEVER PRESS RESPONSES ON A FIXED INTERVAL 90 SEC. SCHEDULE

EXPERIMENT 8

Introduction

The final experiment is, in a sense, separate from the preceding seven experiments in that it deals with collateral behaviour on a different schedule of reinforcement, the fixed interval (FI) schedule. As a consequence of reviewing the results of the first seven experiments,it became increasingly clear that the probable function of stereotyped collateral behaviour on DRL schedules is to inhibit,or suppress,certain premature responses, where such responses are likely, and thereby facilitate the temporal spacing of lever press responses. However it was apparent from many cumulative records that the transition from woodgnawing to lever pressing was abrupt. Observatio of many subjects has shown that an animal may be gnawing the wood facing away from the lever; at the end of the IRI the animal would quickly look up, turn round, and press the lever, all in not much over a second.

One is left with the question, then, why does the subject abruptly stop gnawing and press the lever at one point in time rather than any other? The behaviour chain hypothesis has been shown not to fit the experimental data, and the utility of the "counting"explanation has been questioned. This experiment was an attempt to address the question from another angle.

Thomas (1971) has reported the effect of denying a rat the opportunity to emit collateral behaviour which had developed on a FI 217 sec. schedule. The FI schedule requirements are that the first response occurring after the fixed interval of time has elapsed is reinforced. There is no constraint on premature responses, which are merely ineffective. Typically responding during the interval shows a positively accelerating rate following a post reinforcement pause; this pattern of behaviour is sometimes referred to as "scalloped" responding. The explanations put forward for the maintenance of this pattern of behaviour have been in terms of mediating chains of behaviour (Ferster and Skinner, 1957) or delayed reinforcement (Dews, 1962) or more recently, the relative proximity principle (Jenkins, 1970).

The interesting finding reported by Thomas was that, despite the fact that grid-gnawing had superceded lever-press responding for much the greater part of the interval, the immediate effect of introducing the false floor was that, in the following interval, the subject reverted to a "scalloped" pattern of lever press responding.

One of the recent explanations of DRL performance (Staddon, 1972; Frank and Staddon, 1974) has stated that:- "If it is assumed that .... two types of activity (interim and terminal: for instance woodgnawing and lever pressing) are reciprocally inhibitory (c.f Staddon - 1972), then prevention of the interim activities would leave the terminal response as the behavior of next priority in the situation".

One might argue that if Thomas' results are not due to some other explanation, such as regression to an earlier behaviour pattern, then this is evidence that, in the FI situation, the terminal response not only appears in place of the interim behaviour but does so in a structured manner. In the FI situation this may say something about supposed mediational variables linking the woodgnawing and, after woodgnaw removal, the lever press distributions. That is, are the two behaviours controlled by variables which are independent of one another? If they are, how might this knowledge aid a functional analysis of collateral behaviour in DRL performance?

This present experiment was run to confirm and if possible extend the experimental findings of Thomas (1971).

Method

Subjects: Three Rats (Laboratory Numbers 52, 53 and 54) maintained as described in the General Method section, at 85% of their free feeding bodyweight.

Apparatus: As described in the General Method section.

Procedure: Following adaptation, magazine training and brief exposure to the CRF schedule all subjects were run on a variable interval (VI) 30 second schedule for 5 daily sessions lasting 30 minutes. No wood was present in the experimental space. Following this all subjects were run for 60 daily sessions on a fixed interval(FI) 90 seconds schedule during which 25 reinforcements were obtained. Wood was present in the experimental space throughout the exposure to FI 90 sec.

For five days prior to the final (test) day, an adaptation procedure (prior to wood removal) similar in every respect to that carried out in Experiment 2 was introduced immediately after the 12th reinforcement. The experimenters hand was placed on the woodblock for 3 seconds, then withdrawn leaving the woodblock in place. On the test day this procedure was carried out as usual except that the woodblock was removed.

Results:

All three subjects developed collateral woodgnawing behaviour. This development was gradual, woodgnawing replacing lever press behaviour over many sessions. This is illustrated by the cumulative records of session 30 on the FI 90 sec. schedule, 30 days prior to the test day (Figure 75) One subject (Rat 52) was producing very few left (reinforced) lever responses. Typically, interval behaviour for this subject on this day consisted of woodgnawing following reinforcement, followed by several right (not reinforced) lever press responses and finally one left (reinforced) lever which was invariably reinforced.

On this 30th session Rat 53 produced a great amount of post-reinforcement gnawing followed by lever press responses on both levers, more or less equally distributed. Rat 54 produced less gnawing behaviour (the wood was nibbled but barely marked) very little right lever responding and considerably left (reinforced) lever responding.

By the final (test) day the behaviour had stabilised and reflected a pattern of behaviour which was consistent for each animal over at least the preceding 10 sessions. Figure 76 shows the mean number of both left and right lever responses in each session for the 25 sessions prior to the test day expressed as the number of each type of lever press response per 90 sec. interval. This behaviour is also shown in the cumulative records of each subject prior and following wood removal on the test day (Figures 77 - 79). It was not possible to analyse this woodgnawing behaviour using a computer, but the woodgnawing data from this session for Rat 52 is produced below.

90 sec. interval (divided into 10 sec. categories)

	0-9	10-19	20-29	30-39	40-49	50-59	60-69	70-79	80-89	90+
Total No. of "gnaws"(from 12 intervals)	108	283	263	312	234	259	252	265	289	75

The Pearson Product Moment correlation coefficient for the above data is -0.0935.

Removal of the woodblock resulted in the immediate emission of patterned lever press responding, of a type which had never been

Figure 75

This shows the cumulative record of each subjects performance on the fixed interval (FI) 90 sec. schedule of reinforcement on the 30th day of exposure to this schedule.

Each "gnaw" stepped the upper pen upwards once. A left (prescribed) lever response is indicated by a downward "hatchmark" of the upper pen. A right (not prescribed) lever response is indicated by a downward "hatchmark" of the lower pen. A reinforced response in in addition to producing an upper pen "hatchmark" also resets the upper pen.

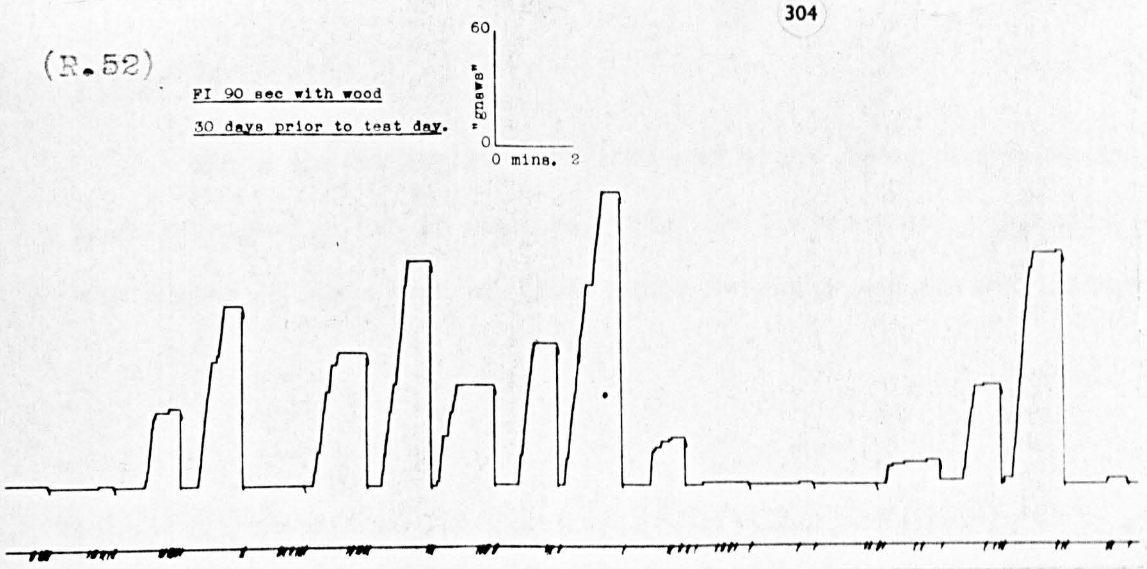
Figure 75

Expt. 8 Rat 52, 53, 54

(R.52)

FI 90 sec with wood

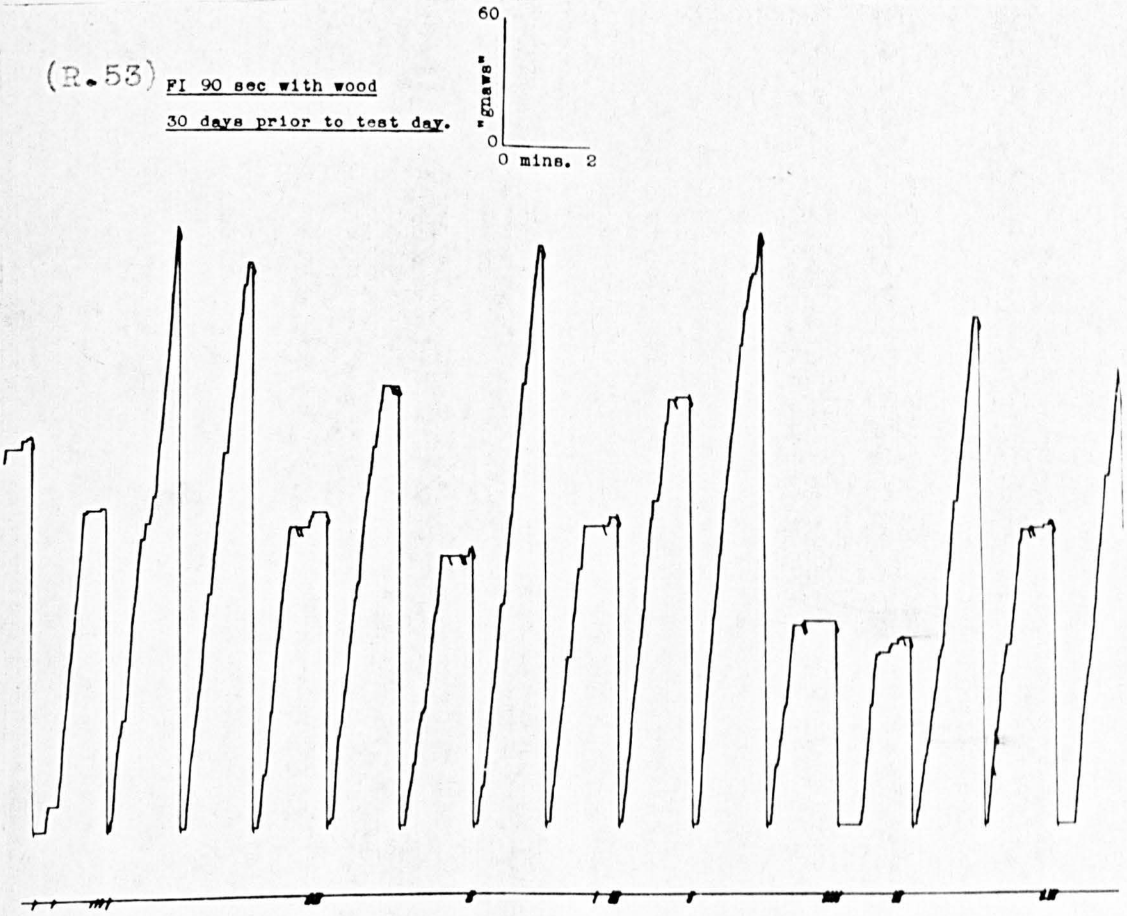
30 days prior to test day.



(R.53)

FI 90 sec with wood

30 days prior to test day.



(R.54)

FI 90 sec with wood

30 days prior to test day.

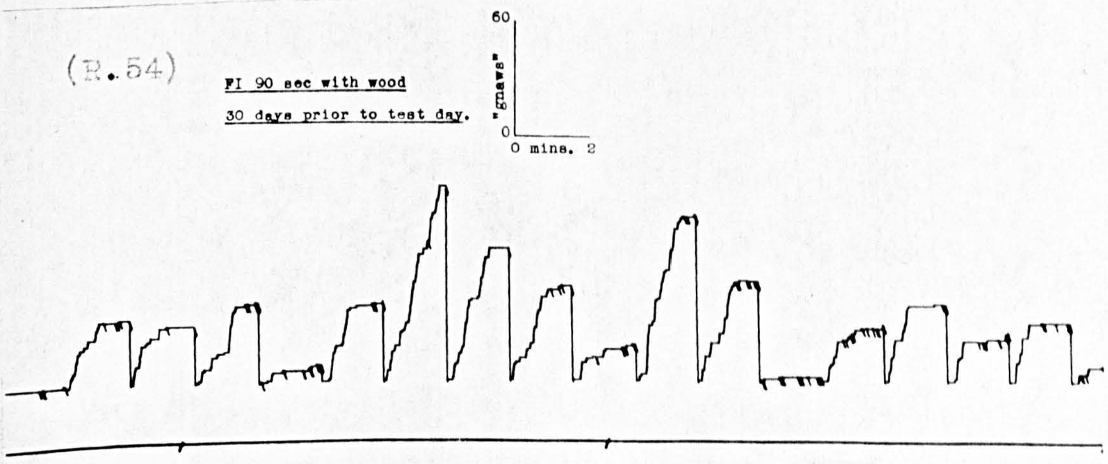
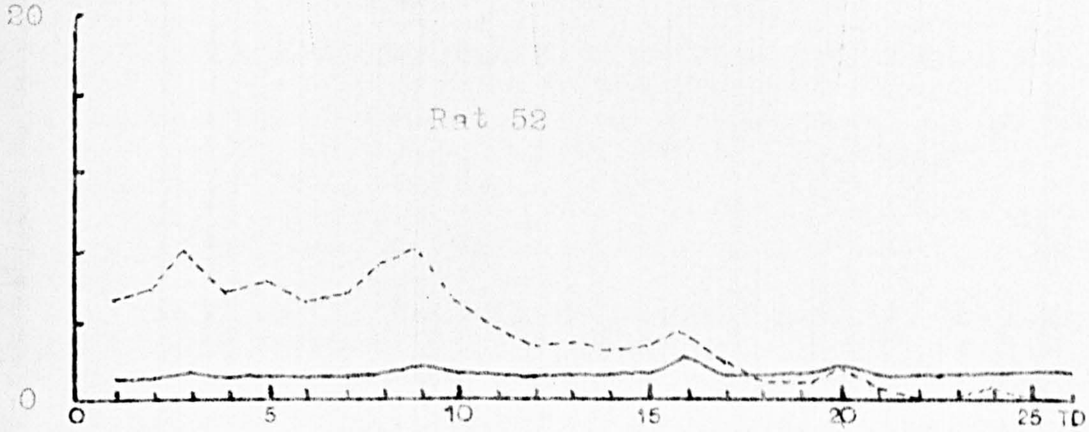


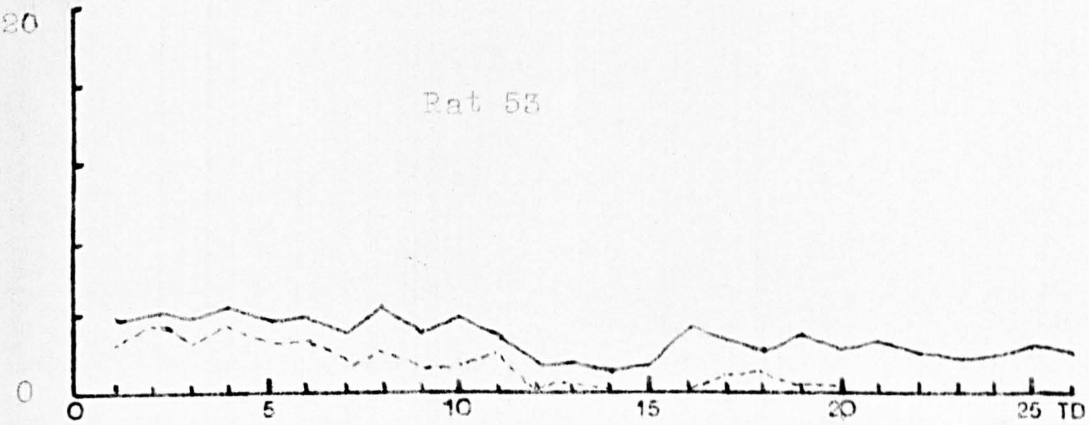
Figure 76

Shows the mean number of both left and right lever responses in each session for the 25 sessions prior to the test day expressed as the number of each type of lever press response *per* 90 sec. interval.

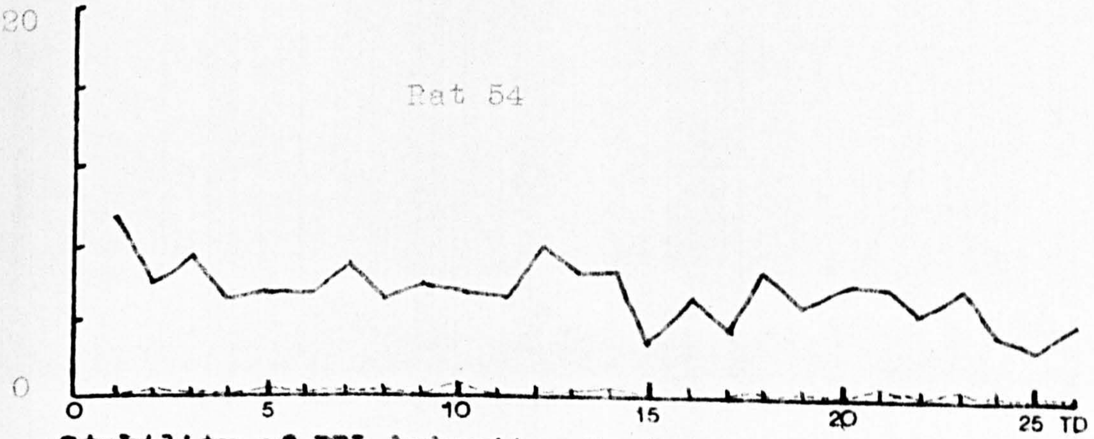
Expt. 8 Rats52-54 Figure 76



Stability of DRL behaviour, last 25 days before Test Day (TD)



Stability of DRL behaviour, last 25 days before Test Day (TD)



Stability of DRL behaviour, last 25 days before Test Day (TD)

— Mean number of left (reinforced) lever responses *per* session
--- Mean number of right lever responses *per* session

Figures 77 - 79

These show the cumulative record of that subjects performance on the final (test) day both prior to wood removal and after wood removal.

The format for the period prior to wood removal is the same as for Figure 75. Following wood removal each left (prescribed) lever response stepped the upper pen upwards once. A right lever response produced a hatchmark on lower pen record. A reinforced response (left lever) reset the upper pen.

Figure 77

Expt. 8 Rat 52

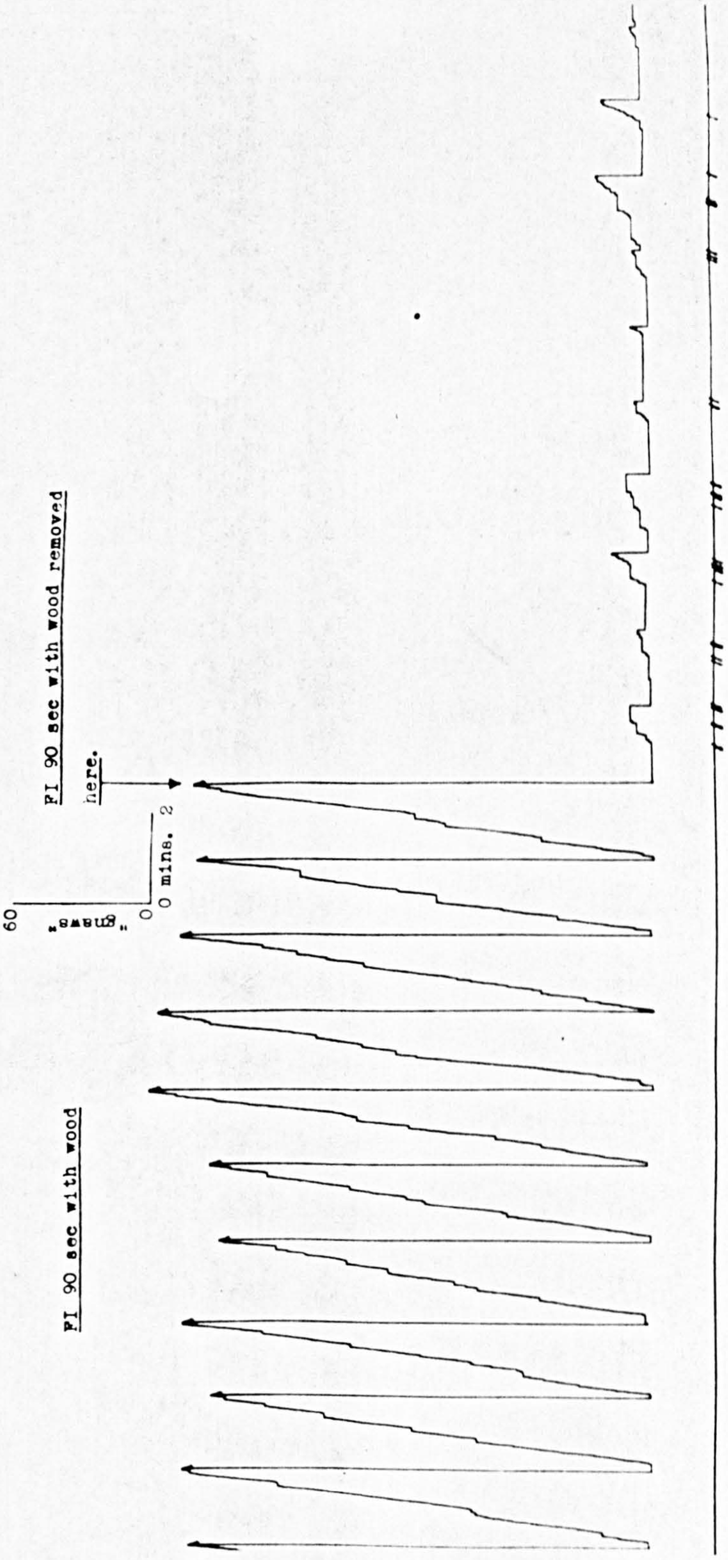


Figure 78

Expt. 8 Rat 53

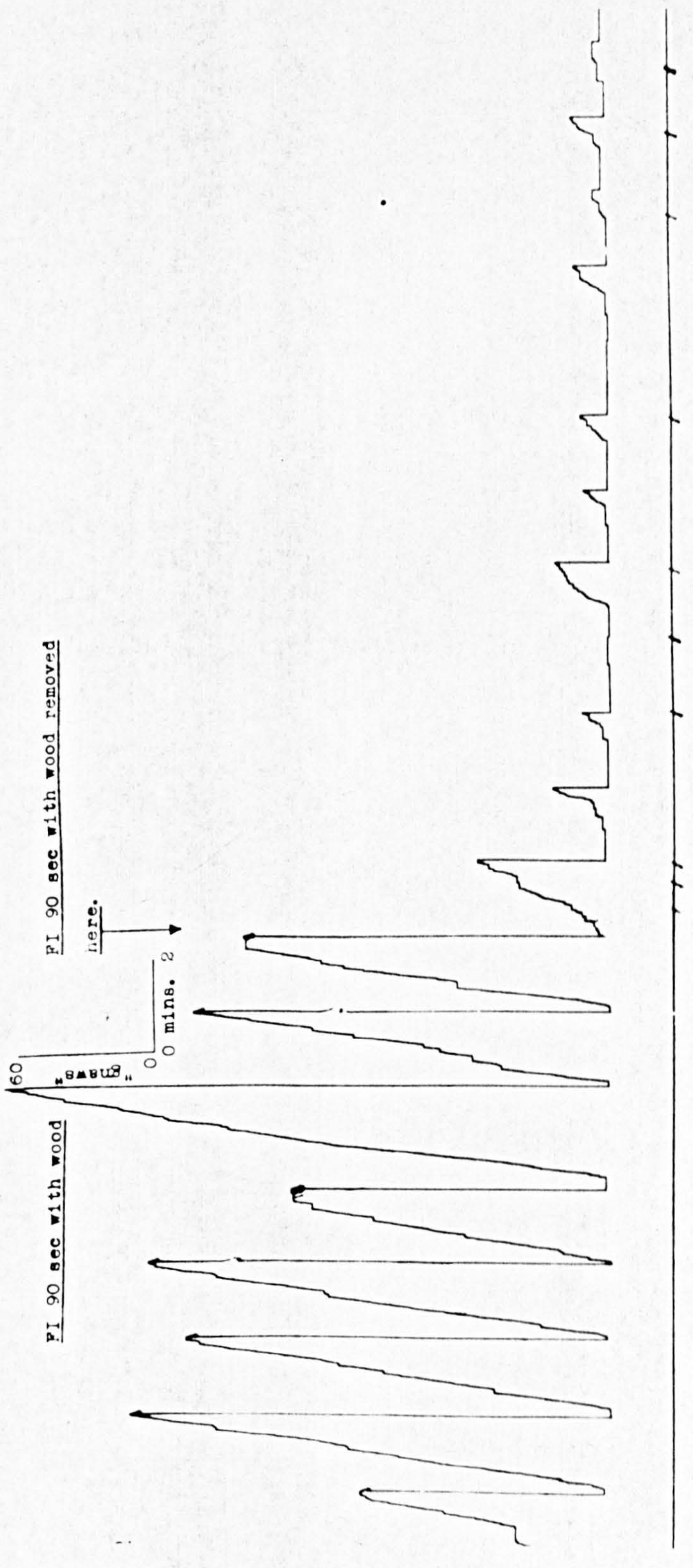
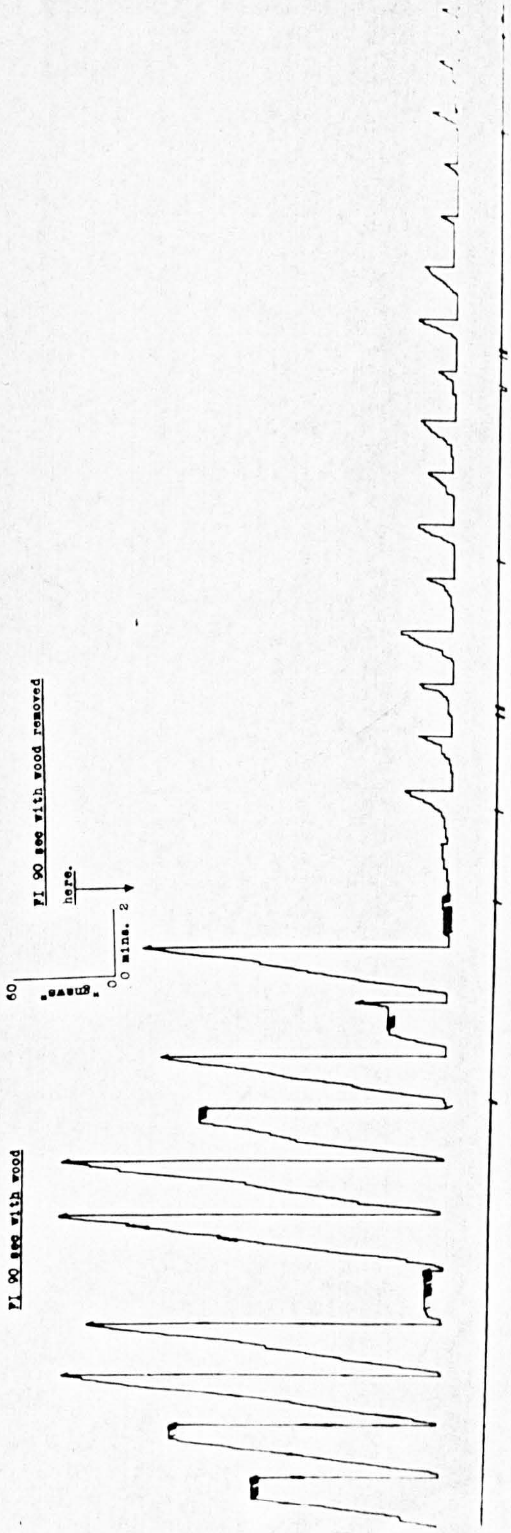


Figure 79

Expt. 8 Rat 54



emitted previously by these subjects. This pattern was either "scalloped" indicating a positively accelerating response rate through the interval (Rats 53 and 54), or a "break and run" shape indicating a post reinforcement pause followed by a sequence of relatively uniform rate lever press responding (although in this case, Rat 52 responding occurred on both levers).

Discussion

The results of this experiment confirm and extend the findings of Thomas (1971) in that denying a subject the opportunity to emit the collateral behaviour on stable FI schedules resulted in an immediate emission of a 'scalloped' pattern of lever press responding typical of stable FI schedule performance.

One argument, which might be put forward to explain the results obtained by Thomas, is that regression to an earlier pattern of behaviour took place when in a sense earlier stimulus conditions were reintroduced. This is in fact a weak argument since introducing a false floor was a novel procedure and, if anything, should have disrupted patterned lever press behaviour resulting in the production of variable rates of responding of consistent pattern.

In the present experiment the two patterns of responding were both typical of types of response patterns seen in stable FI performance. The 'scalloped' pattern is associated with stable FI performance, (Ferster and Skinner, 1957) and the 'break and run' pattern with prolonged exposure to an FI schedule (Cumming and Schoenfeld, 1958). It is interesting to note that the animal which produced the latter pattern of lever press responding following wood removal, was also the animal to produce very accurate and efficient performance on the FI schedule prior to wood removal (Rat 52). This efficiency is reflected in the very few unreinforced left lever responses and in the lack of gnawing in the 90+ sec. category which indicates that if responses followed gnawing immediately then, what lever responding there was, appears to have been very accurately timed.

In the present experiment these patterns of behaviour had never been emitted under stimulus conditions when the wood was not present. As stable FI performance appeared in terms of post reinforcement pausing, these pauses were "filled" with collateral woodgnawing so that in this experiment the regression hypothesis just does not appear to fit the data.

Another important point to emerge from this experiment, with relevance to an earlier experiment, is that the fact that patterned behaviour was emitted immediately after wood removal casts doubts on the interpretation of such procedures as being disruptive. This was a possible criticism of the second experiment in this thesis, and the results of this present experiment give additional support to the necessarily tentative conclusions of that experiment, limited as they were at the time by these procedural doubts.

These results appear to belong to a group of results discussed by Mackintosh (1974) where it has been shown that animals, having been exposed to a non contingent FI schedule, and then transferred to a standard, response contingent FI schedule, immediately show a typical FI scallop pattern of responding (Trapold, Carlson and Myers, 1965; Zamble, 1969). Mackintosh (1974) has said that these results suggest that: "a typical FI scallop may appear without subjects having been exposed for any length of time to any instrumental contingency" (p.170 - 171). Surely the problem posed by these results and the results of this present experiment, is - how does reinforcement effect the probability of responding which for one reason or another is not overtly emitted by the subject, in such a way that, as soon as it is permitted to occur, it does so in a structure stable manner?

Explanations of this type of result could be of many types.

A "two factor" learning theory approach is favoured by both Zamble (1969) and Trapold et al. (1965), who suggest that mediational proprioceptive behaviours, patterned by fixed time reinforcement, control the lever press responding on the response contingent FI schedule. Other explanations would probably rely to a degree on some mediational process (either by an intervening variable, as above, or by some hypothetical construct such as a memory of lever press response probabilities with a value less than 1.0.)

The explanations of this result are of little value to the present investigation. The rationale for this experiment, apart from validating the wood removal process as a non-disruptive procedure, was to provide some evidence for the Staddon suggestion that interim and terminal behaviours may be considered to be some sort of priority hierarchy in temporal schedules.

On the limited evidence available from this experiment, it would appear that the woodgnawing distribution was not similar to the lever press distribution which appeared when the opportunity to emit woodgnawing was removed. This suggests that for the FI schedule, at least, a mediational explanation may not suffice. It is more likely that the woodgnawing and lever press distributions were controlled by variables independent of one another.

It may be that one of the very few ways of distinguishing between competing, inhibition or suppression explanations of the role of collateral behaviour in DRL performance, is dependent on the degree to which lever press responding and collateral behaviour may be said to be controlled by variables which are independent of one another. This point will be taken up in greater detail in the next chapter.

SUMMARY OF EXPERIMENT 8

SUMMARY

Experiment 8 investigated the effect of removing the opportunity to emit collateral behaviour on the distribution of lever press responses on a fixed interval 90 sec. schedule of reinforcement.

The difference between the woodgnawing and lever press response distributions suggests that these distributions may be controlled by variables which are independent of one another.

The results of this experiment suggested that the wood removal procedure employed in Experiment 2, while criticised at the time as being a novelty procedure to an uncontrolled degree, was probably not disruptive to any marked extent.

CHAPTER VIII

GENERAL DISCUSSION and CONCLUSIONS:

GENERAL DISCUSSION

Introduction

In the following general discussion, the main conclusions from the previous eight experiments will be used to evaluate the theoretical interpretations of stereotyped collateral behaviour which have appeared in the literature.

Besides examining the experimental methods used in this investigation to suggest where, and how, these might have been improved, this discussion will attempt to find the most appropriate description for the function(s) of stereotyped collateral behaviour in DRL schedule performance.

The final section of this discussion looks at the implications of such a function for further research on timing behaviour.

In this discussion only results of significance to the argument will be mentioned and then not in the detail employed in the earlier individual experiment discussions. Principal conclusions from this discussion will be annotated to facilitate a summary.

Most experimental reports of stereotyped collateral behaviours occurring on DRL schedules (see Ch.III) have illustrated the idiosyncratic and peculiar nature of such behaviours. In most experiments the topography of the behaviours which have been reported varies considerably from subject to subject. In the present experiments there were no environmental constraints on the type of collateral behaviour which the subjects could emit, but the presence of the woodblock made woodgnawing a highly probable behaviour. That gnawing is a highly probable behaviour by the rat where wood blocks are present has been attested to by Valenstein, Cox and Kakolewski (1970); Miller (1951); Roberts and Carey (1965). The only constraint on the emission of woodgnawing was the position within the experimental space where it could occur. The woodblock was secured and could not be moved. This constraint also applied to the most notable previous example of collateral woodgnawing by rats on a DRL schedule (Laties et al. 1969).

Kramer and Rilling (1970) have listed a number of the characteristics of DRL performance in their review of the literature on this schedule. The most common of these (apart from the characteristic low rates of responding) are the bimodal IRT distribution, 'bursts' of responding, the 'wave-like' sequential pattern of successive IRTs and the prevalence of collateral behaviour. Without exception the performances of the twenty subjects involved in the preceding experiments all fell within this general description, albeit some of the performances varied in the degree to which each of these characteristics occurred.

Where the representative nature of a subject's data has been questioned it was normally because the stability of the DRL performance either between or within sessions, was in doubt.

It is therefore reasonable to assume that the data obtained in the present DRL experiments are from behaviour which resembled the typical reported DRL performance (Statement 1).

The main aim of this investigation was to provide a more detailed analysis of stereotyped collateral behaviour on DRL schedules than had previously been produced. In order to obtain sufficient amounts of quantitive data to make this detailed analysis, it was necessary to develop some automatic method of recording the woodgnawing. The woodgnawing sensor which was developed and indeed the choice of woodgnawing as the behaviour for study, resulted in a series of compromises which imposed limitations on the type of experiment which could be performed.

The choice of beech wood as the type of wood to be gnawed meant that clear records of woodgnawing were obtained. The subjects could not tear off large pieces and gnaw them else-where, thus reducing the likelihood of unrecorded gnawing and, apparently, preventing wood ingestion. Unfortunately, gnawing of beech wood produced fine dust which after long exposure increased the risk of inhalation pneumonia in the subjects. This dictated the use of short daily sessions and also limited the overall length of experiments.

The necessity for the wood sensor rod to be removed after each group of daily sessions (to free the apparatus for other use) meant that very detailed comparisons between daily sessions for the same subject were not possible. However comparisons between subjects on the same day, when the rod was firmly clamped,were possible.

Perhaps the greatest limitation in the present series of studies was the method used to measure rates of woodgnawing within an IRI. Due to the lack of apparatus which could transfer, onto computer punch tape, two events which might occur simultaneously, it was necessary to employ a method which recorded the time at which every tenth "gnaw" occurred,rather than, for instance, how many "gnaws" occurred in every consecutive 1 second category within an IRI. The latter method would have involved many instances where a time base event and a behavioural event were contemporaneous. In the former method the time at which each event occurred could be recorded and as "gnaws" and lever presses very rarely occurred together there was no problem with contemporaneous events. This method was therefore employed.

However, this method led to difficulties in assessing whether apparent changes in "rate" of woodgnawing, inferred from the times to complete 10 'gnaws', were due to pauses between sequences of woodgnawing at a uniform rate, or were indeed non-discrete changes in gnawing rate.

This method of recording the behavioural events imposed a further limitation on the detailed analysis of woodgnawing in that almost inevitably some gnawing (a maximum of 9 "gnaws") was not assessed for "rate" at the very end of a gnawing sequence prior to the lever press response.

Of the three major limitations mentioned the latter two are the ones most easily overcome. The use of apparatus which could efficiently record contemporaneous events would obviate both difficulties. The limitations of woodgnawing as a collateral behaviour in studies of this sort could perhaps be overcome by using some other behaviour.

It was apparent from Experiment 3 that while water licking can occur as a collateral behaviour on DRL schedules it has two characteristics which might limit it's use as a behaviour in studies concerned with stereotyped collateral behaviour. Firstly, it is a predominantly post food phenomenon, so that other unrecorded collateral behaviour tends to occur following a non reinforced response. Secondly, it appears to be insensitive to factors which might produce changes in rate during an IRI. In particular pausing of any duration seldom occurs during a sequence of post-pellet licking. (Falk, 1972; Bond, 1973). This could be a limitation if changes in rate of collateral behaviour were of particular interest (see next section).

Another behaviour which has been reported to occur reliably as a collateral behaviour is wheel-running (Levitsky and Collier, 1968; Segal, 1969). However it's use as a collateral behaviour to DRL performance does not appear to have been reported. This behaviour has the obvious limitation that excessive amounts (Sixty 360° revolutions a minute is a typical response rate: Schaeffer and Premack 1962) produced in short periods of time would lead to fatigue, thus introducing an uncontrolled variable into the experimental conditions.

One reported behaviour which does not appear to have major limitations of this sort and which has been reported as a reliable schedule induced behaviour is air or nitrogen licking (Mendelson and Chillag, 1970). It is possible that this behaviour may prove to be a ready alternative to woodgnawing in future experiments of the kind reported in this investigation.

The limitations of the procedures used in this present investigation were considerable. However in most cases, they were necessary compromises to obtain data of a type which, prior to the introduction of these procedures, had proved difficult to measure with much accuracy (Statement 2).

The results of experiments (Experiments 1 and 3) which were concerned primarily with the distribution of stereotyped collateral behaviour within IRIs suggested that:-

(1) The duration of the post response "pause" prior to the initiation of a sequence of stereotyped collateral behaviour in an IRI, was inversely related to the amount of stereotyped collateral behaviour which was subsequently emitted in that IRI (Statement 3).

(2) In the latter half of woodgnawing sequences within IRIs, the times required for 10 "gnaws" to occur were less variable than corresponding measures in the earlier half of such sequences (Statement 4).

The relationship between post response "pause" and the subsequent amount of stereotyped collateral behaviour in an IRI is difficult to interpret. It is inconsistent with the finding that the post reinforcement pause varies directly with the length of the interval on FI schedules (Schneider, 1969), and with the finding that post reinforcement pause varies directly with the size of the ratio requirement in fixed ratio (FR) schedules (Ferster and Skinner, 1957; Felton and Lyon, 1966).

A representative estimate of the change in post response "pauses" is about 3 secs: from about a 10 seconds "pause" in a 13 second IRT, to about a 7 seconds "pause" in a 27 + secs. IRT. It was therefore the case that small reductions in the post response "pauses" were followed by relatively large increases in amount of collateral behaviour. It might be argued that in IRIs of equal duration and with a fixed "quota" of behaviour, that long post response pauses must of necessity be followed by less collateral behaviour. This argument does not however fit the present results because neither the duration nor the possible amount of behaviour in an IRI were in any way "fixed" prior to the response which terminated the interval. In any case, in the hypothetical example given above, a 3 second reduction in post response "pause" cannot be equated with a six or seven fold increase in amount of gnawing and a 20 + second increase in the total duration of the IRI.

A reasonable explanation for this result can be offered if appeal is made to a concept like "probability" of woodgnawing. This concept need not necessarily be reflected in changes in woodgnawing rate if the assumption is made that woodgnawing is a unitory rate phenomenon. Instead,one might expect that increased probability of woodgnawing would be reflected in an earlier start to, and a greater amount of, woodgnawing in an IRT. This of course, assumes that woodgnawing probability remains constant throughout an IRT, but otherwise varies either randomly or as a consequence of some other, unidentified variable, such as fatigue or aversion to incremental amounts of gnawing over a session. There was evidence in Experiment 5 that gnawing sequence within IRTs extinguished completely,or not at all In other words, that considering inter response woodgnawing as a unit, with constant probability of gnawing during that unit, gains some support from the extirction data.

When considering each IRI sequence as a unit which is more stereotyped in it's later half, the recent results of Hawkes and Shimp (1975) are relevant. They showed that patterns of responding such as the FI scallop may be considered as a unit. Reinforcement was made contingent on the emission of a pattern of responding which was previously determined by the experimenter and such patterned responding was developed and maintained by this procedure. In the context of the present series of experiments, if the pattern of increased stereotypy in IRIs had some functional significance for accurate timing behaviour, and the woodgnawing sequence within an IRI were single units of behaviour, then reinforcing these units at some slight delay may have been sufficient, according to the

Hawkes and Shimp results, to maintain that pattern.

There appear to be two equally likely interpretations of the detailed computer analysis of woodgnawing. The results of Experiment 1 showed that the times to complete ten "gnaws" (decade durations) did not vary significantly in any consistent direction during the IRIs, but that the variance of decade durations did decrease as the IRI progressed. Therefore, either the woodgnawing behaviour emitted earlier/

earlier in an IRI consisted of sequences of gnawing, the rates of which were slightly, but not significantly, higher than those emitted later in the IRI, with more small pauses between sequences of uniform rate woodgnawing occurring earlier in the IRI or, that woodgnawing was non-discrete in the sense that sequences did not occur at a uniform rate separated by pauses, but that gnawing rates earlier in the IRI were both higher and lower than the equivalent rates later in the IRI. This would account for the evidence that mean decade times during the IRI did not vary significantly.

One criticism of these interpretations might be that there was an upper momentary (Premack, 1965) limit to woodgnawing and that the nearer woodgnawing "rates" approached this limit then necessarily the less the variance of decade durations must become. This criticism can be countered in two ways. There is no statistical evidence that decade durations did decrease later in the IRIs and furthermore there are several examples in the detailed woodgnawing analysis of decade duration of between 1.5 and 2.0 seconds, which suggest that the momentary rate limit of woodgnawing is in fact a lot higher than that suggested by the typical decade duration of approximately 3.5 seconds.

The evidence for considering gnawing as a relatively invariant rate phenomenon is considerable. In particular the results of hypothalamic stimulation are relevant. Valenstein, Cox and Kakolewski (1969) review the results of such experiments which elicit "stimulus bound" (ibid) behaviours like eating, drinking and copulatory behaviour, all of which, as Premack (1965) has pointed out, tend to occur "at constant momentary rates" (p.125). Within this group of stimulus bound behaviours is included gnawing (Valenstein, Cox and Kakolewski, 1970). It has been demonstrated that hypothalamic stimulation in the presence of the appropriate stimulus conditions (hence stimulus bound) causes abrupt and consistent switching from one behaviour, gnawing, to another, drinking (ibid).

A detailed description of this type of woodgnawing is given by Roberts and Carey (1965) but apart from mentioning that the gnawing was stereotyped there was no direct measurement of rates:- "When stimulation was applied to points that elicited gnawing, Ss engaged in explaratory locomotion, sniffing and looking around until they encountered the edge of the gnawing board. Gripping the edge with their incisions, they braced their fore paws against an adjacent surface and pulled backwards with head and shoulders. As soon as a splinter or fragement was pulled loose, it was ejected from the mouth, and S returned to biting the edge. The gnawing stopped promptly when stimulation was terminated." (p.319). This excellent description is very typical of the woodgnawing behaviour observed in the initial sessions of Experiment 1 when the collateral behaviour was forming; later,in the stable performance on the DRL 18 sec. schedule, the head movements were less obvious, the incisions chiselling the woodblock in an economical mouth movement,and chips of wood spilling rather than being forcibly ejected fm the mouth.

Further evidence of the relatively invariant "momentary rates" of woodgnawing was presented in the cumulative records of subject s woodgnawing, both pre-experimentally and on the final (test) day in Experiment 1. Sequences of intense, high rate woodgnawing were interspaced with small pauses in the final (test) day performance, and longer pauses in the pre-experimental data.

While the evidence from the experiments in this investigation does not allow a conclusive description of the distribution of woodgnawing within an IRI to be made, it seems likely that woodgnawing occurred in sequences of relatively uniform momentary rate. These sequences were possibly shorter and separated by more pausing earlier in the IRI than sequences later in the IRI. Broadly it may be stated that behaviour later in the IRIs was significantly more stereotyped than behaviour early in the IRIs.

The question of how the function, if any, of collateral behaviour on DRL schedules can best be described can be approached by looking at different aspects of the functional analysis of collateral behaviour undertaken in this investigation,in the light of the theoretical interpretations which have appeared in the literature.

It appeared from the present results that the efficiency of stable DRL performance was positively related to the emission of stereotyped collateral behaviour (Statement 5). Of the twenty subjects involved in these experiments only two failed to produce stable stereotyped collateral behaviour on a DRL schedule. Both these animals also failed to achieve the degree of efficiency (50% - 80% expressed as the efficiency ratio) which was evident in the performance of those subjects who did emit stereotyped collateral behaviour.

One of these subjects (Rat 12 Exp. 1) produced sequences of heterogeneous behaviour and the other subject (Rat 75, Exp. 7) was observed in a transition stage where emission of stereotyped collateral behaviour, for short periods of the session, coincided with a rise in reinforcement frequency.

In Experiment 3 it was noticed that increases in efficiency ratios were accompanied by increased total amounts of stereotyped collateral behaviour per session. The removal of one collateral manipulandum and substitution of it by another manipulandum, typically led to a decrease in efficiency ratios until the second stereotyped collateral behaviour was established, whereupon efficiency ratios increased. This observation was given further support by the results of Experiment 7 which showed that stereotyped collateral behaviour, of the type examined in Experiment 1, appeared in the performance of subjects following the removal of a stimulus signalling the availability of reinforcement on a DRL 18 sec. schedule. Reintroduction of the signalled DRL condition resulted in three out of the four subjects returning toward the baseline (signalled) performance. This typically involved a "superstitious" type of collateral behaviour without the vigorous oral activity of the unsignalled condition. These results were supported by observations made by Marcucella (1975: personal communication) using similar schedule parameters. As the unsignalled condition was, of course, a typical DRL 18 sec. condition, these results provide strong support for the contention that stereotyped collateral behaviour may be necessary for the emergence of stable DRL performance with high (50% - 80%) efficiency ratios.

A number of experimenters (Anger, 1956; Kelleher, Fry and Cook 1959; and Belleville, Rohles, Grunzke and Clark,1963) have reported that no stereotyped collateral behaviour was observed as part of DRL performance in their experiments. This would suggest that such behaviour is not necessary for timing behaviour to occur. The results of Experiment 2 would appear to support this contention. Removing the opportunity to emit the stereotyped collateral behaviour on a DRL 18 sec. schedule, where stable performance with the stereotyped woodgnawing collateral had develped, led to a rapid increase in lever press response rates. However the IRT distributions of each subject in this condition showed that lever press responding was being spaced differently with respect to time, though few IRTs exceeded 18 seconds in duration. The second modal category in the distributions, indicative of timing behaviour, occurred in the 6-12 second categories.

One might argue that based on the present results, experiments on the DRL schedule which report no observed collateral behaviour might also report low efficiency ratios in DRL performance. This does not appear to be the case; in the Kelleher, Fry and Cook (1959) study where, in the absence of the detailed data a rough computation indicates efficiency ratios on DRL 18 sec. LH 3 sec. of 70% +. As in the Anger (1956) study the results are presented as IRTs/Opportunity which is calculated by dividing the possible number of responses in any category interval into the actual number of responses in that interval. Without either, or both, values it is difficult to estimate the efficiency ratios from the IRT/Opportunity measure. Very roughly one can surmise that the greater the gradient of the IRT/Opp graph after the criterion IRT duration, the greater the efficiency ratio.

Both the Anger (1956) and Belleville et al.(1963) results came from complex schedules where, either differential reinforcement of long (>40 sec.) IRTs was intermittent (Anger 1956), or a DRL (10 seconds) was part of a very complicated multiple schedule used as a baseline for space flight tests of chimpanzee performance (Belleville et al. 1963). In neither case can comparisons with typical DRL performance be made with confidence.

The Kelleher et al.(1959) result however must remain as a unequivocal example of accurate timing behaviour without observed stereotyped collateral performance; the only parameters of this experiment which were perhaps atypical were, the deprivation level (65% of free feeding bodyweight), and the duration of each session

(2 hours). As in the Anger experiment rats were the subjects.

The results of Experiments 2, 3 and 7 indicate clearly that while stereotyped collateral behaviour may not be necessary for timing behaviour to occur, the presence of such behaviours in the rat's performance on DRL schedules usually results in increased efficiency of lever press responding. Any interpretation that stereotyped collateral behaviour may be a useless adjunct to ongoing, reinforced responding is, therefore, not supported.

Having established that stereotyped collateral behaviour has some function in DRL performance, how can this function best be described?

Operationally, lever press responding on a DRL schedule must be spaced in the following way to maximise reinforcement frequency:-

Lever press responses must not occur for the specified interval following the last response, and must then occur as soon as this specified interval has elapsed.

There are therefore two process involved in this procedure, (1) the withholding or absence of lever press responding, (2) the emission of a lever press response after some criterion duration of non-responding has elapsed. It would be of considerable theoretical interest if a single supposed function of stereotyped collateral behaviour could explain both the absence of lever press responding and ~~t~~the accurately "timed" emission of the subsequent lever press response in any IRI.

Schwartz and Williams (1971) have shown that pigeons have difficulty not responding (by pecking a key) on a DRL schedule. Provision of a second, irrelevant, key led to most pecking taking place on that irrelevant key, with occasional pecks on the original key. These latter pecks were then often reinforced because the irrelevant pecking provided the requisite pausing in original key pecking to fulfil the schedule requirements.

The argument has been put forward by several experimenters that pecking is a highly probable behaviour by pigeons in the presence of food, particularly if a salient object (like a lighted key) is present in the experimental space. If it is assumed that in a somewhat similar manner rats have difficulty in not emitting a response which has previously been reinforced, then possible functions for stereotyped collateral behaviour become clearer. Firstly the collateral behaviour may compete with, inhibit or suppress lever press responding, and secondly may supplement the timing process by which the collateral behaviour occurs for some duration, ceases and a lever press response is emitted.

The first question to be answered, therefore, is what in the light of the empirical evidence to date is the most appropriate description of the process by which collateral behaviour occurs rather than lever press responding?

Initially the possible descriptions appear to divide into two groups, depending on interpretations of the factors maintaining collateral behaviour. Ethological interpretations suggest that motivational factors implicit in the DRL schedule might maintain collateral behaviour, while other, operant interpretations suggest that, independent of the relationship between collateral behaviour and lever pressing, the latter behaviour is probably maintained by adventitious reinforcement.

The difficulty in evaluating the degree to which ethological concepts like 'redirected' and 'displacement' activity are useful in explaining the prevalence of certain types of collateral behaviour is that virtually endless experimental predictions can be made from the many theoretical interpretations of the casual mechanisms involved in such ethological concepts. McFarland (1966) has reviewed these

theoretical differences in the process of describing his theory of displacement. Here they will simply be listed:-
General Drive (Frustration Effect) theory based on the work of Amsel (1958); Arousal theory (Bindra, 1959); Theories of disinhibition (Van Iersel and Bol, 1958; Sevenster, 1961); Failure in negative feedback (Bastock, Morris and Moynihan (1953).

The results summarised in Statement 5 that these stereotyped collateral behaviours appear to increase the efficiency of, and therefore are presumably functional in, DRL performance, must not obscure the likelihood that,as with adjunctive behaviours under other circumstances, the variables which initiate such stereotyped collateral behaviour may be very different from those that maintain them in stable DRL performance (see Bond, 1973: p.132).

The topography of wood gnawing early in the subject's exposure to the DRL schedule requirements has been described (Experiment 1 and p. of this chapter.). It was very different from the stereotyped, economical, topography of woodgnawing in the final sessions after DRL performance had stabilised. It is a matter for conjecture whether the factors which consistently lead to the production of oral collateral behaviours are best described in ethological or operant conditioning terms. The observation made by the experimenter in virtually all cases of DRL performance development, but seen very clearly in Experiment 7, that the first widespread occurrence of the collateral behaviour coincides with increased efficiency of DRL performance suggests that these behaviours result from the process by which lever press response rates are reduced. Prior to this rate reduction it is the case that the rat is faced with the lever, presses upon which are occasionally reinforced. McFarland's 1966 interpretation of displacement activity neatly reflects this situation.

"Early students of the displacement problem (e.g. Tinbergen 1952) assumed that an animal's motivational state remains constant over certain periods of time. For example, an animal which is predominantly thirsty will be observed to indulge in drinking behaviour, and other types of behaviour appear irrelevant, because the observer assumes that only the predominant system can be active. However, according to the present theory, the predominant system can be "cut off" by a switch of attention, which results from frustration. This mechanism allows another activity to appear, and this new activity is entirely relevant to its own causal factors. This is essentially a disinhibition hypothesis, and differs from standard disinhibition theory only in the mechanism by which disinhibition takes place". (p.231). For a detailed discussion of "cut off" concept the reader is referred to Chance (1962). It is interesting, to recall at this point the Valenstein et al.(1969) results which showed the ease with which the types of behaviours elicited by hypothalamic stimulation can be controlled by the relevant stimulus situation. In their study eating, drinking and gnawing were virtually instantaneously interchangeable by presenting the relevant stimulus (to a non deprived animal). The preponderance of oral activity in collateral behaviours may be due to the fact that under the early DRL performance conditions "the switch of attention", hypothesised by McFarland, results in the next most probable behaviour under the stimulus conditions, i.e. gnawing. If this is the correct interpretation then this would explain the ubiquity of drinking (poly dipsia) on schedules of intermittent (and presumably "frustrating") reinforcement. A very similar analysis to this has been made by McFarland (1970).

It appears that ethological concepts may clarify the somewhat secondary question of why certain collateral behaviours (and indeed adjunctive behaviours in general) may be initially emitted on schedules of reinforcement. However such concepts do not seem to be sufficiently precise in their experimental predictions to be of value in a functional analysis of stereotyped collateral behaviour occurring with lever press responding on a DRL schedule. (Statement 6).

Assuming that the best description of this function is not an ethological one, how else might the function be described?

Another possible variable in the DRL situation which might maintain collateral behaviour is adventitious reinforcement.

It has been pointed out earlier that the distribution of woodgnawing through an IRI in Experiment 1 might be the equivalent of the "scalloped" pattern associated with performances on FI schedules. Where the behaviour occurs at nearly constant rates the increased duration of the sequences of this behaviour may be thought of as a measure of increased relative probability. In stable and highly efficient DRL performance the occurrence of reinforcement contiguous with the collateral behaviour resembles a variable time (VT) schedule with a small range of variability.

The effects of adventitious reinforcement are therefore a reasonable interpretation of the observed distribution of woodgnawing within an IRI. Two observations made in the course of this investigation suggest, however, that the adventitious reinforcement interpretation should be treated with reserve.

First, in an experiment not reported in this thesis, rats were run for over three hundred daily sessions on a DRL 18 sec. schedule. Stability of performance was very marked by the end of this time, and yet the distribution of woodgnawing was very similar to that observed in Experiment 1. It might be expected that long exposure to reinforcement contingencies which closely resembled a FT schedule would lead to a pause and run pattern similar to that reported by Ferster and Skinner (1957) in experiments which involved long exposure to an FI schedule; this was not the case in the present experiment.

Secondly, in Experiment 5 when woodgnawing ceased to be emitted in extinction of DRL 18 sec. performance, the effect was abrupt when viewed as a within IRI phenomenon. It appeared that normally the entire woodgnawing IRI sequence extinguished together suggesting that interpretations of the stereotyped collateral as discrete sequences of behaviour being effected by delayed non-contingent reinforcement may not be entirely correct.

The implication of both these observations is that gnawing may be an "all or nothing" phenomenon within an IRI, rather than a series of discrete, independent, gnawing sequences. If this is the case then the increased stereotypy of later gnawing in an IRI becomes difficult to interpret as the result of adventitious reinforcement.

If the whole gnawing sequence were treated as a single unit then recent evidence (Hawkes and Shimp, 1975) suggests that patterns, such as increased stereotypy, can be considered as operants when reinforcement is made contingent upon them. Why the particular pattern of increasing stereotypy through the interval should appear is not clear although an attempt to answer this question will be made in the final section of this discussion.

A number of experimenters (Anger, 1956; Catania, 1968; Schwartz and Williams, 1971) have suggested that collateral behaviour on DRL schedules may best be described as a competing behaviour "that occurs in a consistent temporal and sequential relation to reinforced behavior and that, although reinforcement is not explicitly arranged for it, can be shown to be maintained because reinforcement is more likely to occur when this behavior occurs" (Catania, 1968, p.339) This competing interpretation suggests that this adventitiously reinforced behaviour has no other functional relationship with the terminal response in an IRI, other than keeping the subject away from the reinforced manipulandum where situational cues might interfere with the response timing procedure to cause premature and consequently unreinforced responding. In this formulation "lever press responses are simply absent for a given delay" (Richelle 1972 p.230).

This view has some support from the results of Experiments 2 and 4. In Experiment 2 the opportunity to emit the collateral behaviour on a DRL 18 sec. schedule was removed. The lever press rate increased rapidly, although there was evidence that timing behaviour continued albeit less efficiently. One could argue that with the collateral behaviour removed, the subjects did not move away from the lever and were therefore more likely to respond. Again, in Experiment 4 it appeared that giving the subject the opportunity to emit the collateral behaviour further away from the lever, (thus increasing the competing nature of the collateral behaviour) sharply reduced the lever press response rate, in particular reducing the number of premature responses.

However in Experiment 2, allowing that the process of timing lever press responses is independent of the factors controlling competing behaviour, the breakdown of accurately spaced responding was very rapid. However this is only an impression and could be misleading. Slightly premature responses, being unreinforced, would lead to a drop in reinforcement frequency which in turn would presumably interfere with the timing process. An empirical test of which variables are important in this situation is not easy to construct.

In Experiment 4 not only were premature responses reduced by increasing the distance from the lever at which woodgnawing could occur but there was a consistent increase in very long (27 sec +) IRTs. This would suggest that the relationship between woodgnawing and lever pressing is not solely confined to reducing premature responses. The basic hypothetical timing process,and distribution of responses after the criterion IRT duration,should not have been affected if the competing interpretation as described above were correct.

From this examination of the competing behaviour interpretation of collateral behaviour in DRL performance it is apparent that the two concepts, involved in lever press responding not occurring and then occurring accurately in time, are very closely connected. While each is easily described when considered independently (i.e. competing behaviour and timing behaviour), when considered together in the DRL performance they appear to be inextricably compounded.

In this DRL situation any behaviour which reduces lever press responding, by competing with such responding, must also, of necessity, facilitate timing behaviour in the sense that a greater proportion of lever press responses fulfil the schedule requirements. Isolating this facilitation of response timing effect of stereotyped collateral behaviour from the effects of what might be termed temporal discrimination may prove difficult, if not impossible, in the free operant DRL situation (Jenkins 1970). This would be particularly so if it were the case that efficient DRL performance depended on the emission of stereotyped collateral behaviour.

Explanations of how the collateral behaviour may supplement, or even make redundant, the other (hypothesised) response timing process(es) have usually concentrated on two interpretations, chaining and "counting".

In the first, chaining, interpretation the collateral behaviour is seen as forming chains of behaviour consisting of smaller units of behaviour held together by the discriminative stimulus/conditioned reinforcer functions of each unit (Kelleher, 1966). In discussing the results of Experiment 5, on the order in which the two behaviours extinguished, (woodgnawing then lever pressing), it was concluded that the consensus of opinion in the somewhat equivocal results published to date, suggests that for the collateral/response sequence in DRL performance to be regarded as a chain would require lever pressing to extinguish before woodgnawing or at least both behaviours to extinguish together. As the evidence from both Laties et al. (1965, 1962), and Experiment 5 suggests that the opposite is the case then the chaining hypothesis is not supported.

Several studies have shown that organisms can adjust to "counting" schedules in which reinforcement is contingent upon the completion of a fixed number of responses on one operandum followed by a single response on a second operandum in the absence of external discriminative stimuli (Ferster, 1958; Mechner and Guevrekian, 1962; Millenson, 1966; Blackman and Scruton, 1973). A feature of most of these studies is that they confound amount and duration of responding. Nevertheless, the suggestion that subjects may discriminate the duration of an interval by the amount of collateral behaviour within an interval must remain a possibility. A recent study on timing behaviour in female undergraduates responding on a DRL 5 sec. schedule (Stein and Flanagan, 1974) reported that their findings: "Support the conclusion that overt collateral responding can be functionally equivalent to mediative counting during temporally spaced responding".

However, in the present experiments, with rats as subjects, it seems reasonable to assume that the "counting" hypothesis requires that the mean decade durations, and the variance of the mean decade dur-

:ations should be constant throughout the IRI. Unless there is this constant sequential pattern,the concept of counting as a means of mediating duration has no characteristic which would recommend it's use in preference to others.The results of Experiment 1 show that the times to complete 10 "gnaws" in the second half of the IRIs were less variable than those in the first half of the IRIs.However this result is interpreted in terms of changes in rate of gnawing,it does not seem to be compatible with a "counting" hypothesis.

Neither the chaining nor "counting" interpretations of how stereotyped collateral behaviour might increase the efficiency of DRL performance received support from the results of experiments in this investigation (Statement 7)

The competition hypothesis as outlined above suggests that stereotyped collateral behaviour has no part in the timing process but merely removes the subject from the location where premature responses may occur. This formulation infers that "lever press responses are simply absent for a given delay" (Richelle, 1972,p.230). As such it fails to account for the results of Experiment 7. In this experiment a consistent change in the collateral behaviour occured when a signal, which had previously signalled the availability of reinforcement on a DRL 18 sec. schedule, was removed. Were the only function of stereotyped collateral behaviour to prevent premature responding in DRL performance then this behaviour should have occurred in the signalled as well as the unsignalled condition.

The DRL requirements, that lever press responding should not occur for 18 seconds following a prior response, were in operation in both the signalled and the unsignalled condition. The fact that the change to "active", oral, types of collateral behaviour occurred when the stimulus (signalling that the timing requirements of the schedule had been met) was removed, suggests that besides facilitating the non-emission of lever press responses, this particular type of stereotyped collateral behaviour has, in addition, some function in the timing process. The simple competing behaviour hypothesis, as expressed here, is therefore not supported by these results.

It would appear that the relationship between stereotyped collateral behaviour and lever press responding involves a more complicated and possibly "dynamic" process than that suggested by the competition theory. "It can be argued that temporally regulated behaviour implies some process by which a response is not simply absent for a given delay but is withheld during that delay" (Richelle 1972 p.230).

Two recent papers have suggested that the term inhibition might be a relevant term to describe the process necessary for lever press responses not to occur. Staddon (1974) has termed the pause-production on both FI and DRL schedules "inhibitory temporal control", and Richelle (1972) has appealed to the Pavlovian concept of "inhibition of delay" to account for "temporal regulations of behaviour" (Richelle 1972 p.229). It is perhaps appropriate here to draw attention to the use of this term "temporal regularity". It has been mentioned elsewhere in this thesis that this term, as used by Staddon (1972 p.214) and here by Richelle, has much to recommend it as an objective description of timing behaviour which has virtually no theoretical overtones or bias as have terms like temporal discrimination, temporal differentiation and timing behaviour.

A number of experimenters who have revived interest in the term "inhibition" have suggested that it be restricted to instances where:- "A decrease in response output from a stable high level of responding" (Farthing and Hearst 1968, p.749) is "produced by discrete external stimuli" (Hearst, 1972 p.9) It is clear the DRL performance never includes stable high levels of responding, and that the "stimulus", if indeed there is one, is neither discrete nor particularly external.

It is also apparent that Staddon uses the term inhibition in a different manner from that suggested above. His term temporal inhibition is closely allied to the concept of "periods of non-responding or response suppression" and as such, can be dealt with under those headings.

Staddon's use of the term is closely tied to two other concepts: (1) temporal control (Staddon, 1972) and (2) the relative proximity principle (Jenkins, 1970) previously mentioned in Chapter III. This is illustrated by his assertion that:- "If we grant that temporal control follows the relative proximity principle, so that temporal inhibition will be exerted by the stimulus with the lowest relative proximity to reinforcement, and temporal excitation by the stimulus with the highest relative proximity (in a given situation), then this principle explains why it is very difficult to show reliable temporal inhibition by a neutral stimulus superimposed on an FI baseline". (Staddon 1972 p.233).

While experimental predictions based on both temporal control and the relative proximity principle may be possible in FI schedules it is difficult for the present author to see how either may be of independent predictive value in the DRL schedule. Consequently the value of the term inhibitory temporal control in generating experimental predictions which might support its use in discussion of DRL performance, is, for the moment, questioned.

Richelle (1972) justifies the use of the term inhibition in discussions of DRL performance on the grounds that while "the favoured techniques to detect and measure inhibition are precisely those which are irrelevant to the study of the phenomenon in temporally regulated behaviour" (p.232), there are several similarities between performance on DRL schedules and what has been termed the "symptoms or by-products of inhibitory control" (Hearst, 1972, p.15). In particular, Richelle presents evidence that two of these "symptoms" of inhibitory control, stimulus aversivness and stress-induced breakdowns, may be induced in cats by exposure to either DRL 60 seconds on DRL 40 seconds each with a 10 second limited hold. Richelle states: "As far as temporally regulated behaviour is concerned, these aspects should be considered, at least for heuristic purposes, as central rather than secondary (or "by-product") means to detect and measure inhibition" (1972 p.232)

Assuming Richelle is correct (and of course it is logically weak to suggest that because A implies B then all cases of B must imply A), then how does the inhibition concept facilitate the interpretation of the basic problem posed by the experimental results in this investigation - how can behaviour which is not necessary for temporal regularity increase the efficiency with which lever press responses as spaced in time? Inhibition might replace competition as a seemingly more dynamic process by which lever press responses are prevented from occurring but how the process might facilitate the timing as opposed to the response prevention process is unclear from Richelle's statements.

The concept of inhibition as formulated by Richelle appeals to internal mechanisms for the attentuation in responding on DRL schedules (as did Pavlov's (1927) original term-inhibition of delay). Richelle says:- "Compensation for inhibition might possibly be achieved by either an output of responses of the same topography as the operant response, or by any kind of motor behaviour. If so, collateral behaviour (sometimes called mediating behaviour) would have nothing to do with the time measuring proper: its effect on the quality of temporal regularity would be accounted for by it's aspecific compensatory function (1972, p.234 present author's italics). It is this "aspecific compensatory function" which requires considerably more explanation before Richelle's interpretation can be adequately discussed.

It is apparent that Richelle is aware of the problem posed by any response reduction method, that it must also aid the timing process. It is not clear how the term "aspecific compensatory function" would facilitate the separation of the response reduction and timing functions of stereotyped collateral behaviour.

The term which fits the results of the experiments reported in this thesis, while at the same time not implying hypothetical constructs which might facilitate the tempoal regularity of behaviour, is the term "response suppression". Normally the term "suppression", when used in the experimental analysis of behaviour, refers to decreases in response rate, from a stable higher rate, as a result of some process. (Lyon,1968). In the sense that when stereotyped collateral behaviour occurs there is a consistent increase in the efficiency of DRL performance (and therefore a consistent decrease in response rate) the function of stereotyped collateral behaviour may be functionally described as response suppression.

In Experiment 7 responding following a response was suppressed for some time during the signalled condition. There was little evidence of the "active oral" type of collateral behaviour observed in the unsignalled condition. Technically it would be argued that the "no-tone" stimulus in the first (signalled) condition and the stereotyped collateral behaviour in the second (unsignalled) condition fulfilled the same function:- response suppression. This analysis is somewhat confounded by the fact that the no-tone stimulus was in fact present throughout the second condition. This suggests that a useful comparison could be made between two groups of subjects, one with a tone present when responding should not occur (reinforcement availability would then be signalled by "no-tone") and a second group as in Experiment 7. Should the stimulus for response suppression and stereotyped collateral behaviour be functionally equivalent, one might predict a significant difference between the two groups in the number of sessions required to attain some criterion of stereotyped collateral behaviour in the unsignalled condition. The group which had a discrete external stimulus for response suppression might be expected to develop stereotyped collateral behaviour sooner.

As has been pointed out earlier it is probable that the improvement in "timing behaviour", in DRL performances where stereotyped collateral behaviour is emitted, is due to a complex interaction between the DRL schedule requirements, the topography of the collateral behaviour and the probability, for one reason or another of premature responses. As such the stereotyped collateral behaviour may be said to mediate efficient DRL performance but can in no way be regarded as "a temporal receptor" (Catania 1970 p.36)

. . . .

The results of these experiments lead the present author to question the utility of terms like "timing behaviour" and particularly "temporal discrimination" in the DRL performance context. Stereotyped collateral behaviour appears to be necessary for efficient DRL performance yet it's function in that performance is still not clear.

In his discussion of DRL performance Catania (1970) has maintained, wrongly in the present author's view, that whether the single process of differential reinforcement is described as temporal discrimination or temporal differentiation is immaterial, as the two processes cannot be distinguished empirically. The term temporal discrimination has been appealed to so often in the experimental analysis of behaviour (see Ch.1) that it would seem important that it's use in any given situation be justified.

The discussion of the stimulus properties of the environment in DRL schedules in terms of the discrimination of duration is, in this author's opinion, premature. Until there is a clear demonstration that animals can space responses apart in time accurately without producing overt stereotyped collateral behaviour the most parsimonious analysis of DRL performance should perhaps concentrate on the role of differential reinforcement in maintaining behaviour patterns necessary for efficient DRL performance. The "restraint" type of experiments discussed earlier have yet to show that accurately spaced responding can occur on a DRL schedule without some kind of stereotyped collateral behaviour mediating these responses (Richardson and Laughead, 1974).

Perhaps the main contribution to the analysis of stereotyped collateral behaviours in DRL performance which this present study may make, is in assessing which of the explanatory terms "competition" or "inhibition" has the greatest heuristic value, or if, indeed, at an empirical level they are synonymous. In the discussion above, the descriptive term "suppression" has been favoured as being most useful in objective discussion of DRL performance. However it is a term which is not normally used in the literature dealing with the function of stereotyped collateral behaviours on the DRL schedule.

In reviewing the ways in which the terms competition and inhibition have been used in the literature on this subject, the most striking difference appears to be in assumptions about the degree to which the variables controlling the terminal response (in this case lever pressing) and the interim response (woodgnawing or water licking) are independent of one another.

The term competition appears to be most often used in explanations where the interim behaviour is assumed to be maintained by the same reinforcing event which maintains the terminal event. In the DRL situation, the interim behaviour would therefore be functional because the organism cannot do two things at once,and the interim behaviour physically removes the organism from the locality where premature terminal responses are most likely to occur. However it has been pointed out in several of the experiments (1,5 and 8), that the interim behaviour in both DRL and FI schedules does not have a distribution which can readily be equated with the stable behaviour associated with behaviour maintained by either response contingent or adventitious reinforcement on approximately fixed duration schedules of reinforcement. This use of the term competition implies that the occurence of a reinforced response _is_ controlled by some timing process and that the interim behaviour plays a functional part in increasing reinforcement frequency by minimising premature terminal responses.

The term inhibition appears to be used in explanations which assume that the terminal behaviour is maintained at a high probability or "strength" (Nevin, 1974) but is prevented from occurring by sequences of interim behaviours which are maintained by some other variable. Catania (1970) has suggested that a dynamic situation arises between positive reinforcer maintained terminal behaviours, and interim behaviours maintained by negative reinforcement, where a drop in local reinforcement frequency is hypothesised as an aversive event. (p. 4).

If one follows this line of argument, and includes the result reported by Hawkes and Shimp (1974) on the maintenance of patterns of responding by reinforcement, then one might conclude that the focus of attention shifts, from "temporal discriminations" in the sense implied by Catania (1970) and Skinner (1938), to "developing a new formulation of the basic processes at work in close temporal sequences" (Jenkins, 1970 p.104). In other words this argument stresses the process by which reinforcement maintains units of patterned responding, such as the FI "scallop", rather than concentrating on the purely temporal characteristics of DRL performance.

Given that there does exist a useful conceptual distinction between competition and inhibition explanations of the role stereotyped collateral behaviour fulfils in DRL performance, which of the two explanations received the most support from the results obtained in this investigation?

As already mentioned the collateral woodgnawing did not appear to have the characteristics of adventitiously reinforced or "superstitious" behaviour. It was not labile and subject to gross topographical shift (Skinner, 1948; Staddon and Simmelhag, 1971). It did not, to any appreciable degree, resemble in distribution behaviours reputedly maintained by delayed reinforcement. That is, there was little evidence of long post reinforcement pausing or "scalloped" patterning, even in very efficient and stable DRL performance which descriptively resembled a response contingent fixed interval schedule with some built-in variance. Both these points suggest that the simple competition explanation does not gain support from these results.

The most important result in this context, was that obtained from Experiment 7. In this experiment it was noted that behaviour resembling reports of superstitious behaviour did develop in the first condition where a stimulus signalled reinforcement availability. This condition removed the necessity for "temporal discrimination" while retaining the penalty for premature responding. When these subjects were exposed to a normal unsignalled condition where no overt cues for reinforcement availability were present the subjects emitted typical oral topographies of collateral stereotyped behaviour.

If the simple competition explanation were correct the conditions prevailing in the first, signalled component were sufficient for stereotyped collateral behaviour to develop. The fact that they did not is taken as evidence against this explanation.

(8) The weakness of the simple competition explanation is such that, of the two explanations, the inhibition explanation is favoured as being potentially the most useful for further research

CONCLUSION:

In the General Discussion several statements have been made pertaining to the experiments in this investigation and what the results might suggest about the function of stereotyped collateral behaviour in DRL performance.

(1) It seems reasonable to assume that the data obtained in these DRL schedule experiments are from DRL performances which were representative of the typical reported DRL performances.

(2) The limitations of the procedures used in this investigation were considerable. However, in most cases they were necessary compromises to obtain data of a type which, prior to the introduction of these procedures, had proved difficult to measure with much accuracy.

(3) It appeared that the duration of the post response pause, prior to the initiation of a sequence of stereotyped collateral behaviour in an IRI, was inversely related to the amount of stereotyped collateral behaviour which was subsequently emitted in that IRI.

(4) In the later half of woodgnawing sequences within IRIs, the times required for 10 "gnaws" to occur were less variable than corresponding measures in the earlier half of such sequences.

(5) It appeared from the present results that the efficiency of stable DRL performance was positively related to the emission of stereotyped collateral behaviour.

(6) While ethological concepts might clarify the question of why certain collateral behaviours may initially be emitted on DRL schedules, they do not appear to be sufficiently precise in their experimental predictions to be of value in a functional analysis of stereotyped collateral behaviour in stable DRL performance.

(7) Neither the chaining nor the "counting" interpretations of

how stereotyped collateral behaviour might increase the efficiency of DRL performance received support from the results of this investigation.

(8) The objectivity of the term "response suppression" as a description of the function of stereotyped collateral behaviour leads it to be favoured above explanatory terms like "response competition" or "response inhibition". However of these two terms, the latter would appear to be the most accurate reflection of the processes at work in DRL performance.

In the sense that stereotyped collateral behaviours both prevent responding and facilitate the timing process in DRL performance, they can be said to mediate the spacing of lever pre responses by rats on DRL schedules, especially those examples of temporal regularity, which as revealed by the efficiency ratios and reinforcement frequency have been described as highly efficient timing behaviour.

GLOSSARY

(After Catania 1968 p. 327 - 349)

BIMODAL DISTRIBUTION: A relative frequency distribution with two distinct peaks or maxima.

BURST: A series of lever press responses emitted at a high rate and bounded by responding at a lower rate.

COLLATERAL BEHAVIOUR: Behaviour which is emitted as part of schedule performance but the occurrence of which is not a schedule requirement.

COVERT BEHAVIOUR: Behaviour that is not directly observable but the existence of which is inferred from changes in observable behaviour.

DECADE: A sequence of ten "gnaws".

DRH: Differential reinforcement of high rates. Schedule:- a response is reinforced if at least a specified number of responses were emitted during a preceding time interval.

ESTES-SKINNER PROCEDURE: Where a stimulus reliably precedes an aversive stimulus.

FI; Fixed interval. Schedule:- the first response to occur after a fixed duration has elapsed is reinforced. Responding prior to this time has no reinforcer consequences and, in stable behaviour is usually positively accelerated.

FR: Fixed ratio. Schedule:- the last response of a fixed number of responses is reinforced.

FT: Fixed Time. Schedule:- reinforcer is delivered after a fixed duration has elapsed. No response requirement.

"GNAWS": A single signal from the transducer of the woodgnawing sensor.

IRI: Interresponse interval: Measured by the amount of stereotyped collateral behaviour occurring between two instances of a response.

IRT: Interresponse time in seconds.

IRT/Op: Interresponse time per opportunity. Conditional probabilities. The probability of interresponse times in a particular class interval, given that a sufficient time had elapsed since the last response to permit an interresponse time to end in that class interval.

LH: Limited hold. The termination of the scheduled availability of reinforcement if the response to be reinforced does not occur within a specified period of time.

MEDIATING BEHAVIOUR: collateral behaviour which, when emitted, increases the efficiency of schedule performance.

PERSONS PRODUCT MOMENT CORRELATION COEFFICIENT:

Coefficient of correlation:

From: Standard Statistical Program 700 series Wang Laborotaries
836, North Street, Tewksbury, Mass.

VI: Variable interval. Schedule: the requirements are the same as for a fixed interval (FI) schedule except that the intervals vary around some mean duration.

VT: Variable time Schedule: the procedure is the same as for a fixed time (FT) schedule except that the intervals vary around some mean duration. No response requirement.

APPENDIX

COMPUTER PROGRAM USED IN DATA ANALYSES

```
ALGOL
LIBRARY
ALGOL

CDIRT;
"BEGIN"
"INTEGER" "ARRAY" EVENT(0: 2000), DISTIRT (0:59);
"REAL" "ARRAY" IRT (1:2000), TIME(0:2000);
"INTEGER" HOLDTIME,HOLDEVENT;
"INTEGER" I,J.N.ABOVE60,K,LENIB,R,UR;
"INTEGER"NR,NUR;
"REAL" SUM,SUMSQ;
"COMMENT" READS IN DATA FROM ONE RAT AND STORES THIS IN
 TWO MATRICES
TIME (1), AND EVENT (1);
"PRINT" PUNCH (3), SAMELINE, 'PLEASE LOAD PAPER TAPE ON READER (1)';
WAIT;
I:=0;
TIME (0): = -1
EVENT (0): =50000;
"GOTO" LOOP;
NEXTRAT;
HOLDTIME: = TIME (N+1);
HOLDEVENT: = EVENT (N+1);
"FOR" 1: =1 "STEP"1"UNTIL" N+1 "DO"
"BEGIN"
TIME (1): = 0;
EVENT (1):=0
END"
TIME (1):=HOLDTIME;
EVENT (1):=HOLDEVENT;
1:=1;
LOOP;
I:=I+1;
"READ"READER (1), J,TIME (1), EVENT (1);
"IF" EVENT (1)=0"THEN""BEGIN"EVENT (1):=40000;
"READ"READER (1),J; "END";
"PRINT"TIME (1), EVENT (1);
"IF"TIME (1) TIME (I-1) "THEN"GO TO"LOOP;
N:=I-1;
"FOR"I:="STEP"1UNTIL"N""DO"
TIME (I):=TIME (I)/100;
"FOR"I:=1"STEP"1"UNTIL"N"DO" "PRINT"TIME (1);
"COMMENT" FORMS MATRIX IRT(I) WHICH CONTAINS -1.0 IF THE ITH
EVENT
WAS NOT A RESPONSE AND THE IRT OF THE (I-1) TH & ITH TRIALS
OTHERWISE;
"FOR" I:=1"STEP"1"UNTIL "N"DO"
IRT (I):=1.0;
"FOR"I:=1"STEP"1"UNTIL "N"DO"
BEGIN"
"IF"EVENT (I)=70000"THEN"GOTO"FINISH;
"FOR" J:=(I?1)"STEP"-1"UNTIL"0"DO"
"BEGIN"
"IF"J=0"THEN" "BEGIN"
```

```
IRT(1):=TIME (I)
"GOTO"STOP;
"END";
"IF"EVENT (J)=70000"THEN"GOTO"STOP;
IRT(I):=TIME (I)-TIME(J);
"GOTO"FINISH;
STOP;
"END"
FINISH;
"END";
"FOR"I:=1"STE½"1"UNTIL"N"DO" "PRINT"IRT(I)
"COMMENT" FINDS MEAN AND VARIANCE OF IRT DISTRIBUTION:
"BEGIN"
"REAL"SUM,SUNSQ,MEANIRT, VARIRT;
"INTEGER"TOTAL;
TOTAL:=0;
SUM:=SUMSQ:=0.0;
"FOR"I:=1"STEP"1"UNTIL"N"DO"
"BEGIN"
"IF"IRT(I) 0"THEN""GOTO"BYPASS;
SUM:=SUM+IRT(I);
SUMSQ:=SUMSQ+IRT(I)+2;
TOTAL:=TOTAL+1;
BYPASS:
"END";
MEANIRT:=SUM/TOTAL;
VARIRT:=(SUMSQ/(TOTAL-1))-(SUM+2)/(TOTAL)=TOTAL);
"PRINT" ''L5' MEAN IRT=',SAMELINE, ALIGNED(4,4),MEANIRT:
"PRINT"''L5'VAR IRT = ', SAMELINE, ALIGNED (4,4), VARIRT;
"END";
"COMMENT" FORMS DISTRIBUTION OF IRTS. INTERVALS OF
LENGTH 1 SEC. ARE USED I.E.J"GE"IRT  J+1. IRTS GREATER THAN
60 SECS ARE GROUPED IN ABOVE 60;
GROUPED IN ABOVE60;
ABOVE60:=0;
"FOR"I:=0"STEP"1"UNTIL"59"DO"
DISTIRT(1):=0
"FOR"I:=1"STEP*1"UNTIL"N"DO"
"BEGIN"
"IF"IRT(I)"GE"60"THEN"
"BEGIN"
ABOVE60:=ABOVE60+1;
"GOTO"END;
"END";
"FOR"J:=0"STEP"1*UNTIL"59"DO"
"BEGIN"
"IF"IRT(I)  J"THEN""GOTO"END;
"IF"IRT(I)"GE"(J+1)"THEN"GOTO"END1"ELSE"DISTIRT(J):=DISTRIRT(J)+1;
END1;
"END";
"END"
"END";
```

```
"PRINT"ABOVE 60;
"FOR"I::=0"STEP"1"UNTIL"59"DO"
"PRINT"DISTRICT(1);
"COMMENT" TO FIND THE NO. OF NIBBLES PRECEDED BY REINFORCEMENT
               AND NONREINFORCEMENT RESPECTIVELY;
R:=UR:=0;
"FOR"I:=1"STEP"1"UNTIL "N"DO"
"BEGIN"
"IF"EVENT(1)=40000"THEN"R:=R+1;
"IF"EVENT(1)=90000"THEN"R=R+1;
"IF"EVENT(1)=50000"THEN" UR:=UR+1;
"IF" EVENT(1)=60000"THEN"UR:=UR:=UR+1;
"END";
"PRINT" 'A';
"COMMENT" CREATES TWO MATRICES RBIN(1,J) AND URBIN(1,J), WHOSES
             ENTRIES (1,J) = THE TIME SPENT ON THE ITH DECADE OF NIBBLES.
             THE ENTRIES ARE MADE IN RAIN IF THE PREVIOUS TRIAL WAS
             REINFORCED AND URBIN IF UNREINFORCED;
"BEGIN"
"REAL""ARRAY"RBIN(0:31,-1:R),URBIN(0:31,-1:UR);
"INTEGER"RI,UR1;
R1:=UR1:=0;
"FOR"1:=1"STEP"1"UNTIL"R"DO"RBIN(0,1):=1;
"FOR"1:=1"STEP"1"UNTIL"R"DO"RBIN(31,1):=0;
"FOR"1;=1"STEP"1"UNTIL"UR"URBIN(0,1):=1;
"FOR"1:=1"STEP"1"UNTIL"UR"DO"URBIN(31,1):=0;
"PRINT"'B';
"FOR"1:=1"STEP"1"UNTIL"30"DO";
"BEGIN"
"FOR"J:=1"STEP"1"UNTIL"R"DO"
RBIN(1,J):=0;
"FOR"J:=1"STEP"1"UNTIL"UR"DO"
URBIN(1,J):=0;
"END";
"PRINT"'C';
"FOR";:=1"STEP"1"UNTIL"N"DO"
"BEGIN"
"COMMENT"IDENTIFIES THE FIRST NIBBLING TRIAL OF A STRING;
"IF"EVENT(1)=70000"THEN"GOTO"CONT1"ELSE""GOTO"OUT1;
"PRINT"'D';
"COMMENT"FINDS LENGTH OF STRING OF NIBBLES & PUTS THIS IN LENIB;
 CONT1:
LENIB:=0;
"FOR"J:=1"STEP"1"UNTIL"1+30"DO"
     "BEGIN"
"IF"EVENT(J)=70000"THEN"LENIB:=LENIB+1
                "ELSE"GOTO"OUT2;
     "END";
"COMMENT"IDENTIFIES WHETHER OR NOT PREVIOUS TRIAL WAS REINFORCED;
OUT2;
"IF"EVENT(1-1)=40000"THEN"GOTO"REINFORCED;
"IF"EVENT(1-1=90000"THEN"GOTO"REINFORCED"ELSE"GOTO"UNREINFORCED;
REINFORCED:
"PRINT"'E';
R1:=R1+1;
"FOR"K:=1"STEP"1"UNTIL"LENIB"DO"
RBIN(K,R1):=TIME(1+K-1)-TIME(1+K-2);
"GOTO"UPDATE1;
UNREINFORCED;
"PRINT"'F';
UR1:=UR1+1;
"PRINT"'L',UR1;
"FOR"K:=1"STEP"1"UNTIL"LENIB"DO"
"BEGIN"PRINT"'L2'',K;
J:=I+K-1;"PRINT"''L'I+K-1=',J;
J:=I+K-2;"PRINT"''L'I+K-2=',J;
URBIN(K,UR1):=TIME(I+K-1)-TIME(I+K-2);
"END";
UPDATE:
I:=1+(LENIB-1);
OUT1:
"PRINT" 'G';
"END";
R:=R1;
UR:=UR1;
"PRINT" ''L5'REINFORCED';
"FOR"J:=1"STEP"1"UNTIL"R"DO"
"BEGIN"
"PRINT" ''L2'';
"FOR"I:"STEP"1"UNTIL"30"DO"
"PRINT"SAMELINE, RBIN(1,J);
"END";
"PRINT" ''L5'UNREINFOCED';
"FOR"j:=1"STEP"1"UNTIL"UR"DO"
"BEGIN"
"PRINT" ''L2'';
"FOR"I:=1"STEP"1"UNTIL"30"DO"
"PRINT"SAMELINE,URBIN(1,J);
"END";
"BEGIN"INTERER" RUN;"REAL""ARRAY"RDEC(1:R),URDEC(1;ur),SUM(1:30),
SUMSQ(1:30);
"REAL"MEAN,VAR;"INTEGER""ARRAY"NUMBER(1:30);
"COMMENT"THIS IDENTIFIES THE LENGTH IN DECADES OF THE ITH IRT AND PUTS
(1) OR URBIN(1);                                PUTS
"FOR"RUN:=0"STEP"1"UNTIL"30"DO"
"FOR"I:=1"STEP"1"UNTIL"R"DO"
"IF" RBIN(RUN,1)   O"AND"RBINC(RUN)+1), 1   .0001"THEN"RDEC(1):=RUN;
"FOR"RUN:=0"STEP"1"UNTIL"30"DO"
"FOR"I:=1"STEP"1"UNTIL"UR"DO"
"IF"URBIN(RUN,1)   O"AND"URBIN  (RUN+1),I    .0001"THEN"URDEC(1):=RUN
"FOR"RUN:=1"STEP"1"UNTIL"30"DO"
"BEGIN""PRINT" ''L2'',RUN;"FOR"J:=1"STEP"1"UNTIL"RUN"DO"
"BEGIN"SUM(J):=0.0;SUMSQ(J):=0.0;NUMBER(J):=0;"END";
"FOR"I:=1"STEP"1"UNTIL"R"DO"
"BEGIN""IF" RDEC(1)=RUN"THEN"
"GOTO"L1"ELSE""GOTO"L2;11:"FOR"J:=1"STEP"1"UNTIL"RUN"DO"
"BEGIN"SUM(J):=SUM(J)+ RBIN(J,1);
```

```
 SUMSQ(J):=SUMSQ(J)+ RBIN(J,1)+2;
 NUMBER(J);=NUMBER(J)+1;"END";
  2:"END";
 "FOR"J:=1"STEP"1"UNTIL"RUN"DO"
 "BEGIN""IF"NUMBER(J)   O"THEN"MEAN:=SUM(J)/NUMBER(J)"ELSE"MEAN:=O;
 "IF"NUMBER (J)  1"THEN"
 VAR:=(SUMSQ(J) /NUMBER(J)-1))-(SUM(J)+2)/(NUMBER(J)*(NUMBER(J)-1))
 "ELSE"VAR:=O;
 "PRINT"SAMELINE,J,MEAN,VAR,NUMBER(J);"END";"END";
 "FOR"RUN:=1"STEP"1"UNTIL"30"DO";
 "BEGIN""PRINT" ''L2'',RUN;"FOR"J:=1"STEP"1"UNTIL"RUN"DO"
 "BEGIN"SUM(J):=0.);SUMSQ(J):=0.0;NUMBER(J):=0;"END";
 "FOR"I:=1"STEP"1"UNTIL"UR"DO"
 "BEGIN""IF"URDEC(i)=RUN"THEN
        "GOTO"L3"ELSE""GOTO"L4;
  3:"FOR"J:=1"STEP"1"UNTIL"RUN"DO"
 "BEGIN"SUM(J):=SUM(J)+URBIN(J,1);
 SUMSQ(J):=SUMSQ(J)+URBIN(J,1)+2;
 NUMBER(J):=NUMBER(J)+1;"END";
 4:"END";
 "FOR"J:=1"STEP"1"UNTIL"RUN"DO"
 "BEGIN""IF"NUMBER (J)  O"THEN"MEAN:=SUM(J)/NUMBER(J)"ELSE"MEAN:=O;
 "IF"NUMBER (J)  1"THEN"
 VAR:=(SUMSQ(J)/(NUMBER(J)-1))-(SUM(J)+2/NUMBER(J)*(NUMBER(J)-1)
 ELSE"VAR:=1
 "PRINT"SAMELINE,J,MEAN, VAR, NUMBER(J):"END";"END";"END"
 "COMMENT"DISCRADS NIBBLES OF LESS THAN 1 DECADE AND RESETS
 R & UR;
 K:=O;
 "FOR"J:=1"STEP"1"UNTIL"R"DO"
 "OF"RBIN(2,J)  .00001"THEN"K:=K"ELSE"=K*1;
NR:=K
 K:=O;
 "FOR"J:=1"STEP"1"UNTIL"UR"DO"
 "IF"URBIN(2,J)   .0001"THEN"K:=K"ELSE"K:=K+1;
 NUR:=K;
 "COMMENT" FORMS TWO NEW ARRAYS NRBIN(1,J)AND NURBIN(1,J).
 SAME AS RBIN AND URBIN BUT RUNS OF BIBBLES OF LESS THAN
 ONE DECADE IN LENGTH ARE NOT INCLUDED;

 "BEGIN"
 "REAL""ARRAY"NRBIN(1:29, 1:NR), NURBIN(1:29,1:NUR);
 K:=O;
 "FOR"J:=1"STEP"1"UNTIL"R"DO"
"BEGIN"
 "IF"RBIN(2,J)  .00001"THEN""GOTO"RSKIP;
K:K=1;
 "FOR"I:=1"STEP"1"UNTIL"29"DO"
NRBIN(I,K):=RBIN(I+1,J);
 RSKIP:
"END";
 K:=O;
"FOR"J:=1"STEP"1"UNTIL"UR"DO"
"BEGIN"
 "IF"URBIN(2,J)  .0001"THEN"GOTO"URSKIP;
 K:=K+1;
 "FOR"I:=1"STEP"1"UNTIL"29"DO"
 NURBIN(1,K):=URBIN(i+1,J);
 URSKIP:
 "END";
 R:=NR;
 UR:=NUR;
 "BEGIN"
 "REAL""ARRAY"RMEAN(1:R),URMEAN(1:UR);
 "INTEGER""ARRAY"NRN(1:R),NURN(1:UR);
 "COMMENT" FORMS TWO NEW VECTORS RMEAN(1)AND URMEAN(I)WHOSE ENTREIS
      GIVE THE MEAN LENGTH OF DECADES IN THE ITH REINFORCED OR
      UNREINFORCED BATCH OF NIBBLES;
 "FOR"J:=1"STEP"1"UNTIL"R"DO"
 NRN(J):=0;
  "FOR"J:=1"STEP"1"UNTIL"R"DO"
 "BEGIN"
 "FOR"I:=1"STEP"1"UNTIL"29"DO"
 "IF"NRBIN(I,J)   .000001"THEN"NRN(J):=NRN(J)+1;
 "END";
"PRINT"""''L'';
 "FOR"J:=1"STEP"1"UNTIL"R"DO"
 "PRINT"SAMELINE, DIGITS(3),NRN(J);
 "FOR"J:=1"STEP"1"UNTIL"UR"DO"
 NURN(J):=0;
 "FOR"J:=1"STEP"1"UNTIL"UR"DO"
 "BEGIN"
 "FOR"I:=1"STEP"1"UNTIL"29"DO"
 "IF"NURBIN(I,J)   .000001"THEN"NURN(J):=NURN(J)+1;
 "END";
 "PRINT"''L'';
 "FOR"J:=1"STEP"1"UNTIL"UR"DO"
 "PRINT"SAMELINE,DIGITS(3),NURN(J);
 "FOR"J:=1"STEP"1"UNTIL"R"DO"
 "BEGIN";
 SUM:=0;
 "FOR"I:=1"STEP"1"UNTIL"NRN(J)"DO"
 SUM:=SUM+NRBIN(I,J);
 RMEAN(J):=SUM/NRN(J);
 "END";
 "FOR"J:=1"STEP"1"UNTIL"UR"DO"
 "BEGIN",
 SUM:=0;
 "FOR"I:=1"STEP"1"UNTIL"NURN(J)"DO"
 SUM:=SUM+NURBIN(I,J);
 URMEAN(J):=SUM/NURN(J);
 "END";
 "BEGIN";
 "INTEGER"NUM;
 "REAL""ARRAY"RMENIB,URMENIB,RVARNIN,URVARNIB(1:29);
 "INTEGER""ARRAY"RNUMNIB,URNUMNIB(1:29);
 "COMMENT"FORMS SIX NEW VECTORS,RNUMNIB(I)CONTAINING
           THE NUMBER OF BATCHES OF NIBBLES OF LENGTH I,
           RMENIB & URMENIB(1)CONTAINING THE MEAN LENGTH OF A DECADE
```

```
        FOR BATCHES OF NIBBLES OF I DECADES LENGTH.
        RVARNIB & URVARNIB(I) CONTAINING THE VARIANCE OF THE LENGTH
        OF DECADES FROM BATCHES OF NIBBLES OF LENGTH I;
"FOR"I:=1"STEP"1"UNTIL"29"DO"
"BEGIN"
SUM:=SUMSQ:=0.0;
NUM:=0;
"FOR"J:=1"STEP"1"UNTIL"R"DO"
"IF"NRN(J) =1"THEN"
"BEGIN"
SUM:=SUM+RMEAN(J);
SUMSQ:=SUMSQ+(RMEAN(J)+2;
NUM:=NUM+1;
"END";
RNUMNIB(1):=NUM;
"IF"NUM  1"THEN"
RMENIB(1):=0"ELSE"RMENIB(1):=SUM/NUM;
"IF"NUM  2"THEN"
RVARNIB(1):=0"ELSE"
RVARNIB(1):=(SUMSQ"(NUM-1))-(SUM+2/NUM*(NUM-1)));
"END";
"FOR"I:=1"STEP"1"UNTIL"29"DO"
"BEGIN"
NUM:0;
SUM:=SUMSQ:=0.0;
"FOR"J:=1"STEP"1"UNTIL"UR"DO"
"IF"NURN(J)=1"THEN"
"BEGIN"
SUM:=SUM+URMEAN(J);
SUMSQ:=SUMSQ+(URMEAN(J)+2;
NUM:=NUM+1;
"END"
URNUMNIB(I):=NUM;
"IF"NUM  1"THEN"
URMENIB(I):0"ELSE"URMENIB(I):=SUM/NUM;
"IF"NUM  2"THEN"
URVARNIB(I):=0"ELSE"
URVARNIB(I):=(SUMSQ"(NUM-1))-SUM+2/(NUM*(NUM-1));
"END";
"FOR"I:=1"STEP"1"UNTIL"29"DO"
"PRINT" ''L2'',SAMELINE,DIGITS(3),I,''S5'',RNUMNIB(I),''S5'',
ALIGNED(4,4),RMENIB(I),''S5'',RVARNIB(I);
"FOR"I:=1"STEP"1"UNTIL"29"DO"
"PRINT" ''L2'',SAMELINE, DIGITS(3),I,'S5'',URNUMNIB(I),''S5'',
ALIGNED(4,4),URMENIB(I),''S5'',URVARNIB(I);
"END";
"END";
"END";
"END";
"GOTO"NEXTRAT;
"END";
```

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