RESPONSE-UNIT FORMATION AND THE OPERANT PREE

THE ROLE OF RESPONSE-UNIT FORMATION IN THE OPERANT PARTIAL REINFORCEMENT EXTINCTION EFFECT

By

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A Thesis
Submitted to the School of Graduate Studies
in Partial Fulfilment of the Requirements
for the Degree
Doctor of Philosophy

McMaster University
February, 1977

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DOCTOR OF PHILOSOPHY (1977)
(Psychology)

McMASTER UNIVERSITY
Hamilton, Ontario

TITLE: The Role of Response-Unit Formation in the Operant Partial Reinforcement Extinction Effect

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NUMBER OF PAGES: xii, 228

Abstract

In both instrumental and operant situations, the number of responses emitted in extinction is greater following partial than following continuous reinforcement. This partial reinforcement effect (PREE) has been the subject of considerable theoretical interest.

The response-unit hypothesis proposed by Mowrer and Jones (1945) accounts for the operant PREE by arguing that when reinforcement follows a sequence of responses, that entire sequence forms a single functional response, or response unit. The hypothesis predicts that the number of individual responses emitted in extinction will increase with response-unit length, but the number of response units emitted will be independent of response-unit length.

A response unit terminates when the subject approaches the foodcup. The response-unit hypothesis argues that this terminal response is controlled by internal stimuli produced by execution of the unit. When such internal control is fostered by the elimination of external cues to response-unit completion, extinction performance is consistent with the response-unit hypothesis: The number of responses emitted increases with acquisition unit length, while the number of units emitted is constant across a wide range of unit lengths.

Fixed ratio (FR) reinforcement schedules provide external cues to ratio completion during acquisition. Several studies have shown

that the presence of such stimuli in acquisition does not prevent the development of internal stimulus control over response-unit termination, but that extinction performance may be affected by the availability of such stimuli in extinction.

In the studies reported in the thesis, the length and number of response units emitted in extinction were examined as functions of the extinction scheduling of external stimuli associated with reinforcement during acquisition.

An early study revealed that extinction performance following FR reinforcement differed considerably in the presence or absence of external cues to ratio completion. In the absence of such cues, extinction unit length exceeded acquisition unit length, and the number of units emitted was independent of acquisition unit length. In the presence of such cues, acquisition and extinction unit lengths were identical, the number of units emitted was much greater, and decreased in a negatively accelerated manner with increasing acquisition unit length.

Subsequent studies, in which the extinction schedule of external stimulus presentation was manipulated, eliminated several alternative accounts of these results, and suggested a modified version of the response-unit hypothesis which rejects the assumption that the number of response units emitted in extinction is independent of response-unit length.

According to this revised response-unit hypothesis, the number of units emitted in extinction depends on the length of both the unit reinforced during acquisition, and the unit emitted in extinction. For any given acquisition unit length, the number of units emitted in extinction decreases in a negatively accelerated manner as extinction unit length increases. This relationship can be expressed as a power function of the form $U = M \times L^{-B}$, where U is the number, and L the length, of the units emitted in extinction. As acquisition unit length increases, the function shifts upward and becomes flatter; thus the number of units emitted in extinction increases with acquisition unit length.

This model accounts for the effect of external stimuli on extinction performance in terms of their capacity to determine extinction unit length by eliciting response-unit termination. The model was shown to be capable of accounting for the results of a number of experiments involving manipulations of both acquisition and extinction unit length.

The results of these studies provided considerable support for a response-unit analysis of the operant PREE, and suggested that such an account might provide the basis for a general theoretical account of both the operant and the instrumental PREE.

Acknowledgements

While a number of individuals have contributed, either directly or indirectly, the the completion of this thesis, space permits only the most outstanding such debts to be acknowledged.

My sincerest thanks to my advisor, Dr. John R. Platt, who has been a source of sagacious guidance, intellectual and moral support, and finite but extensive patience during the entire course of my graduate career--a period of time whose length would have taxed the patience of lesser men. Thanks also to the other members of my committee, Dr. Herbert M. Jenkins, and Dr. Shepard Siegel. I am especially grateful to Dr. Jenkins for his painstaking and constructive criticism of earlier versions of this thesis.

Thanks are also due to Diana Wichie, who conducted Experiment 3, and to Gary Weatherill, who conducted much of the remaining research reported in this thesis. His careful, conscientious attention to this research is undoubtedly responsible for whatever order is apparent there.

I would also like to express my gratitude to the many friends and fellow students who shared, and therefore diminished, the inevitable burdens of graduate studies. Of this number I should like to single out Dr. Dennis Kuch, Dr. Rosemary Barnes, and Dr. Corinne Day.

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Introduction

Thorndike's (1911) Law of Effect stated that satisfying consequences increase, and annoying consequences decrease the strength of a response. With the substitution of more neutral terms like reinforcement and punishment for Thorndike's satisfaction or annoyance, the notion that the rate, vigour, and persistence of a response depends on its consequences became one of the cornerstones of behaviouristic learning theory. Subsequent research confirmed that the rate at which a response was acquired, and the extent to which it persisted in extinction were related in a consistent manner to the parameters of reinforcement.

Very early in the course of examining effects of acquisition variables on response strength, it was observed that occasional omission of reinforcement during acquisition slowed the rate at which learning occurred. Somewhat disturbingly, however, occasional omission of reinforcement during acquisition had an unpredicted effect on extinction: The rate, vigour, and number of responses emitted in extinction was greater following partial than following continuous reinforcement.

While the earliest such studies were conducted by Skinner (1938) in the operant chamber, attention directed to this phenomenon was greatly increased by the studies of Humphreys (1939a, 1939b) using human subjects and a classical conditioning paradigm. Humphreys reported than when half the presentations of a light during acquisition were followed by an airpuff to the eye, the frequency of eyeblinks to the light was lower during acquisition, but higher during extinction, than when all presentations of the light in acquisition were followed by an airpuff. Humphreys interpreted his results in terms of the subjects' expectations concerning the relationship between stimulus events and reinforcement. He argued that partially reinforced subjects came to expect reinforcement on only a portion of their acquisition trials. Consequently, the probability that a response would occur on any given acquisition trial was lower for a partially reinforced than a continuously reinforced subject. During extinction, however, this difference in expectancies worked to increase the resistance to extinction of a partially reinforced subject, who did not expect reinforcement on every trial, and therefore was not "disappointed" as often during extinction as a continuously reinforced subject.

Following the research of Humphreys, the focus of interest in the partial reinforcement extinction effect (PREE) rapidly shifted to the instrumental runway situation, where the problems it posed to fundamental conceptions were clearly articulated (Finger, 1942a, 1942b). The PREE has subsequently been a prime empirical and theoretical concern within instrumental learning. It has provided the impetus for the elaboration of numerous hypothetical processes and mechanisms, and its explanation has served as a testing ground for competing theoretical programmes.

Despite the precedence of Skinner's work, the PREE has received little empirical and still less theoretical attention in the operant literature. Skinner had demonstrated that responses could be acquired and maintained by partial reinforcement, and that responses so acquired were more resistant to extinction than responses acquired under continuous reinforcement. The primary purpose of subsequent research, however, was the examination of response patterns produced by various schedules of partial reinforcement.

The theoretical and conceptual vacuum surrounding the operant PREE has been only partially and ineffectively filled by attempts to generalize or modify formulations derived from instrumental research. Much of the difficulty with such attempts stems from disagreement over the possibility of considering both instrumental and operant paradigms within a common conceptual framework, or over the shape which such a common framework should take. While the distinction between instrumental and operant paradigms is not rigorous, they can be adequately differentiated for present purposes in terms of both the types of behaviours examined and the contraints imposed on the distribution of responding. Instrumental situations typically involve locomotor responses which are segmented into discrete trials; completion of the response initiated an intertrial interval during which further responding is not possible. Operant situations, on the other hand, typically involve manipulative responses (e.g. leverpressing, keypecking, etc.), and, while a discrete-trial procedure is sometimes employed, the subject is more often allowed unrestricted access to the manipulandum.

The research to be discussed in this paper, while primarily concerned with the operant PREE, is neither unrelated nor irrelevant to current theories based on instrumental research, or to issues concerning their application to the operant situation. In order to place this research in its proper perspective, it is therefore necessary to consider, if only in limited detail, several of the most important attempts to place the instrumental PREE within the context of behaviouristic learning theory.

Hull-Spence Theory

Couched as they were in the forbidden lexicon of internal cognitive events, Humphreys' hypotheses had little impact on subsequent attempts to account for the PREE within the growing corpus of behaviouristic learning theory. The latter was shaped largely by the efforts of Clark Hull and Kenneth Spence.

According to Hull-Spence theory, the various parameters of a response, such as rate, vigour, and resistance to extinction, are functions of its excitatory potential (E). This in turn reflects the combination of a number of variables, either in an additive or multiplicative manner, with habit strength (H), a measure of the associative bond between the response and a specific stimulus situation.

In the several versions of the equation for E which emerged from Hull-Spence behaviour theory between the 1930's and 1950's, the effect of reinforcement on a response was always such as to increase E, and the effect of nonreinforcement was always such as to decrease E. According to Hull's (1943, 1952) equation for E, both H and E increase with each reinforced occurrence of a response, the precise magnitude of the increase in E depending on parameters such as amount and delay of reinforcement. The latter were originally held to operate directly on H, but were later postulated to have their effect on E by determining the value of incentive (K), which combined multiplicatively with H in determining E.

Hull also postulated the growth with each occurrence of a response of reactive inhibition (I_R), whose magnitude depended both upon the number of occurrences of the response, and on the frequency and effort of the response. In the absence of responding, I_R dissipated over time. Hull further assumed that I_R was a negative drive, and that its reduction by nonresponding led to the development of conditioned inhibition $_SI_R$, a permanent tendency not to respond. The sum ($\dot{I}_R$) of I_R and $_SI_R$ subtracted from E to reduce response probability. As long as each response was reinforced, however, the growth in H was sufficient to counteract the increment in $\dot{I}_R$. In the absence of reinforcement, a response results in no further increase or decrease in H, but the inevitable increase in $\dot{I}_R$ reduces E. Continuous nonreinforcement thus results in extinction through the accumulation of $\dot{I}_R$ produced by each nonreinforced response.

While Spence's formulation of the equation for E differs in several important ways from Hull's, the concept that extinction results from the growth of a negative inhibitory factor as a function of the number of nonreinforced responses remained. Spence did, however, remove effort and spacing of responses from the set of variables affecting $\dot{I}_R$.

Despite the success of Hull-Spence theory in accounting for many important learning phenomena, and its seminal influence on subsequent research and theory, it was apparent quite early that its inhibitory account of the extinction process could not provide an adequate account of the PREE. The growth of $\dot{I}_R$ during acquisition and extinction should occur at the same rate for both partially and continuously reinforced subjects, and the PREE had been shown to occur even when H was presumably greater for continuously reinforced than for partially reinforced subjects.

There are, however, several additional processes within the framework of Hull-Spence behaviour theory which have been invoked to account for the PREE. The first of these is generalization decrement.

It is well-established that a response which has been reinforced in the presence of a stimulus configuration S_1 will also occur in the presence of a stimulus configuration S_2 with a strength which decreases with the dissimilarity of S_1 and S_2. This decrease in the strength of a response in the presence of stimuli differing from those in the presence of which it was reinforced is called generalization decrement.

In Hull-Spence theory, the excitatory potential of a response in different stimulus situations results from the generalization of H from the stimuli present during reinforcement to a range of similar stimuli. The generalized H of the latter is an inverse function of their distance from the reinforced stimulus along some similarity continuum.

With respect to its application to extinction, and to the PREE in particular, the generalization decrement hypothesis (Sheffield, 1949) argues that the stimuli present in extinction differ from those present in acquisition. At the very least this difference consists of the absence of the stimuli provided by reinforcement. It is further argued that the difference between acquisition and extinction stimulus conditions is greater for continuously than for partially reinforced subjects. This differential similarity arises from differences in the stimuli present at reinforcement during acquisition. For subjects receiving continuous reinforcement, the stimuli accompanying reinforcement include, in addition to whatever external stimulus changes occur, the proprioceptive and other internal consequences of previous reinforcement. For subjects receiving partial reinforcement, however, the stimulus accompaniments of reinforcement include the aftereffects of previous nonreinforcement. Thus the stimuli provided by the continuous absence of reinforcement in extinction is more similar to acquisition for partially reinforced than for continuously reinforced subjects.

A second process related to generalization which has been proposed to account for the PREE is discrimination. The argument in this case is that partially reinforced subjects have more difficulty discriminating extinction from acquisition than do continuously reinforced subjects. The reasoning is similar to that put forward in favour of generalization decrement: Subjects trained on partial reinforcement schedules are less able to detect changes in reinforcement contingencies from acquisition to extinction, since the absence of reinforcement was also a part of the stimulus complex in acquisition. Continuously reinforced subjects, who have never previously encountered nonreinforcement, are much more capable of discriminating the difference between acquisition and extinction.

While the generalization decrement and discrimination hypotheses would seem to be empirically indistinguishable, a number of authors have argued that they make different predictions concerning the effects of certain acquisition procedures on extinction. It has been argued, for example (Jenkins, 1962; Theios, 1962), that the interpolation of a period of continuous reinforcement (CRF) between the completion of partial reinforcement and extinction should eliminate the PREE, since it makes the transition between acquisition and extinction equally discriminable for partially and continuously reinforced subjects. Furthermore, the discrimination hypothesis predicts that an acquisition reinforcement regimen which makes acquisition and extinction more discriminable will decrease resistance to extinction. While manipulations of the latter sort have the predicted effect on resistance to extinction, interpolated CRF between partial reinforcement and extinction does not eliminate the PREE.

Despite the claim that the generalization decrement and discrimination hypotheses can be empirically separated, it is not clear, upon closer analysis, that these positions are markedly different. The generalization decrement hypothesis stresses the importance of the association between the response and the stimuli present at reinforcement, and the relationship between these stimuli and those present in extinction. The discrimination position, on the other hand, stresses the discriminability of the stimuli occurring on either side of the transition between acquisition and extinction. Thus the prediction that interpolated CRF will eliminate the PREE is based on the fact that such a procedure eliminates differences in the stimulus change experienced by partially and continuously reinforced subjects at the onset of extinction. Such a procedure would not be expected to eliminate a PREE based on generalization decrement because prior partial reinforcement insures that the stimuli provided by nonreinforcement have been associated with the response.

It seems unlikely, however, that differential discriminability _per se_ would produce differential extinction performance. The performance of subjects in the presence of extinction stimuli, however discriminable they may be from those present just prior to extinction, cannot readily be understood except in the context of the subject's conditioning history with respect to these or similar stimuli. In analyzing the interpolated CRF procedure, similar considerations suggest that although partially and continuously reinforced subjects may equally readily discriminate the alteration in stimulus conditions at the onset of extinction, we could hardly expect subjects reinforced in the presence of stimuli similar or identical to those present in extinction to respond in the same manner as subjects with no such experience.

To the extent, therefore, that it ignores the subject's previous conditioning history, the discrimination hypothesis provides an ineffective account of the PREE. To the extent, however, that it invokes the subject's tendency to respond with less vigour and persistence to the presence of stimuli discriminably different from those to which the response has been conditioned, the discrimination hypothesis is identical to the generalization decrement hypothesis.[1]

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[1] It should be noted that an associative interpretation of the discrimination hypothesis was obviously the intent of its original authors (Mowrer & Jones, 1945). They viewed their position as similar to that of Humphreys (1939a), but treated the notion of expectancies in extinction in terms of subjects' previous experience with reinforcement in the presence of stimuli provided by previous nonreinforcement.

Contemporary Theoretical Accounts of the PREE

Capaldi's (1966a, 1966b, 1967) sequential theory of instrumental learning utilizes a more elaborate version of the generalization decrement hypothesis to account for the effects of a number of acquisition variables, including partial reinforcement, on extinction performance. According to the theory, a subject's behaviour in extinction depends on the similarity of stimuli present in extinction to stimuli present at reinforcement during acquisition.

Capaldi argues that the stimuli present at reinforcement during acquisition include, in addition to salient external stimuli, the aftereffects or memory traces of previous behaviour and stimulus events. These memory traces encode not only qualitative parameters such as the presence or absence of reinforcement, but also quantitative parameters such as the magnitude and delay of reinforcement, or the number of prior nonreinforced responses. Many of the events encoded are thus drawn from intrinsically multi-valued or continuous stimulus dimensions, each value from which provides a unique internal representation to which the response becomes associated through its contingguity with reinforcement. Other values along the continuum acquire a generalized tendency to elicit the response which diminishes in proportion to their distance from the reinforced value. In a novel stimulus situation, the parameters of a subject's performance depend on the extent to which the stimuli present, by virtue of their similarity to those present at reinforcement during acquisition, possess generalized habit strength.

In the case of partial versus continuous reinforcement, the stimuli with which we are particularly concerned are those provided by the reinforcement or nonreinforcement of the responses preceding a reinforced response. According to Capaldi, the number of nonreinforced responses preceding reinforcement, or N-length, provides a particular stimulus value to which the response becomes conditioned at reinforcement. Thus a continuously reinforced subject is reinforced in the presence of the stimulus aftereffects of N-lengths of zero. Partially reinforced subjects are reinforced in the presence of the stimulus aftereffects of N-lengths which depend on the schedule in force, but which are, in any case, greater than zero.

In extinction, each trial takes place in the presence of the stimulus aftereffects of nonreinforcement, with N-length increasing with each successive nonreinforcement. Generalization decrement decreases response strength for both partially and continuously reinforced subjects once the number of nonreinforced trials exceeds acquisition N-length. This decrease is more rapid for continuously reinforced subjects, as each successive nonreinforcement provides stimulus aftereffects which are necessarily less similar to the aftereffects of N-length zero than to N-lengths greater than zero.

While the theory is more detailed and comprehensive than just outlined, it clearly provides a conceptually simple analysis of the PREE based on a more comprehensive view of the nature of the stimuli present at reinforcement, and the relation of these stimuli to those present during extinction. In essence, sequential theory provides a theoretical outline of the processes which are responsible for the differential capacity of extinction stimuli to elicit responding as a function of the ~~subject~~'s conditioning history.

Another view of the extinction process related to Hull's notions of the growth of conditioned inhibition, is that it results from the conditioning during extinction of responses which are incompatible with the original response. The most carefully elaborated version of the competing response position is contained in Amsel's (1967) frustration theory.

According to frustration theory, repeated reinforcement of a response in a specific stimulus context results in the gradual development of an expectancy or anticipation of reinforcement in that context. Once this expectancy has developed, the absence of reinforcement from that context produces frustration. Frustration has both motivational and stimulus properties; it elicits unconditioned responses, energizes the dominant response in the situation. and provides internal stimuli to which responses can become conditioned.

The frustration account of the PREE is similar to that provided by both sequential theory and the generalization decrement hypothesis in that it stresses the conditioning history of the organism with respect to the stimuli encountered in extinction. According to the theory, partially reinforced subjects are exposed to primary frustration when trials are nonreinforced in acquisition. The stimuli in the presence of which frustration occurs acquire the capacity to elicit conditioned frustration via classical conditioning. By virtue of the similarity between stimuli present during the course of the trial and those present when frustration occurs, the former also come to elicit conditioned frustration and its stimulus aftereffects. Although conditioned frustration may initially evoke and/or energize competing behaviours, the strength of the original response insures that it continues to occur and be reinforced in the presence of frustration-produced stimuli. In the later stages of partial reinforcement, therefore, conditioned frustration both energizes and provides stimuli which elicit, the reinforced response. As the acquisition reinforcement schedule becomes more intermittent, both the amount of frustration and the association between frustration-produced stimuli and the reinforced response increase.

In extinction, both partially and continuously reinforced subjects experience frustration when responding is nonreinforced. The performance of continuously reinforced subjects is disrupted both by the unconditioned effects of frustration and by the novelty of frustration-produced stimuli, while partially reinforced subjects continue to respond in the presence of stimuli which have previously been associated with the performance of the instrumental response.

The primary data for most of modern behaviour theory from Thorndike onward have come from paradigms involving locomotor responses which involve traversal of the experimental space: mazes, runways, jumping stands, etc. Within instrumental paradigms of this sort, contemporary theoretical treatments of extinction and the PREE in particular have been relatively successful. Both frustration and sequential theory are able to account for the most prominent phenomena associated with traditional manipulations of reinforcement parameters, and one or the other is generally capable of providing a satisfactory account of the effects of more complicated manipulations which have been devised to test these theories. Within the instrumental situation, therefore, these two theories, while not necessarily incompatible, constitute the primary competitors for continuing empirical attention.

The Operant PREE

Although a conceptual and theoretical framework within which to integrate the PREE has been established for instrumental paradigms, the situation with respect to operant paradigms is considerably less clear. While the earliest demonstrations of the effects of partial reinforcement derived from Skinner's work, the emphasis of operant researchers on the compilation of relationships between schedule parameters and behaviour, and their distrust of integrative theoretical speculations largely precluded any systematic attempts to create theoretical analyses of phenomena such as the PREE.

The theoretical vacuum surrounding the operant PREE was not filled by the application of theories derived from instrumental research. Theoreticians either assumed the immediate or eventual applicability of instrumental concepts to the operant situation, or explicitly argued their inapplicability due to the failure of operant paradigms to meet various criteria of analogy with those in the instrumental area. Spence (1960), for example, in discussing instrumental extinction, concluded that the operant PREE is a phenomenon which

> "...has little or nothing to do with extinction, but rather is related to the problem of the length of the chain that can be established in instrumental sequences...Translated into the runway situation, these types of studies are not

> nearly so dramatic as they appear in the context of the lever-box, for what they have shown is that one can train a rat to take a great many steps, i.e. run a long way to get a piece of food." (pp. 122-123)

This view of the relationship between operant and instrumental partial reinforcement procedures is one that has been voiced either explicitly or implicitly by a number of authors, and it forms the basis for the only theoretical or hypothetical account of the operant PREE to derive directly from the operant situation.

Skinner (1938) dealt with resistance to extinction in terms of the exhaustion of a fixed reserve of responses established as a result of reinforcement, and decremented by each nonreinforced response. In considering the apparent incompatibility of this conception with the PREE, Skinner argued that

> "...when a reinforcement depends upon the completion of a number of similar acts, the whole group tends to acquire the status of a single response, and the contribution to the reserve tends to be in terms of groups." (p. 300)

Skinner's speculation was first cast into empirically testable form by Mowrer and Jones (1945), who attributed the suggestion to J. S. Brown. Their position, termed the response-unit hypothesis, paralleled Spence's view that operant partial reinforcement varies the number of 'steps' required for reinforcement, and depends critically, as Skinner explicitly acknowledged, on the definition of 'a response'.

In an equation between environment and behaviour, it is necessary that the terms on both sides be unitized and quantified.

With respect to the environment, such quantification typically involves specification of physical parameters, such as duration, magnitude, intensity, etc., of discrete stimulus events. On the behavioural side of the equation, the unit of reference is 'the response'. Since we are generally dealing with a continuous stream of behaviour which does not often present obvious lines of demarcation between adjacent units, it is a common practice in the operant situation to describe the subject's behaviour in terms of the parameters of a unit defined in terms of some arbitrary but conveniently measureable alteration of the environment, such as the closure of a microswitch. On a purely operational level, therefore, a response is simply a convenient arbitrary unit into which ongoing behaviour is divided for the purposes of recording and the scheduling of stimulus events.

On a more abstract theoretical level, however, a response is a unit of behaviour determined not by the arbitrary requirements of the experimenter, but rather by its specific functional relationship to environmental manipulations. A response in this sense is the unit of behaviour on which environmental manipulations are said to have their effect, and which represents the external manifestation of a relatively isomorphic internal process. It is a response in this sense which is 'reinforced', 'generalized', or 'extinguished'.

Because this functional unit cannot be specified _a priori_, the assumption commonly made in the operant situation is that the procedural (or nominal) and functional responses are identical.

Thus, if the schedule of reinforcement and stimulus presentation is defined in terms of the number or distribution of leverpresses, it is assumed that the effects of manipulations such as reinforcement magnitude, delay, etc., can best be understood in terms of their effects on 'the leverpress'; i.e. on 'leverpressing' as a functional response.

The response-unit hypothesis argues that the functional response in the operant situation consists of the entire sequence of behaviours which precede reinforcement, regardless of the number of nominal responses involved. According to this hypothesis, differences in the number of individual responses emitted in extinction following partial and continuous reinforcement do not reflect differences in the strength of the association between that response and the stimuli present in extinction, but rather differences in the nature of the behaviour sequence reinforced during acquisition. An accurate estimation of the resistance to extinction produced by various schedules of reinforcement can be obtained only when such differences are taken into account, and the extinction performance of the subject is expressed in terms of this reinforced behaviour sequence, or response unit.

As elaborated by Mowrer and Jones, the response-unit hypothesis predicts that the number of response units emitted in extinction will be independent of response-unit length, and thus equal following comparable amounts of partial and continuous reinforcement. This hypothesis has received very little attention, and, until recently, even less empirical support.

Mowrer and Jones were the first to test the hypothesis by comparing the resistance to extinction of a leverpressing response in rats following training on several values of a modified fixed-ratio (FR) schedule of reinforcement. Separate groups of rats were reinforced for every press, or only for every second, third, or fourth press. Unlike the usual FR schedule, on which reward delivery occurs immediately following completion of the leverpressing requirement, the schedule employed by Mowrer and Jones (which has since been termed a fixed-number, or FN, schedule) required an additional heterogeneous response, approach to the foodcup, for reinforcement delivery. The purpose of this added contingency was to eliminate the possibility that external stimuli associated with ratio completion might come to exert discriminative control over responding. The authors noted that were such control to develop, responding in extinction might be governed by the subjects' expectations of such stimuli, rather than by the association of reinforcement with the execution of a fixed number of leverpresses.

The results indicated the expected PREE with respect to the number of individual leverpresses emitted: number of leverpresses to extinction increased in an approximately linear manner with acquisition ratio requirement. The number of response units emitted in extinction was calculated by dividing each subject's leverpress output by his acquisition ratio requirement. The results of this calculation indicated that the number of response units emitted in extinction decreased in a negatively accelerated manner with increasing response-unit length. The authors suggested several possible interpretations of this result (including the discrimination hypothesis discussed earlier), and concluded with the suggestion that perhaps resistance to extinction was inversely related to the effortfulness of the response, so that longer units, which presumably require greater effort, would be less resistant to extinction.

Several other studies (Boren, 1961; Weiss, 1961; Weissman and Crossman, 1966; Fischer and Cole, 1968) employing regular FR schedules and a similar calculation of the number of response units emitted in extinction came to similar conclusions regarding the relationship between response-unit length and resistance to extinction.

A new approach to the measurement of response units, together with some very promising data, were reported by Denny, Wells, and Maatsch (1957). In the studies cited above, the number of response units emitted in extinction was derived mathematically rather than measured directly. The calculation employed would provide an accurate estimate of the number of units emitted only if the length of the units emitted in extinction remained the same as the acquisition ratio requirement. Since the parameters of an individual response (e.g. force, duration) are known to change in extinction, it is reasonable to suppose that the parameters of a response unit, notably its length, might undergo similar changes. Denny _et al_ pointed out that since each response sequence in acquisition terminates with an approach to the foodcup, the occurrence of the terminal response in extinction could be used as a behavioural indicator of response-unit termination.

In the study reported by Denny et al, separate groups of rats received various amounts of training on FR schedules requiring either 1 or 5 leverpresses for reinforcement. Following training, extinction was carried out to a criterion of 10 min. without a leverpress. During both acquisition and extinction, approaches to the foodcup were recorded by means of a treadle placed in front of the cup. In the relevant comparisons, the authors reported that FR 5 subjects made significantly more leverpresses to extinction than did FR 1 subjects who received the same number of reinforcements, but that the number of approaches to the foodcup was the same for both groups.

Recent Response-Unit Studies

When our current research programme began, the study by Denny et al constituted the sole empirical support for the response-unit hypothesis. The need for further verification was suggested by aspects of both the procedure and the data reported in this study. Firstly, only two response-unit lengths were examined, thus providing only a speculative extrapolation concerning the relationship between response-unit length and resistance to extinction across the range of ratio values commonly employed in operant research. Secondly, data from the end of acquisition indicated that the number of leverpresses per terminal response was still increasing in the FR 5 group. Thus the extinction data were obtained from subjects whose performance was still being altered by the prevailing reinforcement contingencies. Finally, the extinction procedure employed provided for an external cue to ratio completion in the form of a magazine click presented following every press in the FR 1 condition, and following every 5th press in the FR 5 condition. It seemed possible, therefore, that the results did not reflect the establishment of response units controlled by proprioceptive or other internal stimuli generated by responding, but only the tendency to withhold approach to the foodcup until the external stimulus was presented.

In the first experiment conducted in the present research programme (Day, 1972b) many of these difficulties were overcome.

Groups of rats were trained to leverpress on FN schedules requiring either 1, 5, or 15 leverpresses for reinforcement. As in the Mowrer and Jones study, reward was delivered only when the subject approached the foodcup following completion of 1, 5, or 15 leverpresses since the previous reinforcement. Approaches made prior to completion of the ratio requirement had no programmed consequences. There were, therefore, no external cues to ratio completion, and the termination of a sequence of responses was presumably based on proprioceptive cues associated with the execution of the ratio requirement. Training on this schedule continued for 20 days in order to insure asymptotic performance levels prior to extinction.

Half the subjects in each FN group were trained under discrete-trial (DT) conditions such that each reinforced terminal response was accompanied by a 10-sec. intertrial interval (ITI) during which the chamber was darkened and the lever retracted. The remaining subjects in each FN group were trained under free-operant (FO) conditions such that the lever was continuously available and the chamber continuously illuminated. Our interest in this variable concerned its effects on the integration of the response unit; i.e. the extent to which such conditions either facilitated or inhibited the elimination of nonreinforced terminal responses.

Following training, subjects were extinguished to a criterion of 10 min. without a leverpress under conditions which differed from those in acquisition only in that the food delivery mechanism did not operate.

Figure 1 presents the mean number of leverpresses per terminal response on [illegible] of acquisition as a function of FN requirement and training procedure (DF or FO). Overall, mean number of leverpresses per terminal response was a direct function of FN requirement; this effect was largely restricted to the DF groups, however. In the FO condition, mean acquisition response-unit length was only slightly greater in the FN 5 and FN 15 groups than in the FN 1 group. Subjects in the DF condition were emitting sequences of sufficient length as to be reinforced for nearly every approach to the foodcup. Subjects in the FO condition, on the other hand, emitted sequences so short that several approaches to the foodcup occurred per reinforcement. Since the mean number of leverpresses per cup approach was approximately the same in the FO FN 5 and FN 15 groups, the number of nonreinforced approaches per reinforcement was greater in the latter than in the former group.

Comparing acquisition and extinction response-unit lengths, which are presented in Figure 2 as a function of FN requirement and training procedure, we observed that in the DF condition response-unit lengths increased with FN requirement in both acquisition and extinction. Extinction unit lengths were greater than acquisition unit lengths for the FN 1 group, approximately equal to acquisition unit lengths in the FN 5 group, and shorter than acquisition unit lengths in the FN 15 group. In the FO condition, acquisition and extinction response-unit lengths did not differ, and the latter showed little increase across FN requirement.

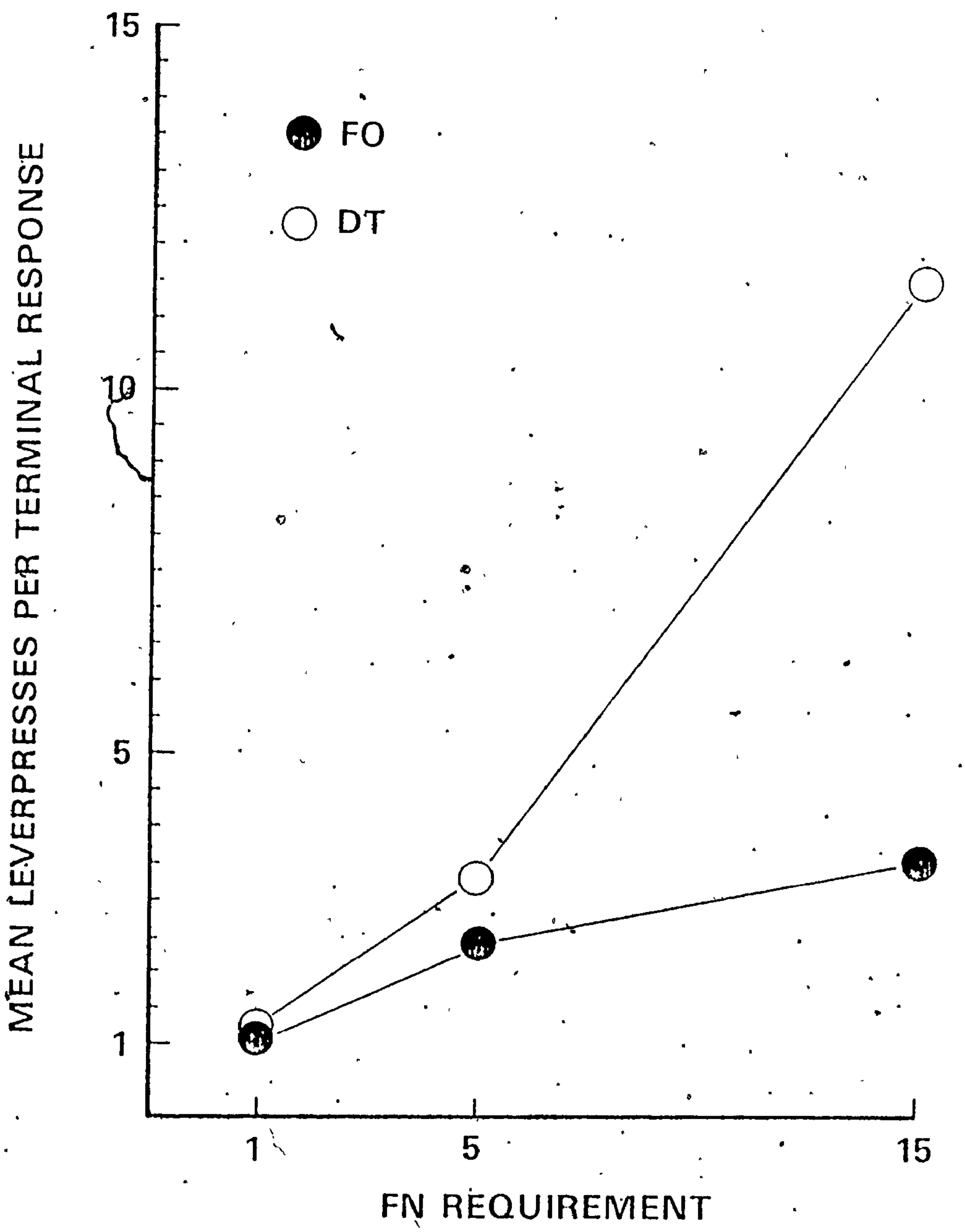


Figure 1

Day (1972b); Mean leverpresses per terminal response on Day 20 of acquisition as a function of FN requirement and training procedure. (DT or FO)

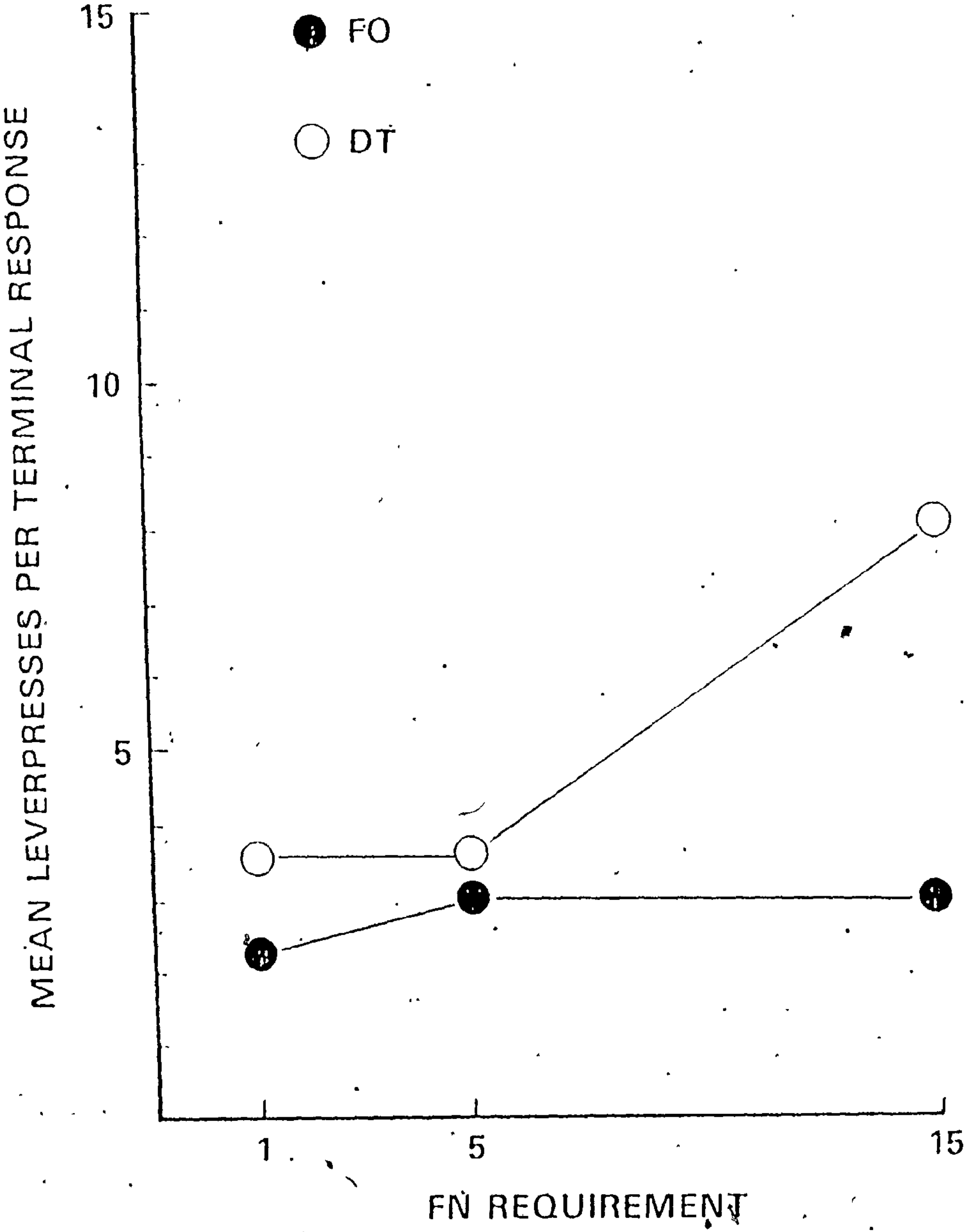


Figure 2

Day (1972b); Mean leverpresses per terminal response in extinction as a function of FN requirement and training procedure

In extinction, the expected PREE with respect to total number of leverpresses was observed in both DT and FO conditions: mean number of leverpresses emitted in extinction increased with acquisition FN requirement in both conditions. These data are presented in Figure 3.

Figure 4 presents the mean number of terminal responses emitted in extinction as a function of FN requirement and training procedure. Here, as in the case of extinction response-unit lengths, we observed significant differences in performance between the DT and FO conditions. In the DT condition, the terminal response data were clearly consistent with the response-unit hypothesis: the number of terminal responses to extinction was independent of acquisition response-unit length, and did not differ significantly across FN groups. In the FO condition, however, there was a significant increase in the number of terminal responses to extinction across FN groups. This relationship appeared inconsistent with the prediction of the response-unit hypothesis, and with the decrease in the number of response units emitted in extinction as a function of acquisition ratio requirement which had been the consistent finding of the studies cited earlier. A closer examination of the data from the FO condition suggested, however, that an expanded version of the response-unit hypothesis could account for these results.

In its most general form, the response-unit hypothesis argues simply that the pattern of behaviour in acquisition is learned and then repeated in extinction. Earlier we identified this pattern with

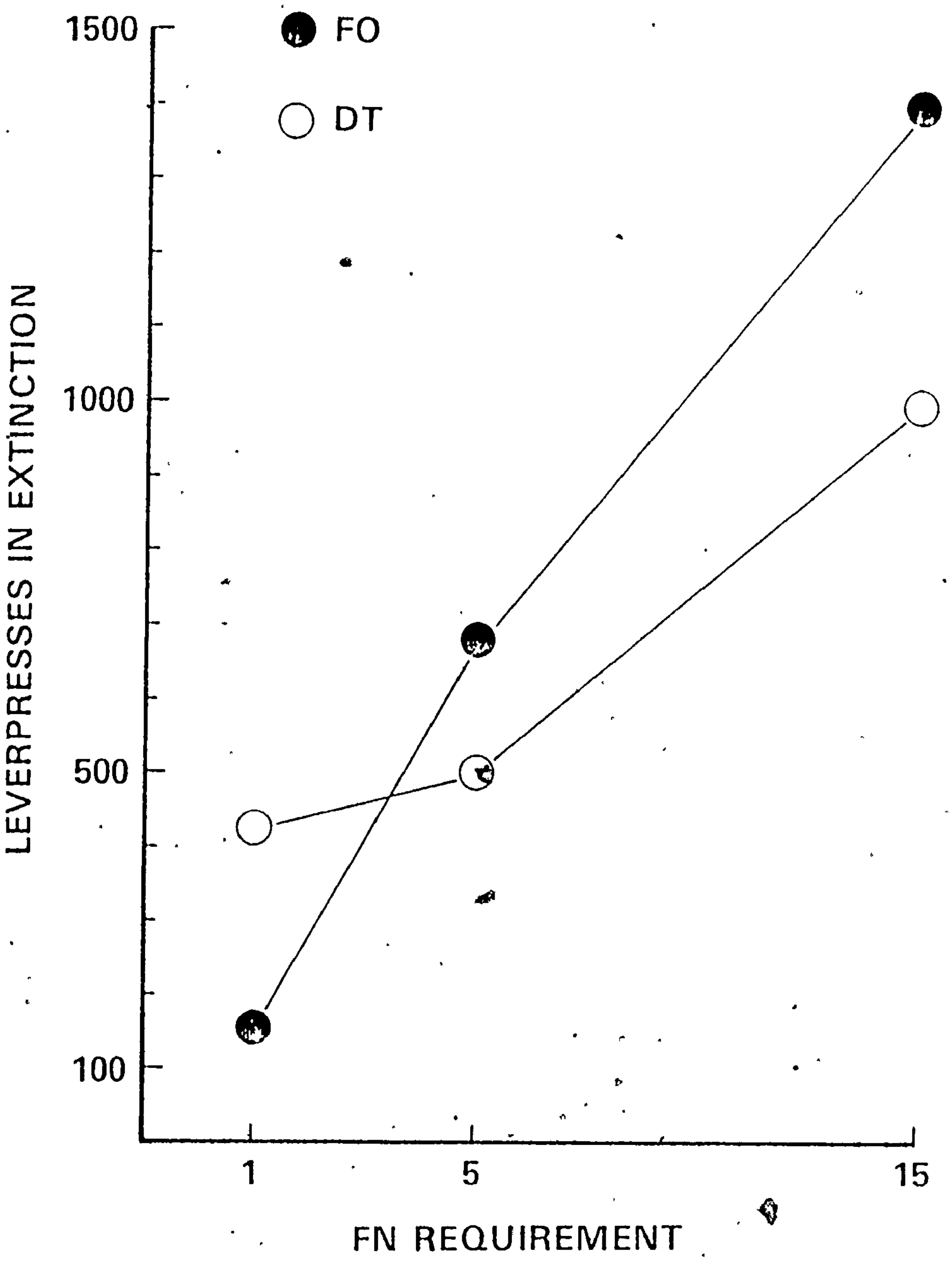


Figure 3

Day (1972b); Mean number of leverpresses to extinction as a function of FN requirement and training procedure.

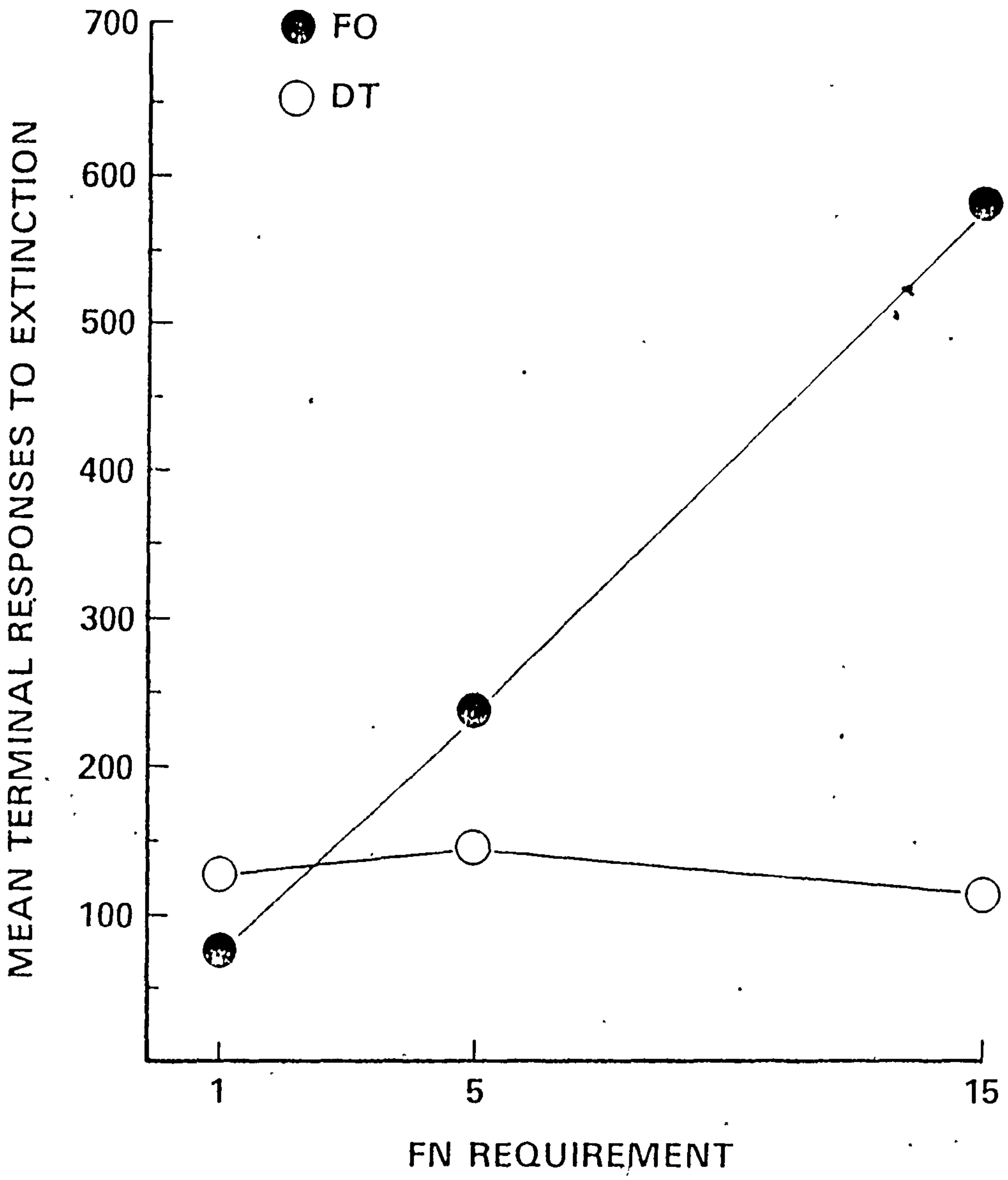


Figure 4

Day (1972b); Mean number of terminal responses in extinction as a function of FN requirement and training procedure.

a single sequence of homogeneous responses (i.e. leverpresses) which terminates with approach to the foodcup and reinforcement. This is an adequate description of the behaviour of the groups in the DT condition. We have already noted, however, that the number of leverpresses per terminal response in acquisition was smaller in the FO than in the DT condition, and that as a consequence, subjects in the FO condition emitted several response sequences, each terminating in foodcup approach, prior to each reinforcement. We shall refer to the response unit composed of a single sequence of leverpresses terminating in foodcup approach as a first-order unit. In these terms, it is clear that while subjects in the DT condition were reinforced for a single first-order unit, subjects in the FO condition were reinforced for a sequence of first-order units. If this is the case, the resistance to extinction of the reinforced response cannot be estimated simply by counting the number of first-order units emitted by FO subjects. A more appropriate procedure would be to count the number of times that each subject emitted that sequence of first-order units which was reinforced during acquisition. This sequence of first-order units will be referred to as a second-order unit. What we must do to calculate the resistance to extinction in the FO condition is to determine the number of second-order units emitted in extinction.

While our procedure provided no means of measuring this value directly, it can be calculated by dividing the total number of first-order units emitted in extinction by the size of the second-order unit reinforced during acquisition. This latter value is simply the mean number of foodcup approaches per reinforcement in acquisition. This calculation, when carried out for both the FO and DT conditions revealed, as predicted, no differences in the mean number of second-order units to extinction in either the FO or DT condition. It should be noted that this calculation of the number of second-order units emitted in extinction is analogous to that employed by Mowrer and Jones (1945) and similar studies to determine the number of first-order units emitted in extinction. In view of our earlier reservations concerning the appropriateness of this method, it is somewhat surprising that the results of a similar calculation in this study did not reveal a negatively accelerated decreasing relationship between number of second-order units to extinction and acquisition second-order unit size. Aside from this reservation, however, the results of this study provided support for a response-unit analysis of the operant PREE.

The results of this experiment in terms of both first- and second-order response-unit formation were further extended in a subsequent pair of studies. In the first (Day, 1972a), our findings with respect to first-order unit formation under DT conditions were replicated and extended. For this purpose, it was desirable to find a situation in which first-order unit size might be manipulated while the development of second-order units was minimized or prevented. To accomplish this, rats were trained on a fixed-consecutive-number (FCN) schedule. The FCN schedule differs from the FN schedule employed by Day (1972b) in that approaches to the foodcup made prior to completion of the ratio requirement reset the requirement. Reinforcement can only occur following a sequence of n consecutive leverpresses followed by foodcup approach. Previous work with this schedule (Platt and Johnson, 1971) indicated that it produced long response sequences, and a high probability of reinforcement of the terminal response.

Groups of rats were trained on FCN schedules requiring 1, 8, or 32 consecutive leverpresses for reinforcement. Half the subjects in each FCN group were trained and extinguished under DT conditions in which a 10-sec. ITI, during which the chamber was darkened and the lever retracted, following each terminal response. In order to assess the role of the ITI in maintaining extinction performance, the remaining subjects in each FCN group were trained under DT conditions, but extinguished under FO conditions with the chamber continuously illuminated and the lever continuously available. Two additional groups were trained and extinguished under DT conditions at FCN requirements of 4 and 16 leverpresses, respectively.

Figure 5 presents the mean number of leverpresses per terminal response at the end of acquisition as a function of FCN requirement and extinction condition. The number of leverpresses per terminal response was a direct function of FCN requirement, and exceeded the requirement in all groups. The number of terminal responses per reinforcement was therefore approximately 1.00; i.e., there was no second-order unit formation. Mean response-unit lengths in extinction

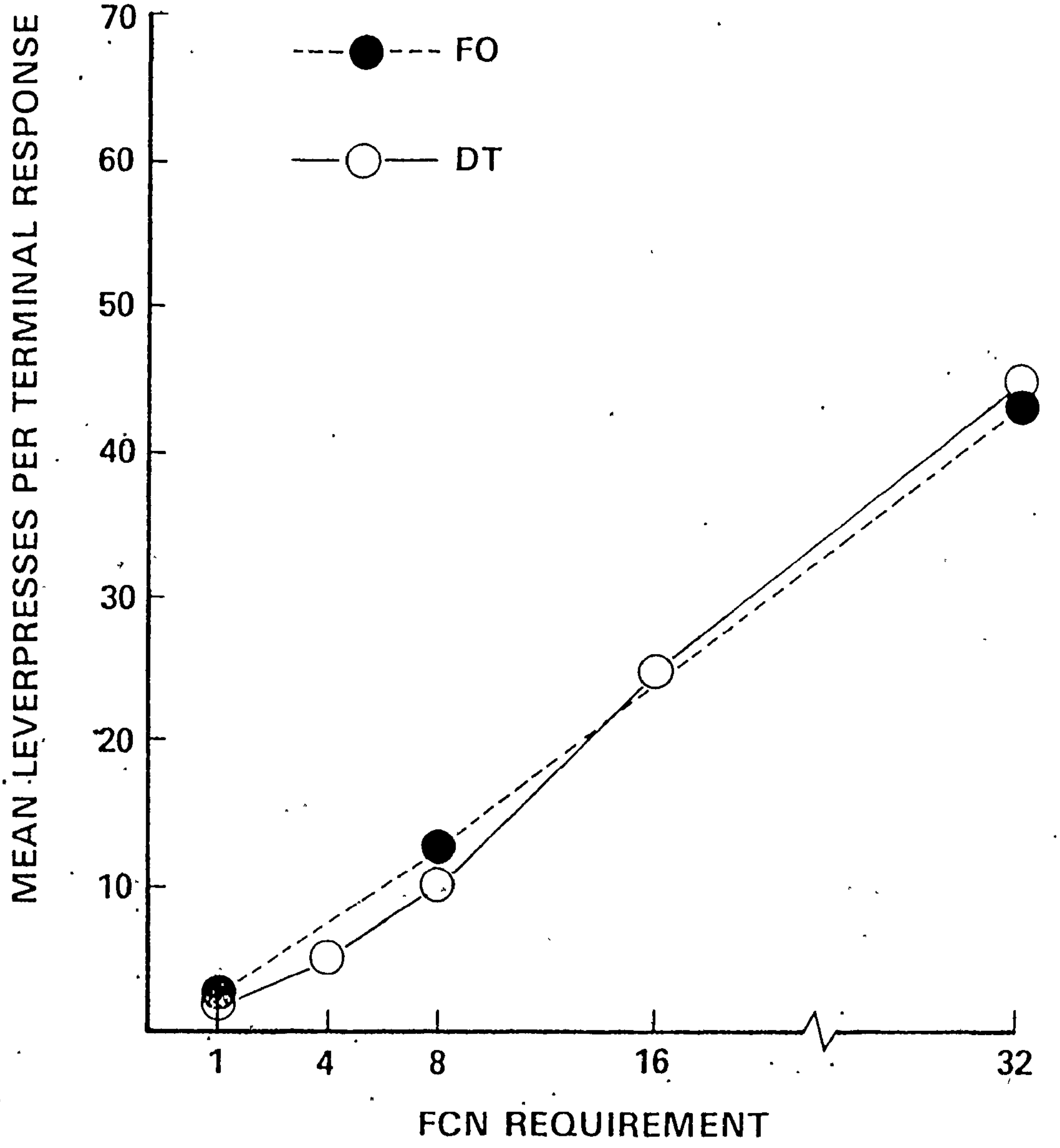


Figure 5

Day (1972a); Mean number of leverpresses per terminal response on Day 20 of acquisition as a function of FCN requirement and extinction condition.

were also a direct function of FCN requirement, and all groups showed an increase in response-unit length from acquisition to extinction. As Figure 6 indicates, the usual PREE with respect to the total number of leverpresses to extinction was obtained.

In Figure 7 is presented the mean number of terminal responses emitted in extinction as a function of FCN requirement and extinction procedure. As predicted by the response-unit hypothesis, there were no differences in the resistance of the response unit to extinction as a function of unit length in either extinction condition. The data also indicated that the omission of the ITI from extinction had no effect on the resistance of the unit to extinction: number of terminal responses emitted in extinction was the same whether or not the presence of the ITI was preserved in extinction.

These results provided additional support for the response-unit hypothesis in terms of the relationship between first-order unit length and resistance of the unit to extinction. The comparison of acquisition and extinction response-unit lengths also indicated that the relationship between unit size and FCN requirement was maintained during extinction.

It should be noted that these results are consistent with the findings of Mowrer and Jones and others concerning the relationship between response-unit length and number of units to extinction: If their method of calculating the number of units to extinction by dividing total leverpress output by acquisition leverpress requirement is applied to the data from the present study, a similar negatively accelerated decreasing relationship between unit length and number

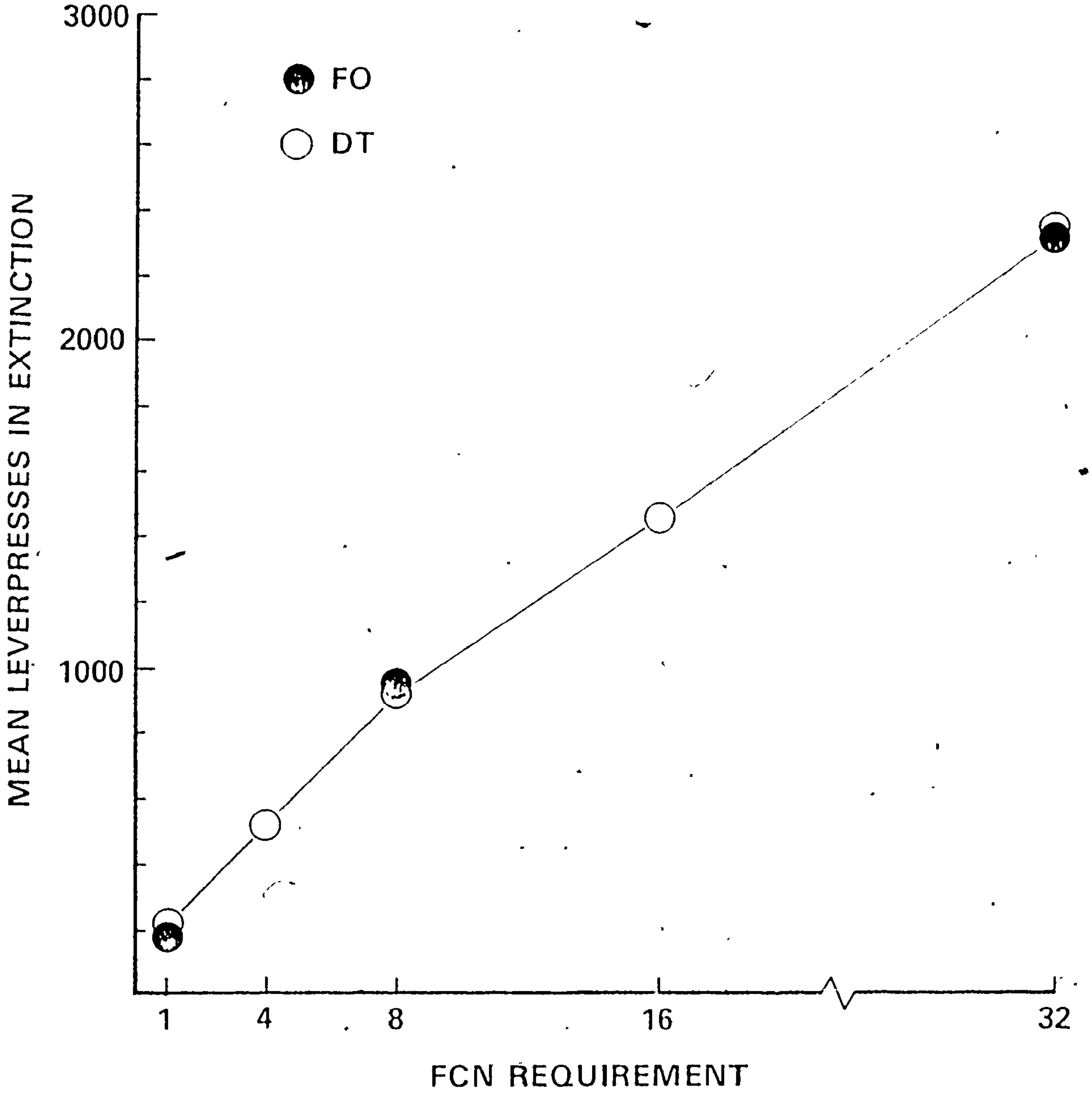


Figure 6

Day (1972a); Mean number of leverpresses to extinction as a function of FCN requirement and extinction condition.

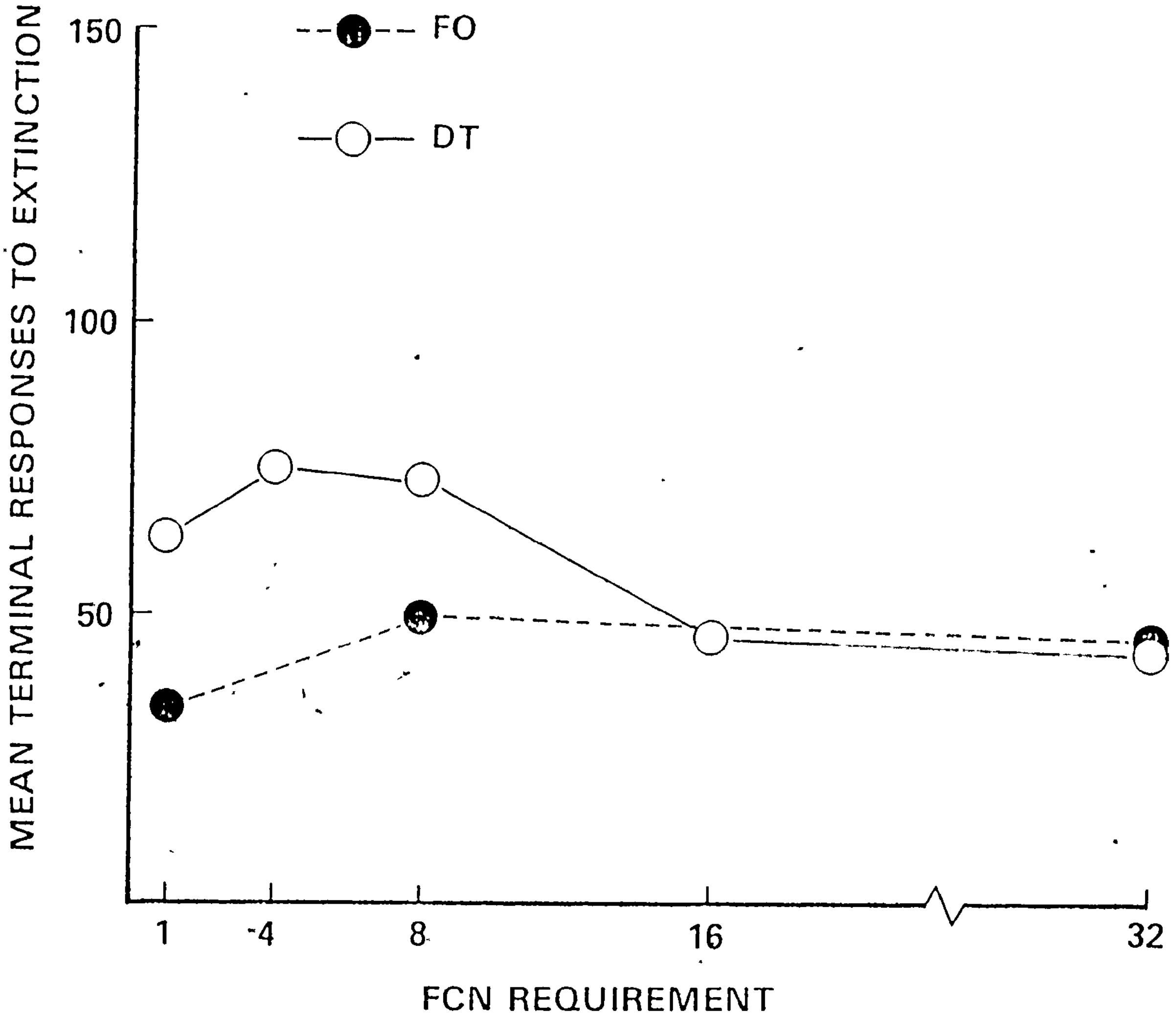


Figure 7

Day (1972a); Mean number of terminal responses to extinction as a function of FCN requirement and extinction condition.

of units to extinction is obtained.

In a subsequent experiment by Day (1973) an attempt was made to examine more directly the effect of second-order unit formation on resistance to extinction. The data provided by Day (1972b) were a fortuitous consequence of a training procedure which significantly retarded or prevented the elimination of nonreinforced terminal responses from the ratio. In the study under consideration, both first-order and second-order unit sizes were manipulated directly.

In Phase 1 of the study, separate groups of rats were trained for 20 days on FCN schedules requiring either 5 or 10 consecutive leverpresses for reinforcement. In Phase 2, FCN responding was placed on an FR schedule of reinforcement such that, for separate subgroups within each FCN condition, reinforcement followed every sequence meeting the FCN requirement, every second such sequence, or every third such sequence. For example, subjects in the FR 3(FCN 10) group were reinforced for every third terminal response which was preceded by 10 or more consecutive leverpresses. It should be noted that this schedule placed no restriction on the number of subcriterion FCN sequences which might precede reinforcement. In this factorial design, therefore, two first-order unit lengths (5 or 10) and three second-order unit sizes (1,2, or 3 first-order units) were combined. Acquisition was carried out under DT conditions for all groups; each terminal response produced a 10-sec. ITI during which the chamber was darkened and the lever retracted. Following Phase 2, all subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. As in acquisition, each terminal response produced a 10-sec. ITI.

Figure 8 presents the mean number of leverpresses per terminal response on the final day of Phase 2 training as a function of FCN and FR requirements. The number of leverpresses per terminal response was significantly greater in the FCN 10 than in the FCN 5 condition, and there was no significant effect of second-order unit size on the length of the first-order components, although there was a tendency in the FCN 10 groups for first-order units to be somewhat shorter in the FR 3 condition.

In extinction, first-order unit lengths were shorter than in acquisition, but the differences in first-order unit sizes as a function of FCN requirement were preserved. Figure 9 presents the mean number of leverpresses per terminal response in extinction as a function of FR and FCN requirements.

Figure 10 presents the mean number of terminal responses emitted in extinction by the several groups. As predicted, the number of first-order units emitted in extinction increased with FR requirement but was independent of FCN requirement. That is, the number of first-order units emitted was independent of the length of the unit, but increased with the size of the second-order unit.

If the formation and extinction of second-order units is analogous to that of first-order units, one would expect the number of second-order units emitted in extinction to be independent of the length of the second-order unit. In calculating the number of second-order units to extinction we are obliged, in the absence of a unique behavioural indicator of second-order unit completion, to have

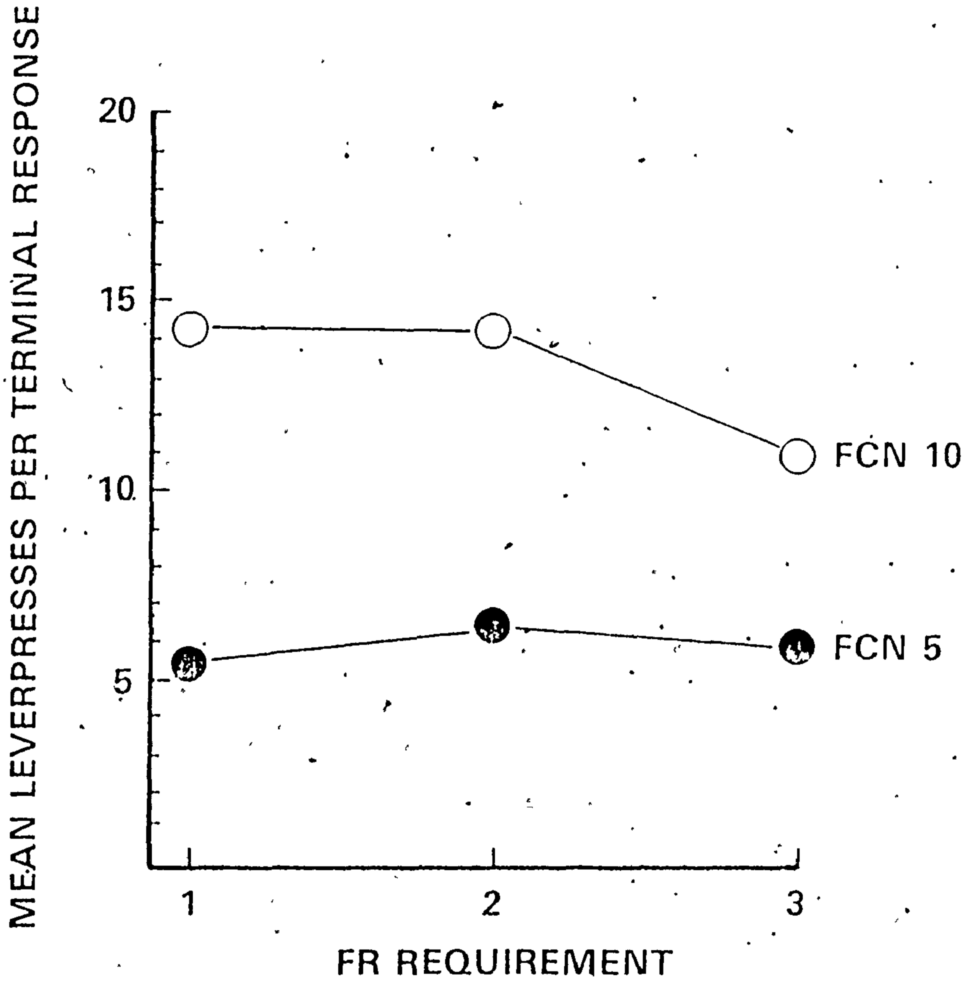


Figure 8

Day (1973); Mean number of leverpresses per terminal response on Day 30 of Phase 2 as a function of FCN and FR requirements.

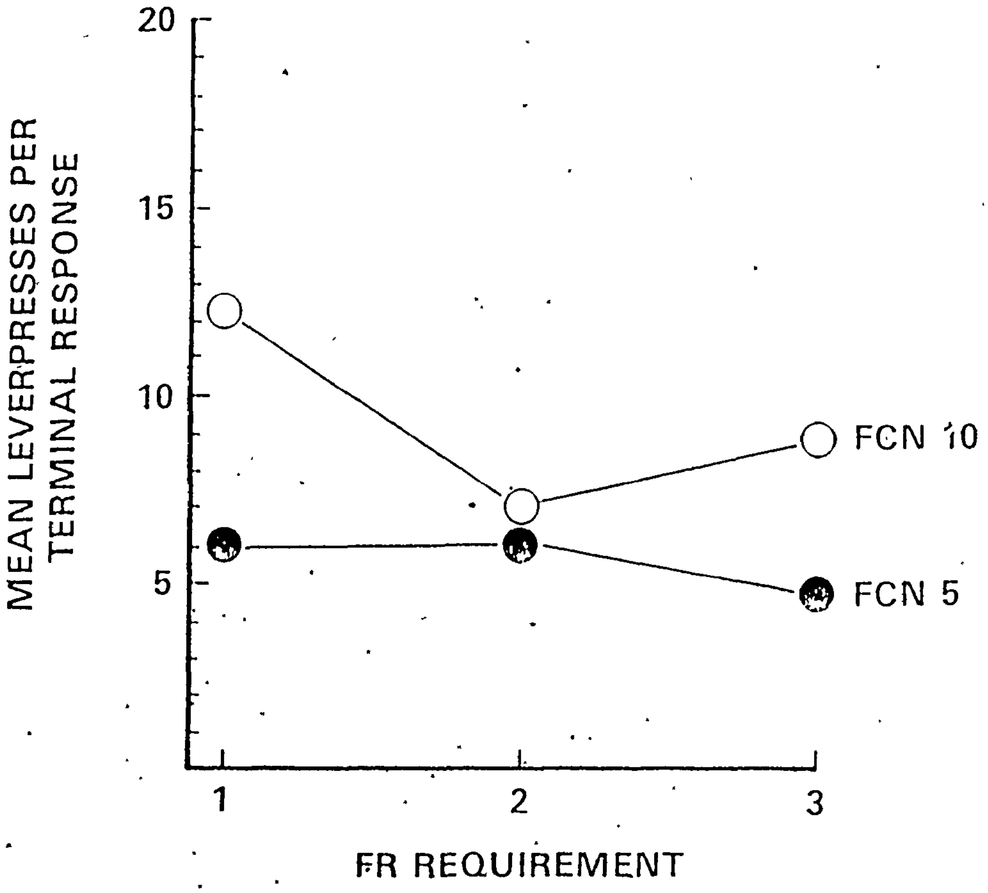


Figure 9

Day (1973); Mean number of leverpresses per terminal response in extinction as a function of FCN and FR requirements.

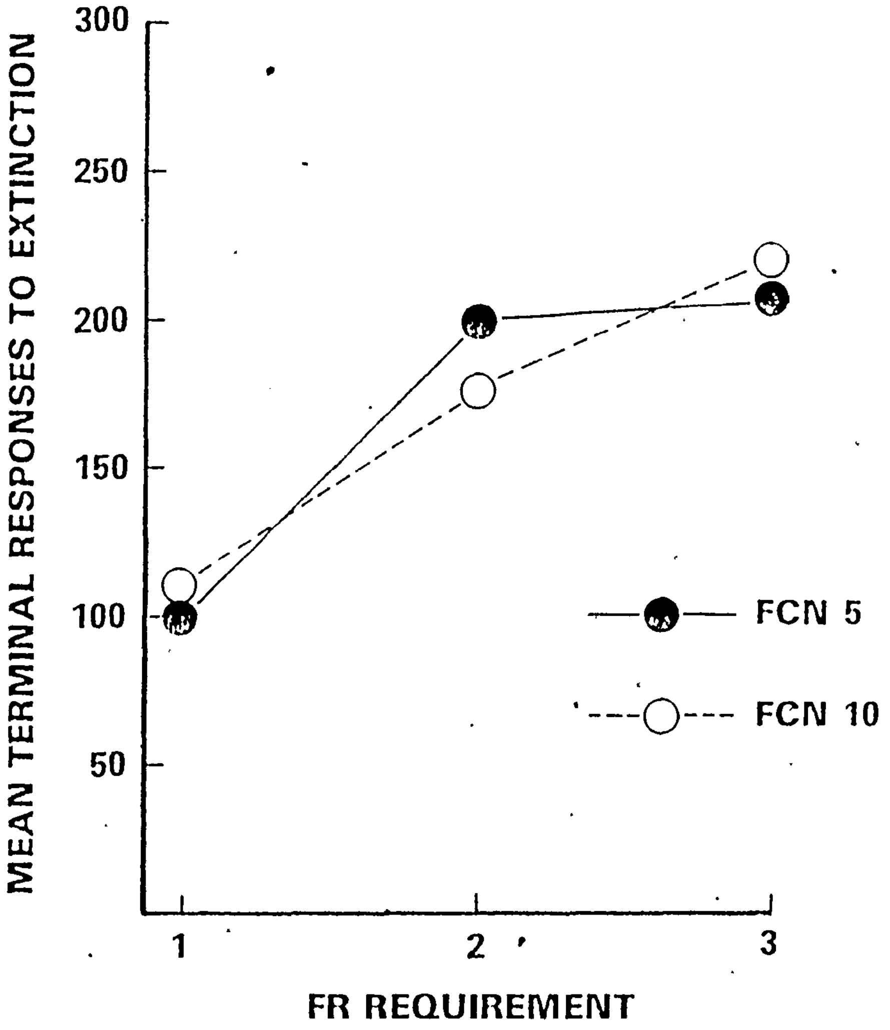


Figure 10

Day (1973); Mean number of terminal responses in extinction as a function of FCN and FR requirements.

recourse to the Mowrer and Jones procedure of dividing the number of first-order units emitted by the number of such first-order units in the second-order unit. This involves dividing the number of terminal responses emitted in extinction by the mean number of terminal responses per reinforcement at the end of Phase 2. The results of this calculation are presented in Figure 11 as a function of FCN and FR requirements. The number of second-order units emitted in extinction decreased with increases in second-order unit size. While this finding did not conform to our expectations based on the results of a similar calculation performed by Day (1972a), it is consistent with the results obtained by Mowrer and Jones with respect to first-order units.

The results of these three studies provided convincing evidence that the process of response-unit formation could provide an explanation of the operant PREE. In those cases in which the behaviour reinforced during acquisition consisted of a single homogeneous chain of individual responses terminating with a heterogeneous response, the data indicated that the mean length of response sequences emitted in extinction was directly related to the length of the sequence reinforced during acquisition. Such a relationship in the absence of external cues to response-unit completion strongly suggests that the subjects' behaviour in both acquisition and extinction was governed by the development of stimulus control over response-unit termination by proprioceptive stimuli associated with the execution of the required sequence. Furthermore, the independence of response-unit length and number of units to extinction, as measured

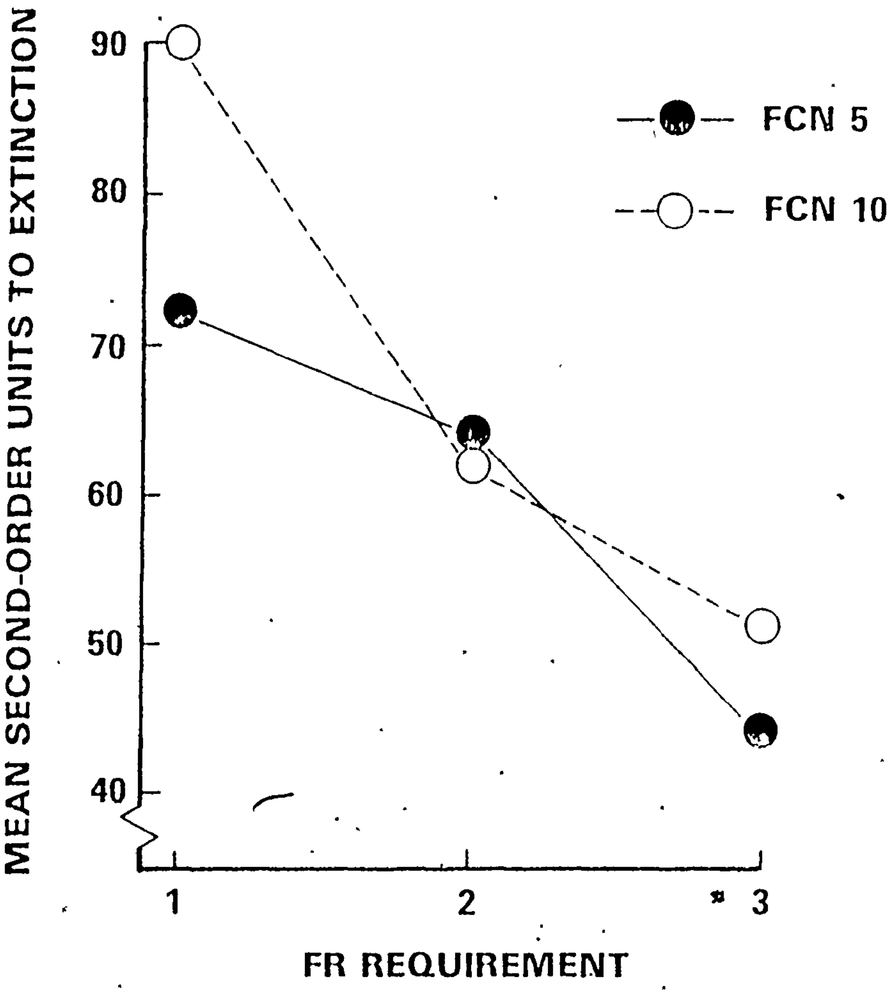


Figure 11

Day (1973); Mean number of terminal responses to extinction divided by mean number of terminal responses per reinforcement in Phase 2, as a function of FCN and FR requirements.

by the number of terminal responses, confirmed the prediction made by Mowrer and supported by Denny et al.

The data also suggested that the integration of behaviour into relatively cohesive units under the control of interoceptive stimuli was a process which may be independent of the complexity of the units of which these integrated sequences are composed. Specifically, we observed what can be described as a hierarchical, two-stage process of response-unit integration. In the first stage, individual responses were integrated into first-order units: homogeneous response sequences terminating in foodcup approach. In the second stage, these first-order units were themselves integrated into second-order units whose composition was dictated by the nature of the subject's entire behavioural output prior to reinforcement.

It is not unreasonable to argue, however, that the modified FR schedules employed in these studies are not the ideal ones in which to test the response-unit hypothesis. While it is difficult to argue that there is any one schedule whose characteristics invest it with unique theoretical significance, the early formulations of the response-unit hypothesis were directed at accounting for extinction performance generated by 'traditional' operant schedules, and FR in particular.

Despite their obvious family resemblance to FR, the FCN and FN schedules employed in these three experiments have characteristics which may result in behaviours which are functionally distinct from those generated by FR schedules. The most obvious and perhaps most important of these differences is the absence of reliable external cues to ratio completion. In FR schedules, reinforcement delivery is almost invariably accompanied by external stimulus changes, the most common of which are the auditory cues provided by the operation of the reinforcement dispenser. Given the salience and discriminability of these stimuli, especially in comparison with those internal stimuli which constitute the only obvious alternative source of reliable cues of reinforcement availability, it is not unlikely that the extent to which the termination of response sequences is under external rather than internal stimulus control is much greater in FR situations. To the extent that the development of internal stimulus control is necessary for, or even equivalent to, response-unit formation, FR performance could not adequately be characterized in such terms.

The possibility that response-unit analysis might be inappropriate for FR schedules is not reduced by the fact that the only study providing support for the response-unit hypothesis in the FR situation (Denny et al, 1957) employed an extinction procedure providing for continued presentation of external stimuli which had signalled reinforcement in acquisition, and which had probably come to exercise considerable discriminative control over terminal responding. The relationship between acquisition FR requirement and extinction response-unit length observed in that study might be attributed to the identity of acquisition and extinction schedules of external stimulus presentation rather than to integration of individual responses into autonomous functional units.

For these reasons, our research subsequent to the studies described above concerned response-unit formation under FR reinforcement.

The first issue to which we directed our attention was whether or not FR reinforcement, with the external cues to ratio completion which it usually provides, results in any discriminative control over terminal responding by proprioceptive stimuli. We were further interested in the extent to which the presence of such external cues in extinction might exert sufficient control over terminal responding to mask any conditioning of proprioceptive stimuli which might have taken place during acquisition. Since both external and internal sources of discriminative stimuli are temporally contiguous when the former are present during extinction, it is impossible to determine whether, and to what extent, the relationship between acquisition and extinction response-unit lengths observed in such situations is due to the integration of the ratio into a cohesive unit whose termination is controlled by stimuli inherent in the execution of the unit.

Our approach to this problem (Day and Platt, 1974) took the form of eliminating the temporal contiguity of external and proprioceptive cues to ratio completion by altering the schedule on which these external cues were presented in extinction. Such a procedure would provide an indication not only of the extent to which proprioceptive stimuli controlled terminal responding, but also of the relative importance of external stimulus control when such stimuli were available in extinction.

Two groups of rats were given 10 days of training on DT FR schedules requiring either 5 or 10 leverpresses for reinforcement. Each reinforcement was accompanied by a 10-sec. IRI during which the lever was retracted and the chamber darkened. Following training, subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. Half of the subjects in each FR group were extinguished with the ITI presented on the same schedule as in acquisition; i.e. following every 5th press for subjects in the FR 5 group, and following every 10th press for subjects in the FR 10 group. For the remaining subjects in each FR group, the ITI was presented on the alternative schedule; i.e. following every 10th press for subjects in the FR 5 group, and following every 5th press for subjects in the FR 10 group. The design was therefore a 2 x 2 factorial combining two levels of acquisition and extinction FR.

Table 1 presents the results of this experiment in terms of the mean number of leverpresses per terminal response in extinction, the mean number of terminal responses to extinction, and the mean number of total leverpresses to extinction. Our information concerning the source and strength of stimulus control over response-unit termination derives from the data concerning the mean number of leverpresses per terminal response. To the extent that terminal responding is under the control of external stimuli, extinction response-unit lengths should approximate the extinction FR requirement. Interoceptive control would be indicated by the tendency of extinction response-unit lengths to approximate the acquisition FR.

The data provided evidence for both sources of control. Regardless of training, subjects extinguished on FR 10 schedules emitted response sequences which were significantly longer than those emitted by subjects extinguished on FR 5 schedules. Conversely, subjects trained on FR 10 schedules of reinforcement emitted sequences

Table 1

Day and Platt (1974); Mean number of leverpresses per terminal response in extinction, mean number of terminal responses in extinction, and mean number of leverpresses in extinction as a function of acquisition and extinction FR requirements.

	Group (Acquisition FR-Extinction FR)			
	5-5	5-10	10-5	10-10
Mean leverpresses per Terminal Response	5.51	7.27	6.09	8.83
Mean Terminal Responses	90.00	69.38	90.25	76.92
Mean Leverpresses	501.00	480.61	545.67	610.80

which were significantly longer than those emitted by subjects trained on FR 5 schedules of reinforcement, regardless of the schedule on which extinction took place.

These data also suggest that the effect of external stimuli was greater than that of internal stimuli, a finding which was not unexpected in view of the salient, multimodal nature of the ITI. What is striking is that evidence of interoceptive control appeared in a situation in which the external cues were not only extremely salient, but actually involved a period during which the only alternative response to foodcup approach was prevented. In the case of subjects shifted from FR 10 to FR 5 in extinction, units longer than the extinction FR could only occur if terminal responding was actually withheld during the ITI.

A second striking result of this study concerns the number of terminal responses emitted in extinction. Our expectations concerning the resistance of the response unit to extinction had been that: 1) there would be no difference in the number of terminal responses emitted in extinction by subjects trained and extinguished at the same FR value; 2) if there were no interoceptive control over terminal responding, or if external control predominated, then there would likewise be no difference between shifted groups in the number of terminal responses, and resistance to extinction in these groups would be essentially identical to that in the unshifted groups; 3) if interoceptive control predominated, or were extensive, there would be decreased resistance to extinction in the shifted groups as a result of generalization decrement, such that the groups shifted from FR 5 to FR 10 would be less resistant to extinction than the group shifted from FR 10 to FR 5, with both shifted groups showing less resistance to extinction than the unshifted groups.

The results, however, indicated that subjects extinguished on FR 10 schedules of ITI presentation emitted significantly fewer terminal responses in extinction than subjects extinguished on FR 5 schedules of ITI presentation, regardless of acquisition FR. This result was difficult to explain in terms of any of the theories or hypotheses we have discussed. It was clearly inconsistent with the prediction of the response-unit hypothesis, since differences in resistance to extinction were apparent between subjects trained and extinguished at the same FR value as well as between shifted subjects. It likewise could not be accounted for in terms of generalization decrement, since the effects of extinction FR were independent of acquisition schedule. Furthermore, it did not appear that either sequential or frustration theory would make any unique predictions concerning the effect of extinction ITI schedule on resistance to extinction.

While this experiment was in progress, we learned of a similar study later reported by Overmann and Denny (1974). In this study, three groups of rats were trained to leverpress on FO FR 10 schedules of reinforcement, and were then extinguished to a criterion of 10 min. without a leverpress, with the sound of the empty food magazine accompanying every 6th, 10th, or 14th press, respectively. The authors reported that while the mean number of leverpresses per terminal response, and the mean number of individual leverpresses to extinction increased with extinction FR, the number of terminal responses emitted was identical for the three groups.

It was primarily the results of this experiment, together with those of Day and Platt (1974) which determined the direction taken by subsequent research. It seemed clear that while the evidence indicated the existence of response units and their role in determining resistance to extinction, the relationship between the length of these units, the conditions under which extinction occurs, and the resistance of the unit to extinction were not as clear as Mowrer and Jones had envisioned and Denny _et_ _al_ had suggested.

The Thesis in Outline

The experiments to be reported below constitute a selected sample from a larger body of research concerning the acquisition and extinction of response units under FR reinforcement schedules. These studies are unified by a common concern with the relationship between acquisition response-unit length and number of response units emitted in extinction--particularly with respect to variations in the extinction scheduling of stimuli which signalled response-unit completion (and reinforcement) in acquisition.

During acquisition, response-unit completion and reinforcement delivery may be accompanied by a variety of stimuli. These include auditory stimuli provided by the operation of the food dispenser, and proprioceptive and other internal consequences of response-unit execution. If acquisition takes place under ITI conditions, the stimuli accompanying response-unit completion also include those events unique to the ITI, such as lever retraction and darkening of the chamber. It was suggested earlier that the continued presence in extinction of external cues for ratio completion in the study by Denny et al might have influenced extinction performance. Evidence of such an effect was obtained by Day and Platt (1974) and by Overmann and Denny (1974). The effects of external stimuli on extinction performance may be determined by several factors--notably the scheduling of such stimuli in acquisition and their scheduling in extinction. Furthermore, extinction performance may be affected by the absence of external stimuli which were present in acquisition. In the studies to be reported below each of these variables is examined.

One of the most common measures of resistance to extinction is the number of individual responses emitted. The data reported by Overmann and Denny clearly indicate that this measure of extinction performance is affected by the schedule on which external stimuli associated with reinforcement are presented in extinction. From the point of view of response-unit analysis, however, the total number of individual responses emitted in extinction is not a primary datum. According to the response-unit hypothesis, extinction performance can be both more adequately characterized and more readily interpreted in terms of the length and the number of response units emitted. Any manipulation which alters the total number of responses emitted in extinction might do so by altering either or both of these response-unit parameters. In the studies that follow, therefore, the dependent variables are those familiar from previous response-unit studies, i.e., mean number of leverpresses per terminal response, mean number of terminal responses, and mean number of leverpresses emitted in extinction.

Because of the number and complexity of the issues and hypotheses considered in these studies, it may be useful at this point to present, in outline form, the general plan of the five experiments which comprise the thesis.

In Experiment 1 the issue addressed was the discrepancy between the studies of Day and Platt (1974) and Overmann and Denny (1974) in the relationship observed between number of response units emitted in extinction and the extinction scheduling of external stimuli associated with reinforcement during acquisition. The results of this experiment suggested that the discrepancy could adequately be accounted for in terms of differences in the criterion for terminal response occurrence employed in the two studies, and that the criterion employed by Day and Platt was the more appropriate.

In Experiment 2, an incomplete factorial design was employed to examine the relationship between acquisition response-unit length and the length and number of response units emitted in extinction as a function of the procedure (whether DT or FO) employed in acquisition and extinction. The results of this experiment indicated that when extinction took place under FO conditions, i.e. in the absence of external cues to response-unit completion, the number of response units emitted in extinction did not vary with acquisition FR requirement, regardless of the procedure employed in acquisition. Under DT extinction conditions, the number of units emitted was greater than under FO conditions, and decreased with increasing acquisition response-unit length.

Several possible explanations for the differences between DT and FO extinction conditions, and between FR groups within the DT condition were considered. These hypotheses revolved around the possible role of ITI presentations:

1. These differences may have resulted from secondary reinforcement of the unit by ITI presentation, the effectiveness of which is a function of the acquisition reinforcement schedule with which the

ITI was associated, or of the schedule on which the ITI was presented in extinction.

2. These differences may have resulted from generalization decrement caused by differences between acquisition and extinction schedules of ITI presentation.

3. In Experiment 2, the total number of leverpresses emitted in extinction as a function of acquisition FR requirement was very similar under both FO and IT conditions. This suggested that observed differences between conditons, and between FR groups within the IT condition might be explained without reference to response units. Perhaps FR reinforcement establishes a fixed leverpress reserve whose size is independent of the extinction conditions under which it is exhausted. According to this leverpress-constancy hypothesis, differences between groups or conditions in the length and number of leverpress sequences emitted in extinction result from analogous differences in the frequency with which terminal responses are elicited during exhaustion of the reserve.

Experiments 3-5 eliminated these hypotheses, and, together with data derived from analyses of within-group performance, suggested additional hypotheses. In Experiments 3 and 4 the schedule of ITI presentation in extinction was varied between groups of subjects trained at the same FR value under IT conditions. In Experiment 3, subjects trained at FR 1 were shifted in extinction to schedules of presentation which equalled or exceeded FR 1. In Experiment 4, subjects trained at FR 20 were shifted to extinction schedules of ITI presentation which equalled or were shorter than FR 20. In both experiments mean extinction response-unit lengths increased, and the number of units decreased, as the frequency of ITI presentation in extinction decreased. These results were incompatible with an explanation of the results of Experiment 2 in terms of either generalization decrement, or differential secondary reinforcement of the unit by the ITI as a function of the acquisition schedule with which it was associated. Furthermore, the observation of a direct relationship between mean extinction response-unit lengths and the total number of leverpresses emitted in extinction eliminated the total-leverpress hypothesis.

Two additional hypotheses concerning differences between IT and FO conditions in the relationship between response-unit length and resistance to extinction were examined: The first suggested that the relationship between response-unit length and resistance to extinction is determined by the mode of stimulus control over response-unit termination: When response-unit termination is under the control of external stimuli, such as the ITI, unit length and resistance to extinction are inversely related; when unit termination is controlled by internal stimuli, unit length and resistance to extinction are independent.

A second hypothesis was based on an analysis of correlations within FR groups between mean extinction unit lengths and resistance to extinction. This unit-length hypothesis suggested that the number of response units emitted in extinction is a direct function of the length of the unit reinforced during acquisition, and an inverse function of the mean length of the units emitted in extinction, regardless of the mode of stimulus control over response-unit termination. Differences between DT and FO extinction conditions are attributed to differences in mean extinction unit lengths under these two conditions.

Experiment 5 constituted a partial test of these hypotheses in which groups of subjects trained at different FR values under DT conditions were extinguished under either internal or external stimulus control of response-unit termination, but with mean extinction unit lengths approximately equated under the two conditions. The results indicated that performance was similar under both conditions, contrary to the mode-of-control hypothesis, but consistent with predictions derived from the unit-length hypothesis.

The unit-length hypothesis is then elaborated on the basis of data from several of these studies, and the extent to which extinction performance in these studies is consistent with the hypothesis, and with a modified version of Mowrer and Jones' (1945) response-unit hypothesis will be examined in detail.

In Experiment 1, the problem under scrutiny was the source of the discrepancy between the results of Day and Platt (1974) and Overmann and Denny (1974) concerning the relationship between extinction FR value and resistance of the response unit to extinction. While the latter had reported the independence of response-unit length and resistance to extinction predicted by the response-unit hypothesis, the former had suggested that resistance of the unit to extinction was inversely related to its length.

One difference between the studies which suggested itself as a possible source of the discrepancy was the criterion for a terminal response. Both Denny et al and Overmann and Denny had recorded every approach to the foodcup as a terminal response. In the Day and Platt study, however, only those approaches to the foodcup immediately preceded by leverpresses were considered terminal responses. Thus only the first of a series of consecutive approaches was recorded. This procedure had the apparent virtue of both eliminating the problem posed by subjects who bobbed in and out of the foodcup on a single visit, and of operationalizing the notion that only approaches which terminated response sequences (referred to as headpokes, or HPs) were terminal responses. The Overmann and Denny results, however, suggested that approaches not preceded by leverpresses (zero-pokes, or OPs) might also have functional significance. The discrepancy between the two studies could be accounted for if the number of OPs to extinction increased with extinction FR in such a manner as to counteract the decrease in HPs with increasing extinction FR.

To examine this possibility, a study similar in conception and outline to that reported by Overmann and Denny (1974) was conducted. Three groups of rats trained to leverpress on DT FR 10 schedules of reinforcement were extinguished such that the ITI followed every 5th, 10th, or 15th press, respectively. During extinction, HPs and OPs were recorded separately.

Experiment 1

METHOD

Subjects

The subjects for this experiment were 11 male and 74 female hooded rats, approximately 120 days old at the beginning of training, obtained from the breeding colony of the Department of Psychology at McMaster University. The experiment was conducted in three replications; 11 males and 12 females participated in Replication 1, 29 females participated in Replication 2, and 33 females participated in Replication 3.

For approximately three weeks prior to, and for the duration of each replication, subjects were fed a single daily ration sufficient to maintain them at approximately 85% of ad lib weight. Session reinforcements were supplemented with Purina Rat Chow to complete the daily ration.

Apparatus

The apparatus consisted of four Lehigh Valley rodent test chambers enclosed in Lehigh Valley sound-insulated chests. On one wall of each chamber a 3.75-cm. circular hole provided access to a foodcup mounted behind the wall. Entry of a rat's head into the foodcup was recorded by means of a photobeam passed across the hole approximately 1.0 cm. behind the wall. A BRS-Foringer pellet dispenser delivered .045-gm. Noyes pellets into the foodcup. Lehigh

Valley retractable levers were mounted approximately 6.5 cm. to either side of the hole, 5.0 cm. above the floor. Only the right-hand lever, calibrated for a static weight of 22 gm. was used. Chamber illumination was provided by a 2.8-W incandescent bulb mounted 17.5 cm. above the foodcup. Experimental control and data collection were accomplished by a Digital Equipment Corporation PDP-8/E computer.

Procedure

Subjects in each replication were divided into three groups of equal size such that the mean body weights of the groups were approximately equal. In Replication 1, group size was 7, with 2 subjects (both female) designated to replace subjects discarded due to apparatus failure, illness, or failure to complete pretraining. In Replication 2, group size was 9, with 2 subjects designated as replacements. Group size in Replication 3 was 10, with 3 subjects designated as replacements.

Pretraining consisted of four sessions of magazine training followed by three or more sessions of CRF. During each magazine training session, subjects received 30 noncontingent reinforcements, each consisting of two .045-gm. Noyes pellets, at intervals ranging from 10 to 60 seconds with a mean interval of approximately 45 seconds. Each reinforcement was accompanied by a 10-sec. ITI during which the chamber was darkened.

Following magazine training, subjects received several sessions of CRF. During each 30-reinforcement session, a leverpress produced two .045-gm. Noyes pellets and a 10-sec. ITI during which the chamber was darkened and the lever retracted. In Replications 2 and 3 the number of CRF sessions was four for all subjects with the exception of four subjects in Replication 3 who received only three CRF sessions due to experimenter error. Subjects in Replication 1 received three CRF sessions with the exception of four subjects (all male) who received five CRF sessions, but received no prior magazine training.

Following pretraining, all subjects received 10 daily 30-reinforcement sessions on an FR 10 schedule of reinforcement. Each reinforcement consisted of two Noyes pellets, and was accompanied by a 10-sec. ITI during which the chamber was darkened and the lever retracted.

At the completion of FR 10 training, subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. During extinction one group of subjects received the ITI following every 5th press (FR 5 group), a second group received the ITI following every 10th press (FR 10 group), and the third group received the ITI following every 15th press (FR 15 group).

Results

By the end of acquisition, discriminative control by the ITI over terminal responding was nearly complete. The mean number of terminal responses (HPs + OPs, referred to as TPs) per ratio on Day 10 of acquisition was 1.08. This dropped to 1.005 if only HPs were considered. Of the 75 subjects, Only 10 had over 1.20 TPs per ratio, and only 4 made over 2.33 TPs per ratio. A Groups x Replications ANOVA performed on the log-transformed Day 10 session times revealed neither Group nor Replication differences. All groups were thus equated for acquisition performance prior to extinction.

Figure 12 presents the mean extinction response-unit lengths (lever presses per terminal response) as a function of extinction FR. Separate calculations were made using either TPs or only HPs in the denominator. For comparison, the figure also includes the mean response-unit lengths obtained by Overmann and Denny using the TP measure. For both terminal response measures, mean response-unit length was an approximately linear, increasing function of extinction FR. Mean response-unit lengths for the HP measure corresponded well to the extinction ratio requirement, while TP response-unit lengths were considerably shorter, and corresponded to those observed by Overmann and Denny using this measure. Separate Groups x Replications ANOVAs revealed the effect of extinction FR to be significant beyond the .001 level for both TP and HP response-unit lengths: *Fs*(2,66) = [illegible] and 67.11. In neither case was the Replications effect or its interaction with Groups significant. This, and all subsequent ANOVAs to be reported, were performed on the log-transformed scores, in order to correct for an approximately linear increase in variance with group mean.

With respect to resistance to extinction, Figure 13 presents the mean number of terminal responses emitted in extinction, ±1 standard error, as a function of extinction FR. Separate functions

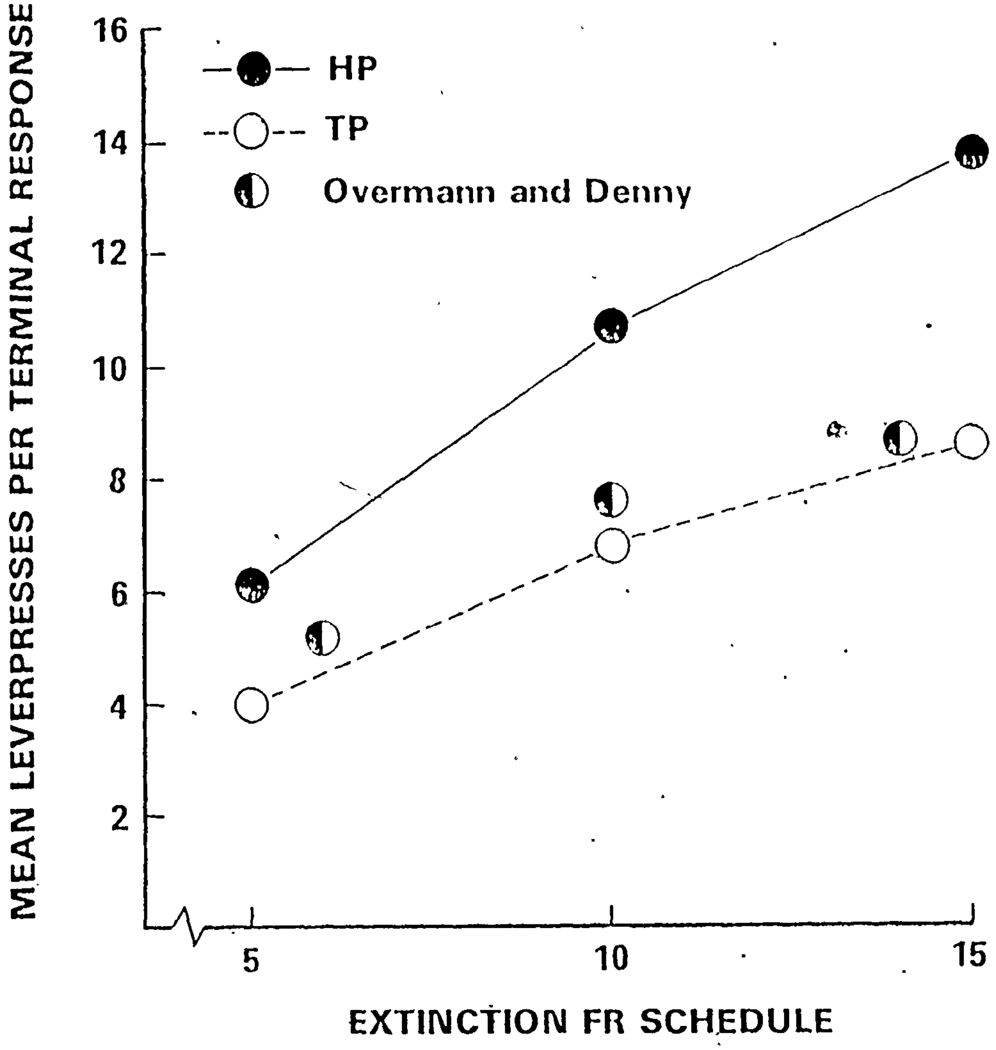


Figure 12

Experiment 1; Mean number of leverpresses per terminal response in extinction as a function of extinction FR schedule.

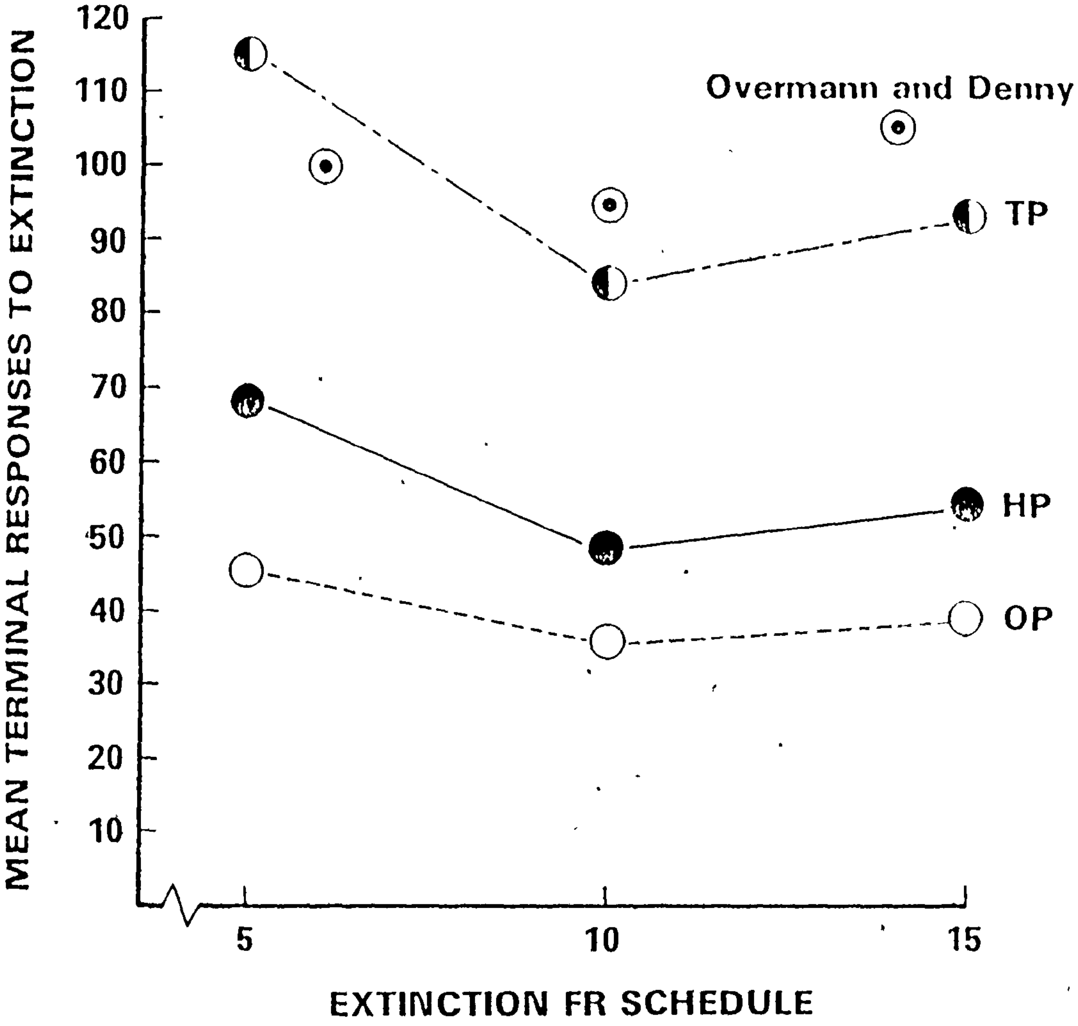


Figure 13

Experiment 1; Mean number of terminal responses in extinction as a function of extinction FR schedule.

are plotted for TP, HP, and OP measures, as well as for the TP data obtained by Overmann and Denny. As was the case in the Day and Platt study, mean number of HPs emitted in extinction was greater for the FR 5 than for the FR 10 group. In addition, the FR 10 group emitted fewer HPs than did the FR 15 group. A Groups x Replications ANOVA showed both the Groups and Replications main effects to be significant at the .05 level: *Fs*(2,66) = 4.11 and 6.30, respectively. The interaction did not reach significance. A subsequent trend test found only the quadratic component of the Groups effect to be significant: *F*(1,66) = 4.27, *p* < .05.

While the pattern of HP and OP means was similar, there were no significant differences between Groups or Replications in the latter case. It was also apparent that the variability in the OP measure was considerably greater than in the HP measure; despite the fact that the OP means were lower than the HP means, the error mean square for the OP ANOVA was four times that for the HP ANOVA.

The pattern of means described for the HP and OP measures was, of course, preserved in the TP measure. In this case, however, only the main effect of Replications was significant; *F*(2,66) = 5.84, *p* < .01. It is apparent from the figure that the TP data from the present study correspond fairly well to those obtained by Overmann and Denny, though the overall resistance to extinction appeared to be slightly lower in the present study.

Resistance to extinction of the leverpressing response is presented in Figure 14 as a function of extinction FR for both the present study and that by Overmann and Denny. In both cases the

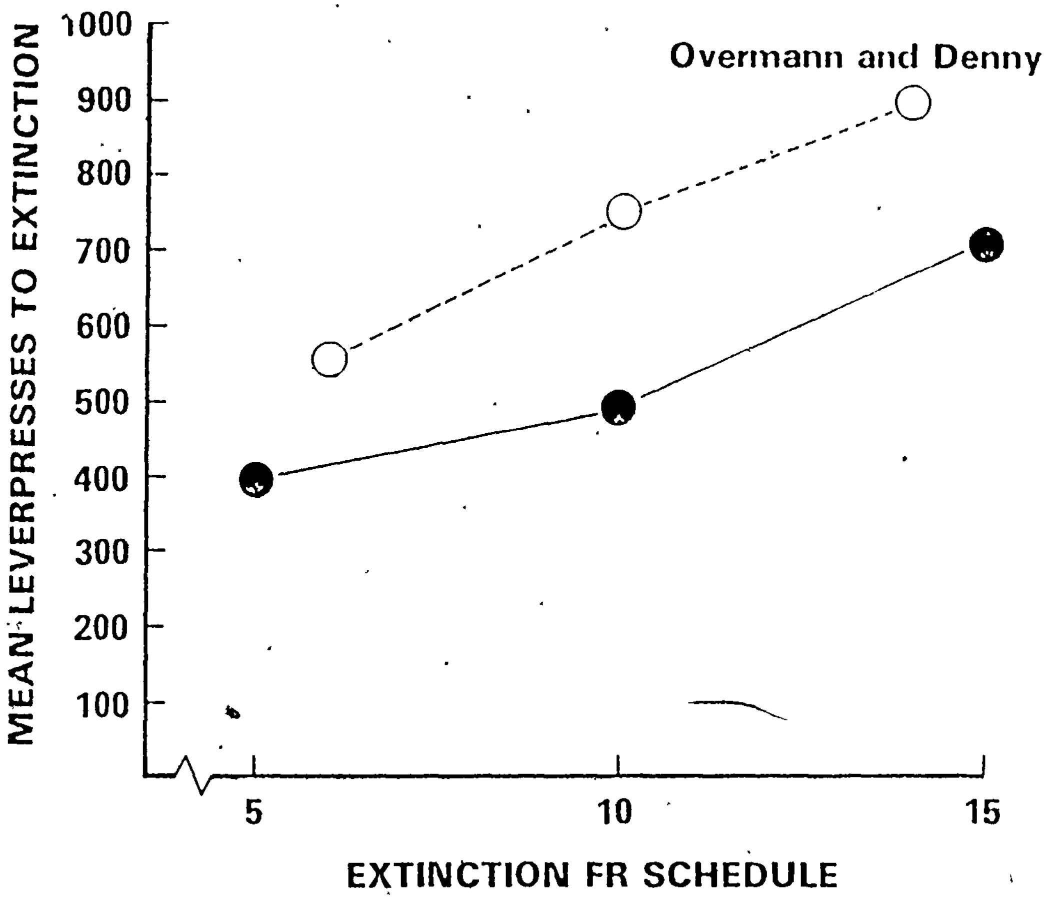


Figure 14

Experiment 1; Mean number of leverpresses to extinction as a function of extinction FR schedule.

number of leverpresses emitted in extinction increased with increasing extinction FR. In the present study, both the Groups and Replications main effects were significant at the .01 level; Fs(2,66) = 19.06 and 7.25, respectively. The interaction did not approach significance. As was the case with the TP measure, overall resistance to extinction was somewhat lower in the present study than in the Overmann and Denny study.

Discussion

It is readily apparent from Fig. 12 that the schedule of ITI presentation in extinction was highly effective in manipulating the mean length of extinction response units. The differences between extinction response-unit lengths (based on the HP measure) and extinction FR are quite small. The differences which do occur in the FR 5 and FR 15 group are consistent, however, with the existence of some interoceptive control over terminal responding: Subjects in both groups emitted response units whose mean length fell between the acquisition and extinction FR requirements. Nevertheless, terminal responding in all groups was predominantly controlled by the occurrence of the ITI.

The data presented in Fig. 13 concerning the number of terminal responses emitted in extinction support the hypothesis that the discrepancy between Day and Platt (1974) and Overmann and Denny (1974) with respect to this measure is due to the recording by the latter of foodcup approaches which did not terminate response sequences. It appears, however, that the absence of significant between-group differences in the TP measure is not due to the existence of diametrically opposed relationships between its HP and OP components and extinction FR, as originally suggested. Rather, it appears that it is the relatively large within-group variability in the number of OPs emitted which is responsible for the disappearance from the TP measure of the significant differences obtained with the HP measure. As we noted above, the within-group variance of the OP measure was four times that of the HP measure, despite the fact that the mean number of OPs emitted was consistently lower than the mean number of HPs emitted.

The relatively close correspondence between the TP data reported by Overmann and Denny and those obtained in the present study lends credence to the view that both sets of data can be accounted for in terms of the differing properties of the HP and OP measures of terminal responding. This resolution of the apparent discrepancy between the two studies does not, however, shed any light on the significance of the difference between the two measures of terminal responding. It is possible, for example, that OPs are simply the result of repeated activation of the recording mechanism on single visits to the foodcup. The existence of considerable idiosyncracy in foodcup-approach topography might well explain the large between-subject variability in this measure. Such a view is consistent with the observation that terminal responses within the ratio are largely eliminated by the end of acquisition. It seems unlikely that subjects who have so obviously discriminated the occasions on which reinforcement is available enter the foodcup.

without prior leverpressing in the expectation of reinforcement. From the point of view of response-unit analysis, the functional significance of approaches which do not terminate response sequences is unclear.

Debate over the functional significance of OPs leaves unresolved the question of the source of the relationship between number of HPs emitted in extinction and extinction FR which was observed both in the present study and by Day and Platt (1974). The results from the latter study suggested that differences in the number of HPs (which we will subsequently refer to as terminal responses) emitted in extinction depended primarily on the conditions under which extinction occurred, and not on the length of response sequences reinforced during acquisition. Furthermore, neither the present study nor that by Day and Platt provided for a comparison between the extinction performance of partially and continuously reinforced subjects. While Overmann and Denny did include a CRF group, their observation that partially and continuously reinforced subjects emitted the same number of foodcup approaches in extinction is difficult to interpret in view of their use of the TP measure of terminal responding.

These considerations made it imperative that extinction performance under several conditions be examined across a range of acquisition FR values including FR 1 (CRF). Experiment 2, to be described below, actually consisted of three studies, which, while conducted separately, form the cells of an incomplete 2 x 2 x 4 factorial design combining four acquisition FR values (1, 5, 10, or 20), two acquisition procedures (FO or DT), and two extinction procedures (FO or DT). The four cells missing from the design are those involving subjects trained under FO conditions at the four FR values and extinguished under DT conditions.

Experiment 2

Subjects

The subjects for this experiment were 132 naive female hooded rats, 120-150 days old at the beginning of training, which were obtained from the breeding colony of the Department of Psychology at McMaster University. For three weeks prior to, and throughout the study, subjects were fed a single daily ration sufficient to maintain them at approximately 85% of ad lib weight. Session reinforcements were supplemented with Purina Rat Chow to complete the daily ration.

Of the 132 subjects, 44 participated in the DT-DT condition, 44 in the DT-FO condition, and 44 in the FO-FO condition. Five subjects in the DT-DT condition were discarded due to illness, apparatus failure, or experimenter error; two each from the FR 1 and FR 5 groups, and one from the FR 20 group. The FR 1 and FR 5 groups therefore contained 9 subjects each, the FR 10 group 11 subjects, and the FR 20 group 10 subjects. In the DT-FO condition, one subject was discarded from the FR 20 group due to apparatus failure, resulting in an n of 11 for all but the FR 20 group which had an n of 10. One subject in the FR 5 group of the FO-FO condition was discarded due to apparatus failure, resulting in an n of 11 in all groups but the FR 5 group, which had an n of 10.

Apparatus

The apparatus employed in this experiment was that described for Experiment 1.

Procedure

Subjects in each experimental condition were divided into four numerically equal groups such that the mean body weights of the groups were approximately equal.

Pretraining for all subjects consisted of four sessions of magazine training and four sessions of CRF. These sessions were conducted in a manner identical to that described in Experiment 1, with the exception that subjects in the FO-FO condition did not receive a 10-sec. ITI following each reinforcement.

Following pretraining, the four groups of subjects in each condition received 10, 30-reinforcement sessions on FR reinforcement schedules with values of 1, 5, 10, or 20 leverpresses, respectively. For subjects in the IT-IT and IT-FO conditions, reinforcement was accompanied by a 10-sec. ITI during which the lever was retracted and the chamber darkened. In the FO-FO condition, the chamber was continuously illuminated and the lever continuously available. In all three conditions, reinforcement delivery was accompanied by the auditory cues produced by the operation of the food delivery mechanism.

Following FR training, subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. In the IT-IT condition, each ratio completion was followed by the 10-sec. ITI. In the IT-FO and FO-FO conditions, extinction occurred under FO conditions, with the lever continuously available, and the chamber continuously illuminated.

Results

Acquisition performance as a function of FR requirement was virtually identical in all conditions. Figure 15 presents the mean number of leverpresses per terminal response as a function of FR requirement and experimental condition on Day 10 of acquisition. For all groups, mean number of leverpresses per terminal response closely approximated the FR requirement.

Figure 16 presents the mean number of leverpresses per terminal response in extinction, ±1 standard error, as a function of FR requirement and experimental condition. In all conditions, mean number of leverpresses per terminal response increased with FR requirement. In the absence of any overlap between groups, data from the DF-DF groups were not statistically evaluated. In the remaining conditions, F tests were conducted on the log-transformed scores, to correct for an approximately linear increase in variance with group mean. The effect of FR requirement was significant in both cases; $F(3,39) = 25.73$, $p < .001$ in the DF-FO condition; and $F(3,39) = 19.21$, $p < .001$ in the FO-FO condition.

In the DF-DF condition, extinction response-unit lengths matched FR requirement in all but the FR 20 group, whose mean unit length fell slightly below the requirement. Mean response-unit lengths in the DF-FO and FO-FO conditions exceeded the ratio requirement; the absolute difference between acquisition and extinction response-unit lengths increased with FR requirement, while the ratio of extinction to acquisition response-unit length decreased with increasing FR requirement.

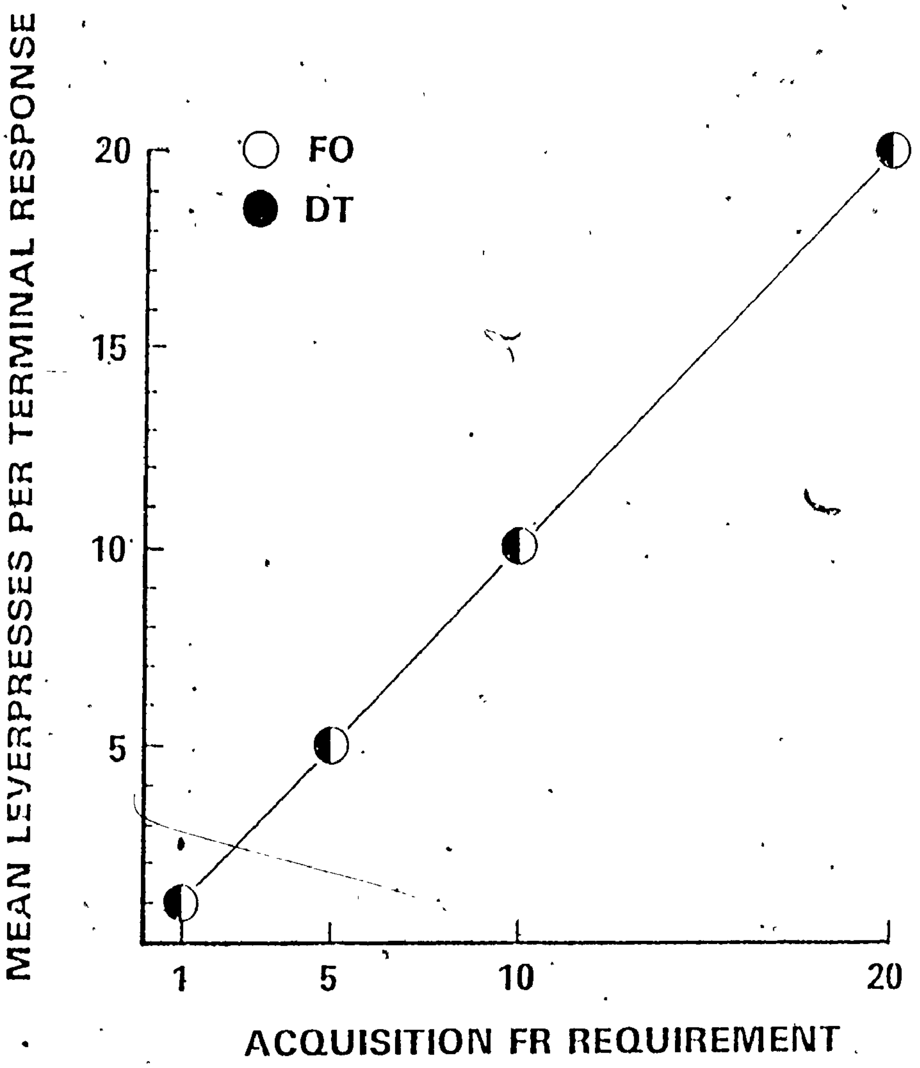


Figure 15

Experiment 2; Mean number of leverpresses per terminal response on Day 10 of acquisition as a function of FR requirement and experimental condition.

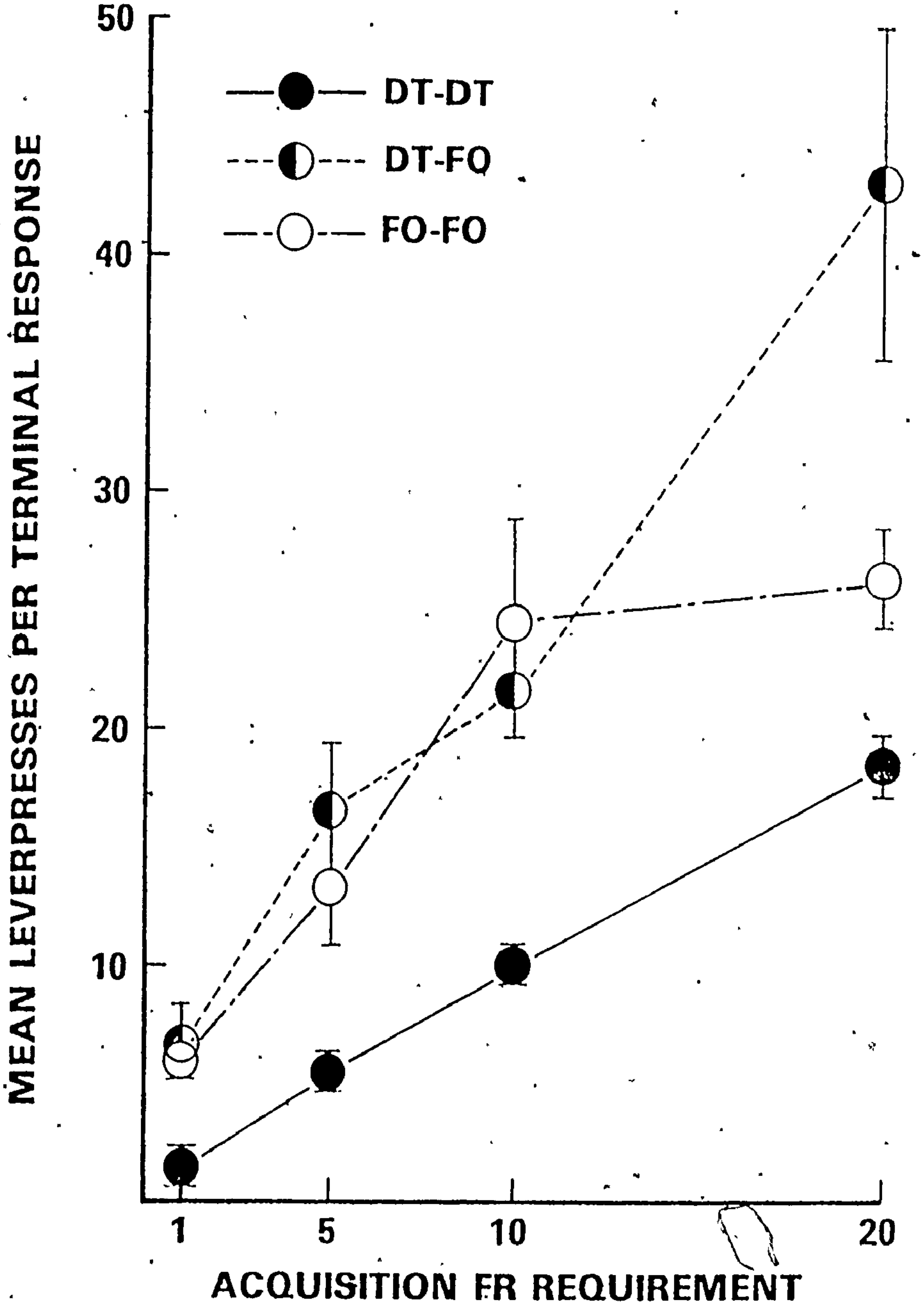


Figure 16

Experiment 2; Mean number of leverpresses per terminal response in extinction, +1 standard error, as a function of FR requirement and experimental condition.

Mean response-unit lengths in the DT-FO and FO-FO conditions were very similar in the FR 1, FR 5, and FR 10 groups, but differed considerably in the FR 20 groups. While it is tempting to view the difference in terms of aberrant performance within the FO-FO FR 20 group, especially in view of the linear relationship between mean response-unit length and FR in the DT-FO condition, closer examination does not bear this out. Within-group variability was much lower in the FO-FO than in the DT-FO FR 20 group, and there is no indication of aberrant individual performance in the former group.

Figure 17 presents the mean number of leverpresses emitted in extinction, ±1 standard error, as a function of FR requirement and experimental condition. In all three conditions, mean number of leverpresses increased in an approximately linear manner with FR requirement. Due to an approximately linear increase in variance with group mean in all conditions, F tests were conducted on the log-transformed scores. The effect of FR requirement was significant in all conditions: $F(3,35) = 29.74$, $p < .001$ in the DT-DT condition; $F(3,30) = 59.71$, $p < .001$ in the DT-FO condition; and $F(3,39) = 37.00$, $p < .001$ in the FO-FO condition. Differences between conditions in the number of leverpresses emitted as a function of FR requirement were relatively small, though these differences were not statistically evaluated due to significant heterogeneity of variance and differences in group size across conditions.

Figure 18 presents the mean number of terminal responses emitted in extinction, ±1 standard error, as a function of FR requirement and experimental condition. In both the DT-FO and FO-FO

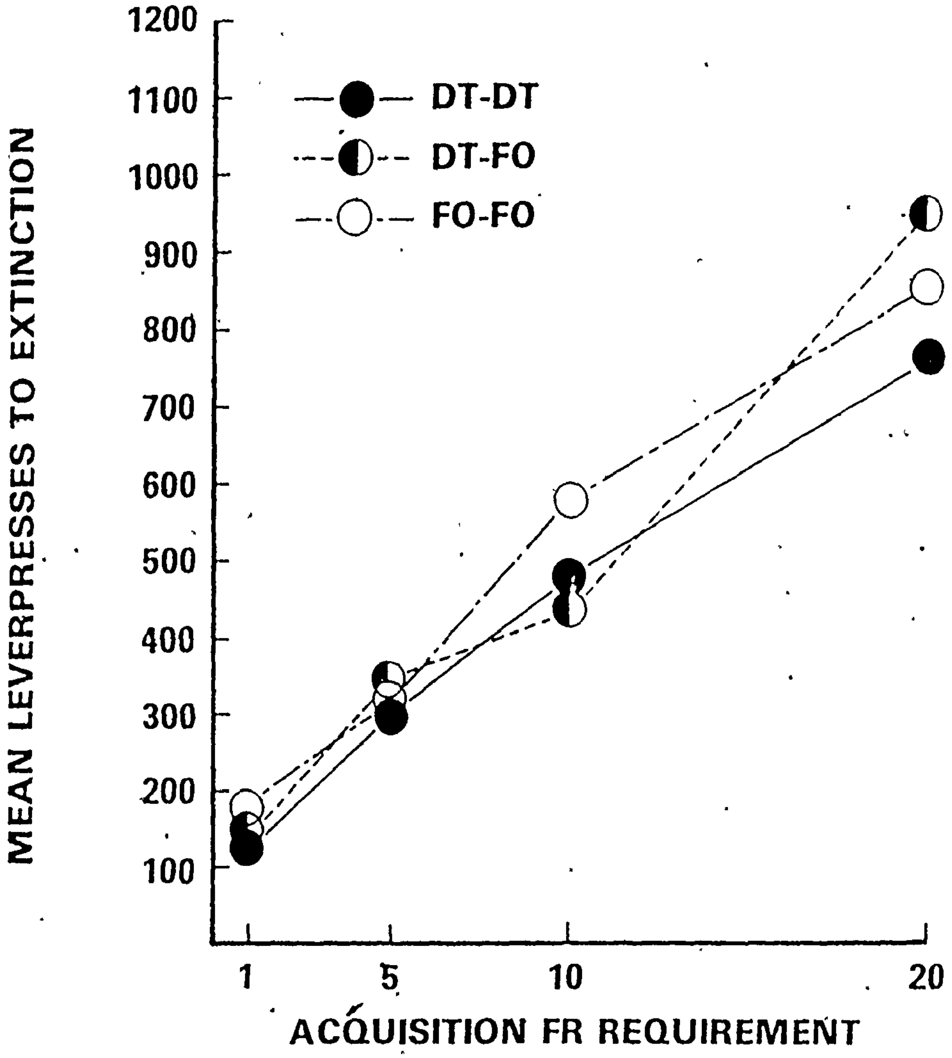


Figure 17

Experiment 2; Mean number of leverpresses in extinction as a function of FR requirement and experimental condition.

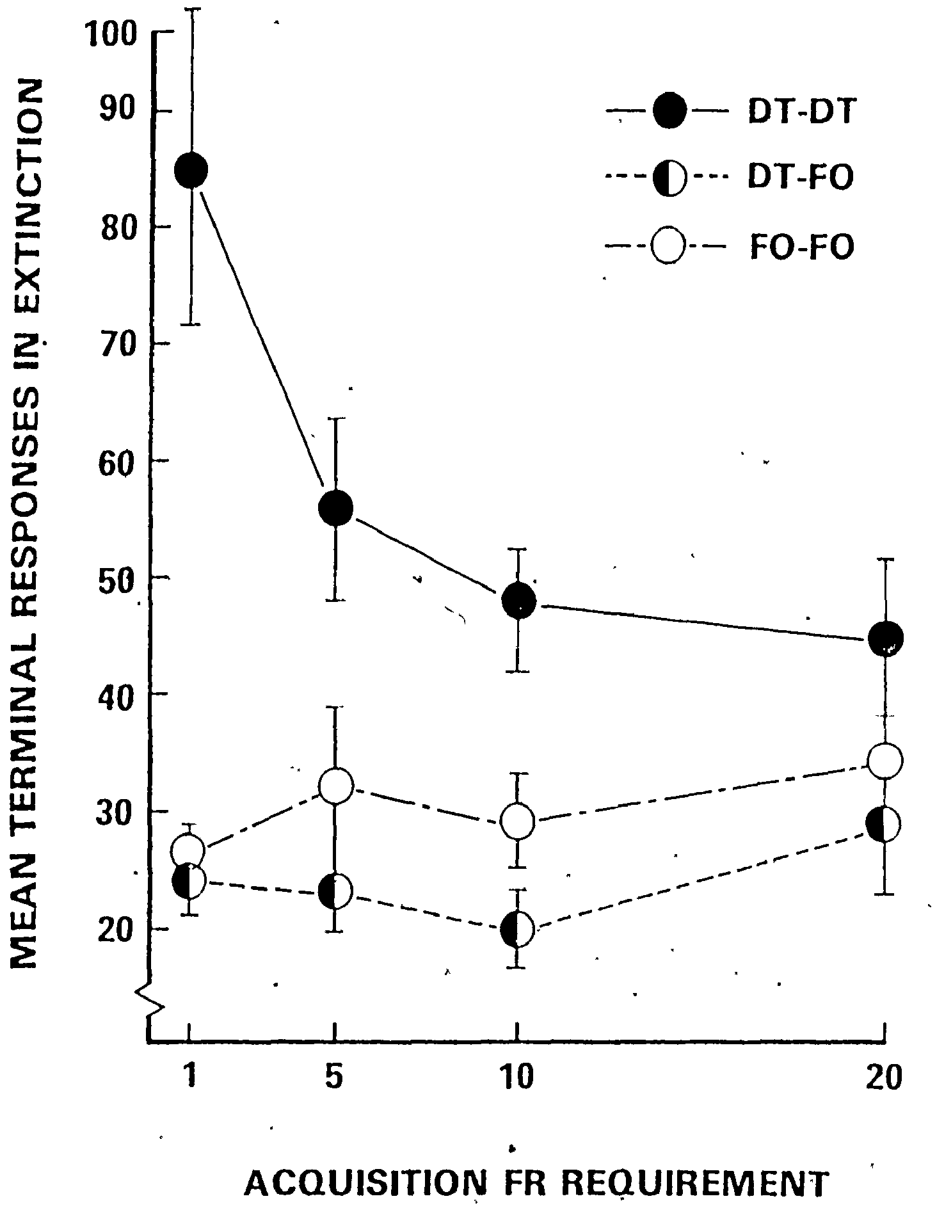


Figure 18

Experiment 2; Mean number of terminal responses in extinction, ±1 standard error, as a function of FR requirement and extinction condition.

conditions, there were no significant differences in the number of terminal responses emitted as a function of FR requirement. The number emitted was somewhat greater in the FO-FO than in the DF-FO condition. This difference reached significance at the .05 level; *F*(1,64) = 5.04. In the DF-DF condition, the number of terminal responses emitted was considerably greater than in the other conditions. Furthermore, the number of terminal responses emitted in the DF-DF condition decreased in a negatively accelerated manner with increasing FR requirement. The effect of FR requirement was significant at the .01 level; *F*(3, [illegible]) = 4.45

Figure 19 presents the mean number of OP's emitted in extinction as a function of FR requirement and experimental condition. In none of the three conditions were there any significant differences in the number of OP's emitted as a function of FR requirement. Differences between conditions were also quite small. These differences were not evaluated statistically due to heterogeneity of variance and differences in group size across conditions. As we had observed in Exp. 1, the within-group variability of the OP measure was greater than that of the EP or terminal response measure. This was true in 11 of 12 FR groups, the sole exception being the FR 5 group in the FO-FO condition.

Discussion

Data obtained in the present study with respect to response-unit lengths provide additional information concerning control of response-unit termination. In all three conditions, reinforcement in acquisition was accompanied by salient external stimulus changes in addition to proprioceptive or other internal correlates of ratio

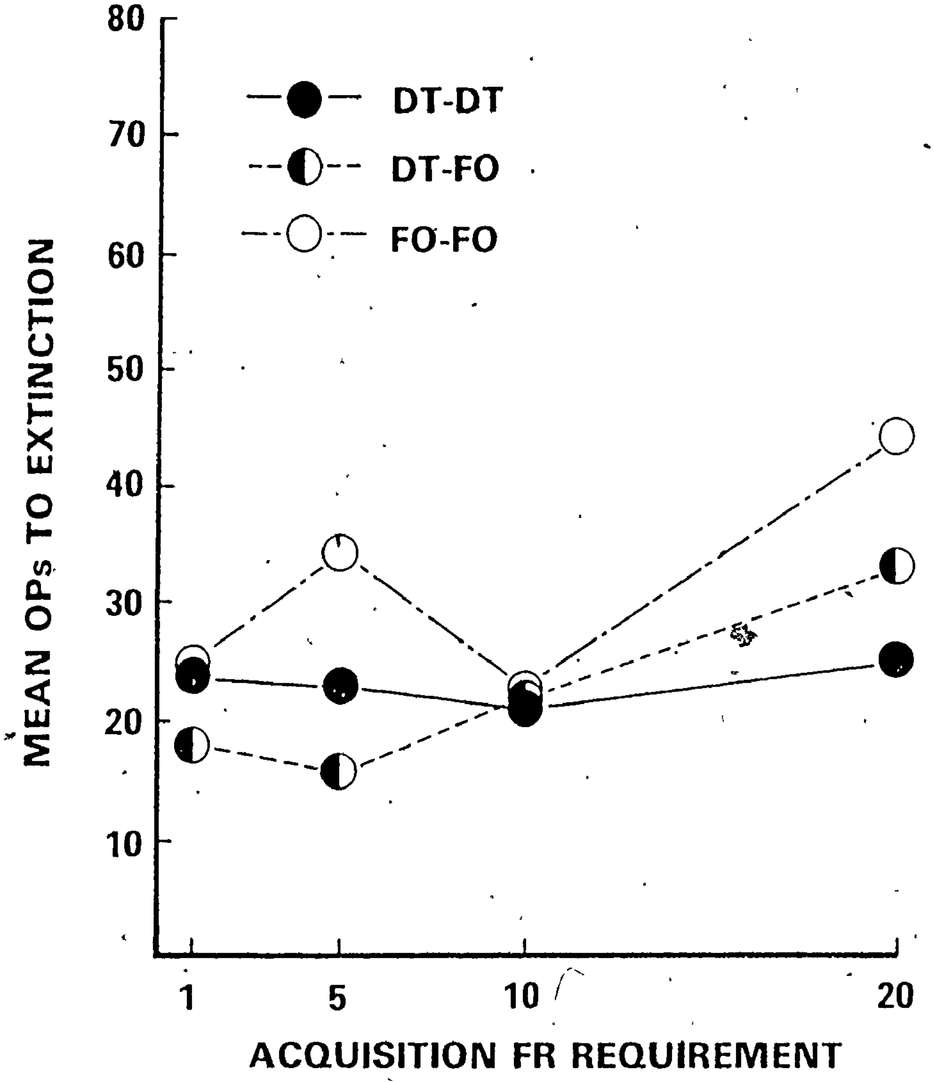


Figure 19

Experiment 2; Mean number of OPs in extinction as a function of FR requirement and experimental condition.

completion. As Fig. 15 indicates, discrimination of stimuli signalling reinforcement availability was essentially complete by Day 10 of acquisition.

The relationship between acquisition and extinction response-unit lengths depends on the nature of discriminative stimuli available in extinction. A comparison of extinction response-unit lengths in the DT-DT condition with those in the DT-FO and FO-FO conditions indicates the importance of external stimulus control over terminal responding. In the DT-DT condition, the continued presence of the ITI resulted in the identity of acquisition and extinction response-unit lengths. The strength of this external discriminative control is indicated by both the correspondence between mean extinction response-unit length and acquisition FR, and the virtual absence of within-group variability in response-unit lengths. In the DT-FO and FO-FO condition, in which external discriminative stimuli were absent from extinction, mean extinction response-unit lengths were considerably greater than acquisition response-unit lengths. In both conditions, however, the direct relationship between acquisition and extinction response-unit lengths indicated the existence of internal stimulus control over terminal responding. The discrepancy between acquisition and extinction response-unit lengths may be due to several factors: Firstly, the presence of salient external cues to reinforcement availability in pretraining and acquisition may have partially blocked the acquisition of discriminative control over terminal responding by internal correlates of ratio completion.

Secondly, during the transition from external to internal control, subjects may ignore internal cues in the expectation that external cues will be presented. Finally, the accuracy of internal stimulus control depends on the subject's ability to discriminate values along a multivalued continuum whose current value is constantly altered by ongoing responding. It may be, therefore, that response sequences must be fairly long before their stimulus consequences are clearly discriminable from the stimulus consequences of nonreinforced subratio sequences.

The differences in mean extinction response-unit lengths between the IT-FO and FO-FO conditions, while not large, indicate that response units in the latter condition were generally shorter. To the extent that this difference is reliable, it may be due to differences in the relative salience of external stimuli present during acquisition. In the IT-FO condition, these included the multimodal stimulus change of the ITI. In the FO-FO condition, the only external cues to ratio completion were auditory stimuli provided by the operation of the pellet dispenser. The absence of the salient visual and tactile components of the ITI may have aided conditioning of terminal responding to internal stimuli. This would be reflected by a more rapid transition to fully internal control, or more accurate discrimination of the internal correlates of ratio completion.

Considering only the number of leverpresses emitted, the present study suggests that differences between IT and FO acquisition and extinction procedures is largely irrelevant to extinction performance. A reliable PREE occurred in all three conditions, and differences in the slopes and intercepts of the functions relating number of leverpresses to acquisition FR were minimal.

Differences between the conditions are apparent, however, when resistance to extinction in terms of number of terminal responses is considered. In the DT-FO and FO-FO conditions, the relationship between acquisition FR and resistance to extinction was consistent with the prediction of the response-unit hypothesis: In both cases the number of terminal responses emitted was the same for all FR groups. In the DT-DT condition, however, number of terminal responses to extinction decreased in a negatively accelerated manner with increasing FR requirement. This relationship is consistent with that reported by Day and Platt (1974) and observed in Exp. 1.

The present results with respect to number of OPs emitted as a function of FR requirement are consistent with and supplement those of Exp. 1. In that study it was observed that number of OPs to extinction did not vary significantly as a function of extinction FR requirement, and that within-group variability on this measure was higher than for terminal responses (HPs). In the present study, number of OPs emitted was independent of acquisition FR requirement, and within-group variability was again higher than for terminal responses. Furthermore, the present data suggest that the OP response is relatively insensitive to acquisition and extinction procedural manipulations which produce significant differences in both extinction response-unit lengths and number of terminal responses as a function of acquisition FR requirement. While these results do not resolve the question of the source of OPs, they further reinforce the impression that measurement of OPs is unlikely to provide any important insight into the relationship between resistance to extinction and acquisition and extinction parameters. The results of Exps. 3-5 bear out this conclusion, and OP measures will not subsequently be reported.

The discrepancy between IT-FO and IT-IT conditions in number of terminal responses emitted indicates that the terminal response function observed in the latter was not due to the IT acquisition procedure, but resulted from either the properties of the IT extinction procedure, or from the relationship between acquisition and extinction procedures. With respect to the latter hypothesis, it could be argued that generalization decrement resulting from the differential similarity of acquisition and extinction was responsible for the differences in resistance to extinction between the conditions. Resistance to extinction in terms of terminal responses was least in the IT-FO condition in which acquisition and extinction differed most, and greatest in the IT-IT condition in which acquisition and extinction differed least. While this hypothesis accounts for differences between conditions in resistance to extinction, it sheds no light on the relationship between FR requirement and resistance to extinction in the IT-IT condition. Furthermore, it is inconsistent with the results of Exp. 1, in which subjects shifted to different schedules of ITI presentation in extinction emitted more terminal responses than subjects for whom acquisition and extinction schedules were identical. A generalization decrement account would predict just the opposite.

If the DT procedure is responsible both for the differences in number of response units emitted between conditions, and for the relationship between FR requirement and number of units to extinction in the DT-DT condition, we must consider the properties of the ITI which may be responsible for these effects. The functional significance of the ITI in extinction derives from its repeated contiguity with reinforcement during acquisition. Stimuli which have this relation to reinforcement have been shown to exhibit two important properties: First, they may be secondary reinforcers; i.e , they may have the capacity to strengthen responses which precede their presentation, even in the absence of the reinforcement with which they were originally paired. Second, they may be discriminative stimuli; i.e. they may elicit, or set the occasion for, the occurrence of responses which have previously been reinforced in their presence. We shall consider in turn how each of these functions may have affected resistance to extinction, in terms of response units, in the present study.

The ITI as a Secondary Reinforcer

The difference between the DT-DT condition and the DT-FO and FO-FO conditions with respect to overall resistance to extinction can be accounted for by the presence of the ITI as a secondary reinforcer in the former condition, and its absence from the latter conditions. The relationship between the number of terminal responses and FR requirement in the IT-DT conditions might be explained in several ways. The first is that the secondary reinforcing capacity of a stimulus may vary with the schedule of reinforcement on which it was established. In order to account for the results in the DT-IT condition, such a position requires that the secondary reinforcing capacity of the ITI decrease with increasing acquisition FR requirement. Several studies have obtained results consistent with this hypothesis (Mason, 1957; D'Amato _et al_, 1958; Armus _et al_, 1964).

The second possibility is that the secondary reinforcing capacity of a stimulus may vary with the schedule on which is is presented in extinction. This hypothesis would account for the terminal response function in the DT-DT condition by positing a direct relationship between the effectiveness of a secondary reinforcer and its probability of occurrence per response. The available evidence, however, suggests the opposite relationship (e.g. Marx, 1958; Davenport and Sardello, 1966; Dutch, 1974a, 1974b; Goodrick, 1974).

The applicability of a secondary reinforcement account to these terminal response data is, however, questionable. What the studies cited above have generally demonstrated is that the effect of a secondary reinforcer depends on its frequency or probability with respect to the response to be reinforced. In the present study, however, there were only minimal differences between FR groups in the DF-DF condition in either the probability or frequency of ITI presentation with respect to the terminal response in either acquisition or extinction. A more important difficulty with secondary reinforcement accounts of these data concerns the temporal relationship between the ITI and the terminal response. The effectiveness of a reinforcer depends on the fact that it is a temporal or contingent consequence of behaviour; a response is strengthened when it produces or is followed by the reinforcing event. In the present case, however, the ITI is _not_ contingent upon nor consequent to a terminal response, but rather precedes and elicits the terminal response. It may be, therefore, that the _discriminative_ rather than the reinforcing properties of the ITI are responsible for the relationship between FR requirement and resistance to extinction in the DF-DF condition.

The ITI as a Discriminative Stimulus

We have noted that the ITI is a highly effective discriminative stimulus for terminal responding; there are several ways in which this discriminative control might account for the present results.

1. The Leverpress Constancy Hypothesis

An examination of response-unit lengths as a function of extinction conditions indicates that ITI presentation altered the number of leverpresses preceding each terminal response, as well as the number of terminal responses emitted in extinction.
In contrast to these differences between conditions is the marked similarity between FO and DF extinction groups with

respect to the number of leverpresses emitted in extinction as a function of FR requirement.

This pattern of results can be accounted for by assuming that it is the leverpress per se, and not a response unit, which is strengthened during acquisition. Skinner (1938) argued that the effect of reinforcement was to increase the size of the reflex reserve; i.e. the number of responses which the subject would emit in the absence of further reinforcement. The size of this reserve depended solely on the parameters of reinforcement, though the rate at which it was exhausted might be affected by extinction conditions. The present data are consistent with the view that the leverpress reserve established by FR reinforcement is a direct function of FR requirement, but independent of the particular extinction procedure (whether IT or FO) employed.

According to this view, the number of terminal responses emitted is irrelevant to resistance to extinction, and depends solely on the frequency with which the terminal response is elicited during the exhaustion of the leverpress reserve. The similarity between the IT-FO and FO-FO groups in the number of terminal responses emitted was due to the fact that the frequency with which terminal responses occurred in extinction (i.e. response-unit length) was also very similar. In the IT-IT condition, the presence of the ITI resulted in a higher frequency of terminal response occurrence, and hence, a greater number of terminal responses in extinction. The terminal response function in the IT-IT condition can be accounted for by assuming that the proportional contribution to the reserve by each acquisition ratio decreases with ratio size. Thus, since extinction ITI frequency equalled the ratio requirement, the fraction of the total reserve exhausted prior to each terminal response increased with extinction FR schedule.

While the leverpress constancy hypothesis adequately accounts for the present data, it appears to be inconsistent with the observation in Exp. 1 that the number of leverpresses emitted in extinction may vary directly with extinction FR schedule, even between groups receiving exactly the same acquisition reinforcement regimen. Furthermore, the view that terminal response occurrence is irrelevant to the exhaustion of the leverpress reserve is difficult to reconcile with the observation that virtually every subject in the three conditions began the 10-min. extinction criterion period with a terminal response, rather than a leverpress. This is not readily attributable to differences in the relative strength of the two responses, since the frequency of terminal responses was seldom greater than that of leverpresses, even at the end of the session.

2. The Unit Length Hypothesis

We have already noted the similarity between the terminal response functions obtained in Exp. 1 and in the IT-IT condition in the present experiment. To the extent that this similarity reflects the operation of similar processes, it suggests the importance of extinction ITI schedule in determining the resistance of the terminal response to extinction. If we accept the notion that the significance of the terminal response is that it is the final component of a functional response unit, then one possible account of these functions is that they result from the effects of ITI schedule on the nature of the units emitted in extinction.

The effect of extinction FR schedule in Exp. 1 was to alter, and in the present study to maintain, the identity of acquisition and extinction unit lengths. Common to both studies is the observation that the number of units emitted in extinction decreases with extinction FR requirement. These data can be accounted for by the hypothesis that the resistance of a response unit to extinction is inversely related to its current length; perhaps, as Mowrer and Jones (1945) suggested, as a function of the effort involved in executing the unit.

According to the simplest version of this hypothesis, the relationship between extinction response-unit length and resistance of the unit to extinction is independent of acquisition unit length. Thus the terminal response function observed in the DT-DT condition would be similar for any subjects extinguished at the same FR values, regardless of acquisition FR. The failure to observe differences in resistance to extinction between groups in the DT-FO and FO-FO conditions is due to the fact that the function relating unit length to resistance to extinction is negatively accelerated: Unit lengths in these conditions were sufficiently great as to fall at or near the asymptote of the function. Overall resistance to extinction in the DT-FO and FO-FO conditions is somewhat lower than expected by this hypothesis. Unit lengths in the FR 1 groups in these conditions were similar to that in the FR 10 group in the IT-DT condition, and should have resulted in similar resistance to extinction.

A second version of the unit-length hypothesis assumes that the function relating extinction unit length and resistance to extinction varies with acquisition unit length, though all are of similar shape and reach a common or similar asymptote. The terminal response function in the DT-DT condition is therefore composed of points from four similar function, each relating extinction unit length to resistance to extinction for a specific acquisition unit length. If the rate at which this common asymptote is reached decreases with acquisition unit length, this would account for both the absence of differences between groups in the IT-FO and FO-FO conditions, and for differences in overall resistance to extinction between these groups and those in the DT-DT condition. Thus the function relating extinction unit length and resistance to extinction is asymptotic at unit lengths of approximately 8.00 for subjects trained at FR 1, and at unit lengths of 15, 25, and 35 for subjects trained at FR 5, 10, and 20, respectively. These unit lengths may approximate the maximum possible at these FR values (given the particular acquisition parameters employed), since it may be difficult to increase extinction unit lengths beyond the value they assume when external cues to unit completion are not available.

If the unit-length hypothesis is correct in assuming an inverse relationship between unit length and resistance to extinction, we would expect that an examination of the performance of subjects within each FR group would reveal a negative correlation between mean extinction unit length and number of terminal responses to extinction. While there was virtually no between-subject variability in extinction unit lengths within DT - DT groups, scatterplots of mean extinction unit length vs. number of terminal responses to extinction for groups within the DT-FO and FO-FO conditions indicated the existence of the predicted relationship. This relationship was negatively accelerated, and was approximately linear in log-log coordinates. Pearson product-moment correlation coefficients between log mean extinction unit length and log terminal responses to extinction were calculated for each group within these conditions. These coefficients, together with the slopes and intercepts of the linear reduction equations are presented in Table 2. The coefficients are generally fairly large, and all are in a direction consistent with the unit-length hypothesis. Furthermore, the general tendency for the slope and intercept of the reduction equations to change monotonically with acquisition FR requirement is consistent with the version of the hypothesis which argues that the shape of the unit length/terminal response function varies with acquisition FR.

Comparable consistency was observed when correlation coefficients were calculated in a similar manner for the groups in Exp. 1: These coefficients were - .480, - .452, and - .476 for subjects in the 5, 10, and 15 groups, respectively. When all subjects were combined, the coefficient dropped slightly to - .421. The size and uniformity of these coefficients is noteworthy in view of the fact that they

Table 2

Experiment 2; Correlations between log mean extinction unit length and log terminal responses to extinction for FR groups in the DT-FO and FO-FO conditions, and slopes and intercepts of the associated linear reduction equations.

		FR Group			
		1	5	10	20
DT-FO	r	-.78	-.79	-.43	-.85
	slope	-.71	-.72	-.53	-.89
	intercept	1.76	2.19	1.98	2.80
FO-FO	r	-.30	-.77	-.89	-.57
	slope	-.17	-.65	-1.05	-.77
	intercept	1.54	2.11	2.81	2.58

include subjects from three independent replications whose overall extinction performance differed significantly.

It should be noted that these correlations might arise as artifacts of the relationship between extinction unit length and ordinal unit position. If the length of units emitted in extinction decreases across successive units in a similar manner for all subjects within a particular FR group, then mean extinction unit length for any subject will decrease as the number of units emitted in extinction increases. If the function relating unit length to ordinal unit position is identical for all subjects within a group, the correlation between mean unit length and number of units emitted is due to between-subject variability in the number of units emitted. Thus the causal relationship between mean unit length and number of terminal responses emitted would be opposite to that suggested by the unit-length hypothesis. That is, while the unit-length hypothesis argues that variations in the number of units emitted is the result of differences in mean unit length, the artifact hypothesis argues that variations in mean unit length are the result of variations in the number of units emitted. This question can be resolved by examining mean unit lengths across successive 5-unit blocks for subjects within the same FR group. If the unit-length hypothesis is correct, between-subject differences in overall mean extinction unit length should be reflected in the block means. If the correlations are artifactual, however, between-subject differences in block means should be unrelated to overall mean extinction unit length.

Comparison of mean unit lengths across successive 5-unit extinction blocks fully supported the unit-length hypothesis. In all DT-FO and FO-FO groups, differences between subjects in block means were clearly related to overall mean unit lengths. Representative within-group differences are presented in Figures 20 and 21. Figure 20 presents mean unit lengths across successive 5-unit blocks of extinction for six subjects in the DT-FO FR 5 group. Three of the subjects had overall mean unit lengths which fell below the median unit length for the group, and three had mean unit lengths which fell above the median. Figure 21 presents the same data for six similarly-selected subjects from the FO-FO FR 10 group. In both cases it is clear that block-by-block unit means are related to overall mean unit lengths.

At this point we have exhausted the evidence within this study which might assist us in determining the source of the difference in resistance to extinction between the three conditions, and, more importantly, between the several groups in the DT-DT condition. While not all of the hypotheses advanced to account for these results are equally plausible, none can confidently be discarded. All of these hypotheses cite the presence and frequency of the FTI as the crucial factor determining the number of terminal responses emitted in extinction, either because it contributes to the similarity of acquisition and extinction, or because of its reinforcing or discriminative properties.

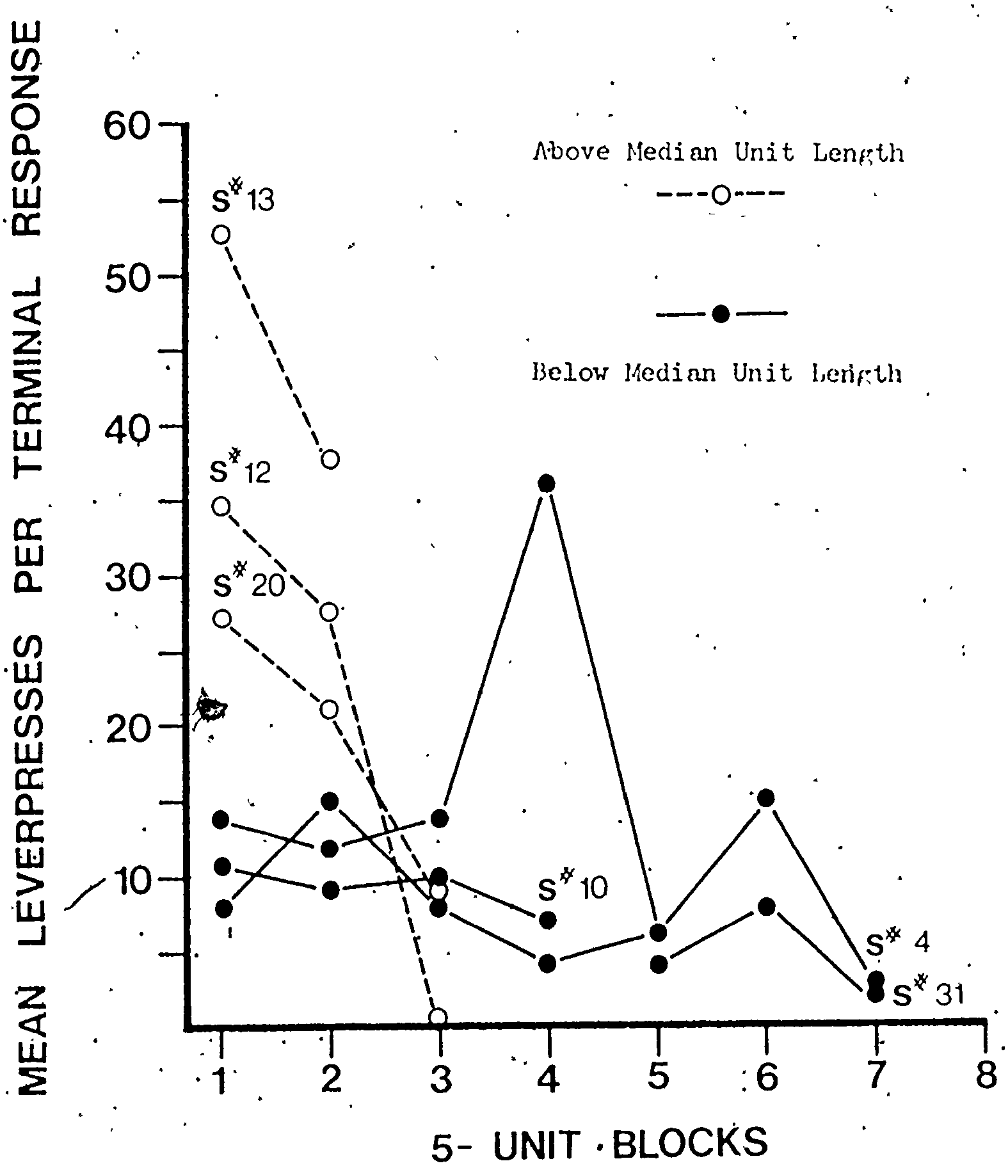


Figure 20

Experiment 2; Mean number of leverpresses per terminal response as a function of 5-unit blocks in extinction for 6 subjects in the IT-FO FR 5 group.

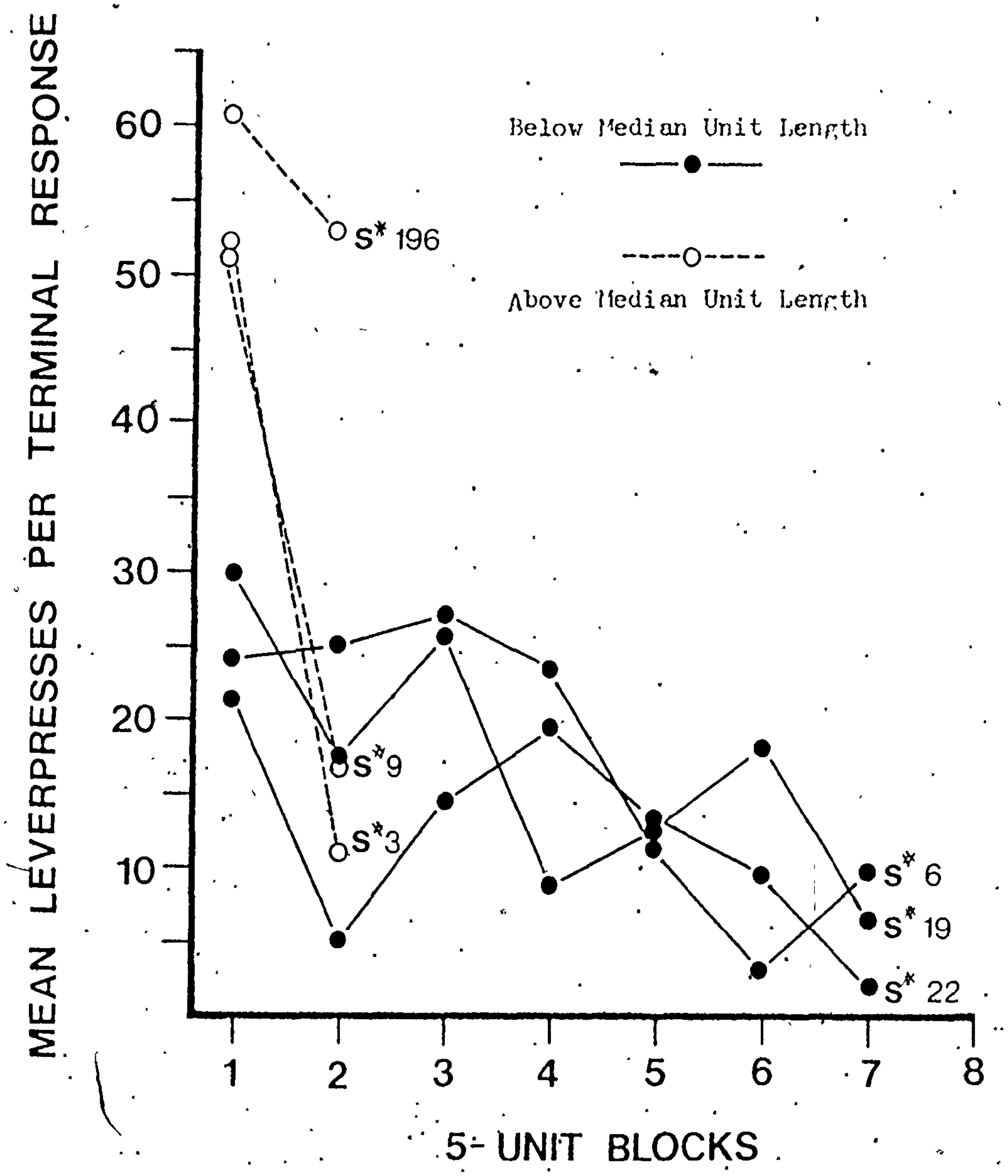


Figure 21

Experiment 2; Mean number of leverpresses per terminal response as a function of 5-unit blocks in extinction for 6 subjects in the FO-FO FR 10 group.

While it is clear that the presence of the ITI is responsible for differences between DF and FO extinction procedures, its role in determining the relationship between FR value and number of terminal responses to extinction in the DF-DF condition is not clear. Since acquisition and extinction schedules of ITI presentation were completely confounded, it is not possible to determine whether the relationship between FR value and resistance to extinction is due to extinction ITI schedule *per se*, to acquisition reinforcement schedule, or to some relationship between the two.

The necessity of eliminating this confounding suggests the usefulness of the procedure employed in Exp. 1, in which subjects trained on a DF FR procedure were extinguished on the same (matched-DF) or on a different (shifted-DF) schedule of ITI presentation. While the results of that study cast doubt on several of the hypotheses discussed above, the rather circumscribed extinction manipulations involved limit ambitious extrapolation. In the two studies to be described below, the shifted-DF procedure was employed to examine the effects of a wide range of extinction ITI frequencies on subjects trained at a single FR value.

In Experiment 3, subjects trained on a DF FR 1 schedule of reinforcement were extinguished without the ITI (FO), on an FR 1, 2, or 4 schedule of ITI presentation, or with the ITI following every terminal response regardless of unit length (FN). This procedure permitted at least a partial test of several of the hypotheses outlined above:

1. Secondary reinforcement. If the relationship between FR value and resistance to extinction in the DT-DT condition is due to the differential effectiveness of the ITI as a secondary reinforcer, as a function of the reinforcement schedule on which it was established, then subjects trained at the same FR value should emit the same number of terminal responses in extinction under DT conditions. Furthermore, subjects in the FN group should be at least as resistant to extinction as DT FR groups due to the contingency between ITI presentation and the occurrence of a terminal response.

2. Leverpress constancy. According to this hypothesis, alterations in ITI frequency during extinction should have no effect on the total number of leverpresses emitted by subjects trained on the same FR schedule. The number of terminal responses emitted should increase with ITI frequency in extinction.

Experiment 3

Subjects

The subjects for this experiment were 32 naive female hooded rats, 130-150 days old at the beginning of training, obtained from the breeding colony of the Department of Psychology at McMaster University. For approximately three weeks prior to, and throughout the study, subjects were fed a single daily ration sufficient to maintain them at 85% of *ad lib* weight. Session reinforcements were supplemented with Purina Rat Chow to complete the daily ration.

Apparatus

The apparatus employed was that described in Experiment 1.

Procedure

Subjects were divided into 5 groups of 6 rats each such that the mean body weights of the groups were approximately equal. The remaining two subjects were designated as replacements for subjects discarded due to illness, experimenter error, apparatus failure, or failure to complete pretraining.

Due to injury, one subject from the FR 1 group and one from the FR 4 group were discarded. Four additional subjects, one each from the FR 1, FR 2, FR 4, and FN groups were discarded due to apparatus failure. At the beginning of extinction one subject in the FN group exhibited behaviour strongly indicative of illness or injury (failure to respond for 5 min. when placed in the chamber) and was discarded. One replacement subject was assigned to each of the FR 4 and FN groups. As a result, n = 4 for the FR 1 and FO groups, and 5 for the remaining three groups.

Pretraining consisted of four days of magazine training and four days of CRF. It was conducted in a manner identical to that described in Exp. 1, and for the DF acquisition groups in Exp. 2. Following pretraining, subjects received 10 sessions of FR 1 reinforcement. Each of the 30 reinforcements per session consisted of two Noyes pellets, and was accompanied by the usual 10-sec. ITI.

Subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. The ITI was presented following every press, or following every 2nd or 4th press for subjects in the FR 1, FR 2, and FR 4 groups, respectively. In the FN group, the ITI followed each terminal response. In the FO group, the ITI was never presented, and the chamber was continuously illuminated with the lever continuously available.

Results

Figure 22 presents mean extinction response-unit lengths, ±1 standard error, for the several groups. In this and subsequent figures, the groups have been arranged along the abscissa in decreasing order of ITI frequency in extinction. The FN group is therefore placed between the FR 4 and FO groups. Mean extinction unit length increased in a nearly linear manner with decreasing ITI frequency. In the FR groups, mean unit length equalled or exceeded the extinction FR value. Due to an approximately linear increase

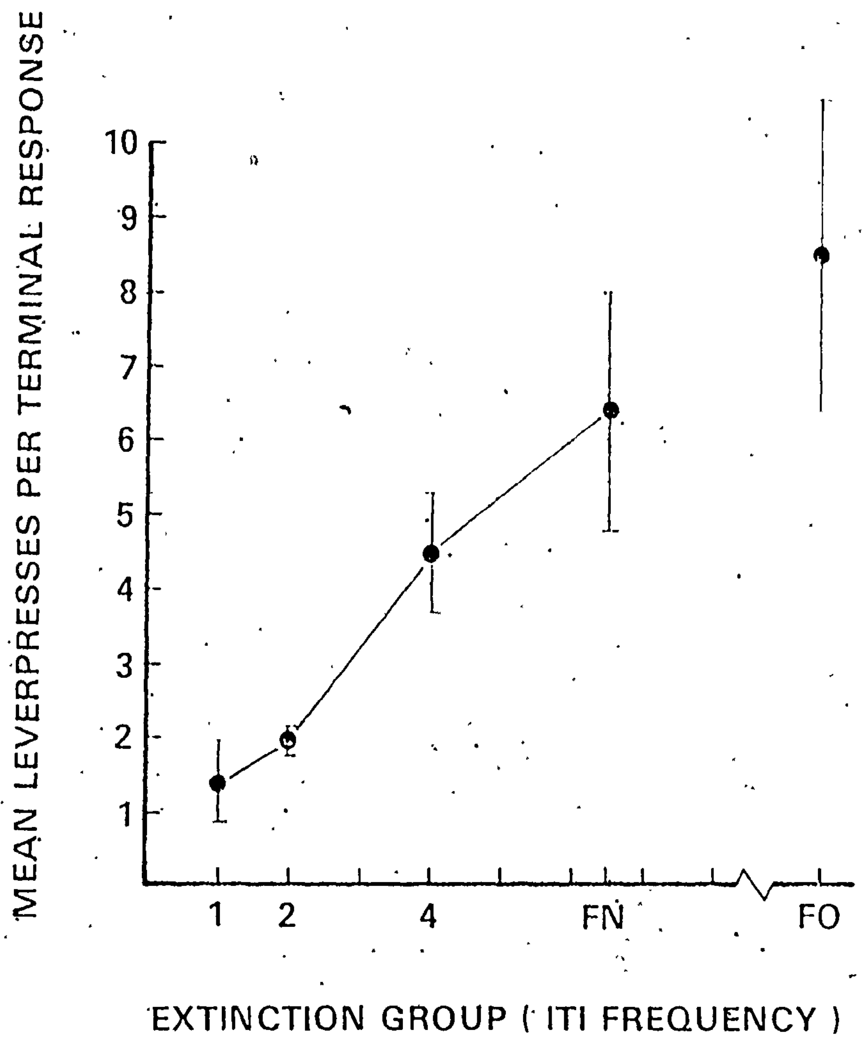


Figure 22

Experiment 3; Mean number of leverpresses per terminal response in extinction, ±1 standard error, as a function of extinction condition.

in variance with group mean, an F test was performed on the means of the log-transformed scores. Group differences were found to be significant at the .01 level; F(4,18) = 17.92.

The mean number of terminal responses emitted in extinction, ±1 standard error, are presented in Figure 23. The number of terminal responses emitted decreased monotonically with decreasing ITI frequency with the exception of a slight increase in terminal responses from the FR 4 to the FN group. Group differences were significant at the .01 level; F(4,18) = 6.16.

Figure 24 presents the mean numbers of leverpresses emitted in extinction, ±1 standard error. In this case, there was no indication of a monotonic relationship between extinction ITI frequency and number of leverpresses emitted. While there is a linear increase in leverpresses emitted between the FR 2 and FN groups, subjects in the FR 1 group emitted approximately the same number of leverpresses as subjects in the FR 2 group. Subjects in the FO group emitted many fewer leverpresses than did subjects in the FN group. No statistical comparisons were performed on these data, which represent the product of mean unit length and number of terminal responses to extinction.

Discussion

The match between the rate of ITI presentation and mean extinction unit length in the present study confirm earlier observations concerning the efficacy of external discriminative control over terminal responding. In addition, mean extinction unit length in the FO condition matched closely the performance of

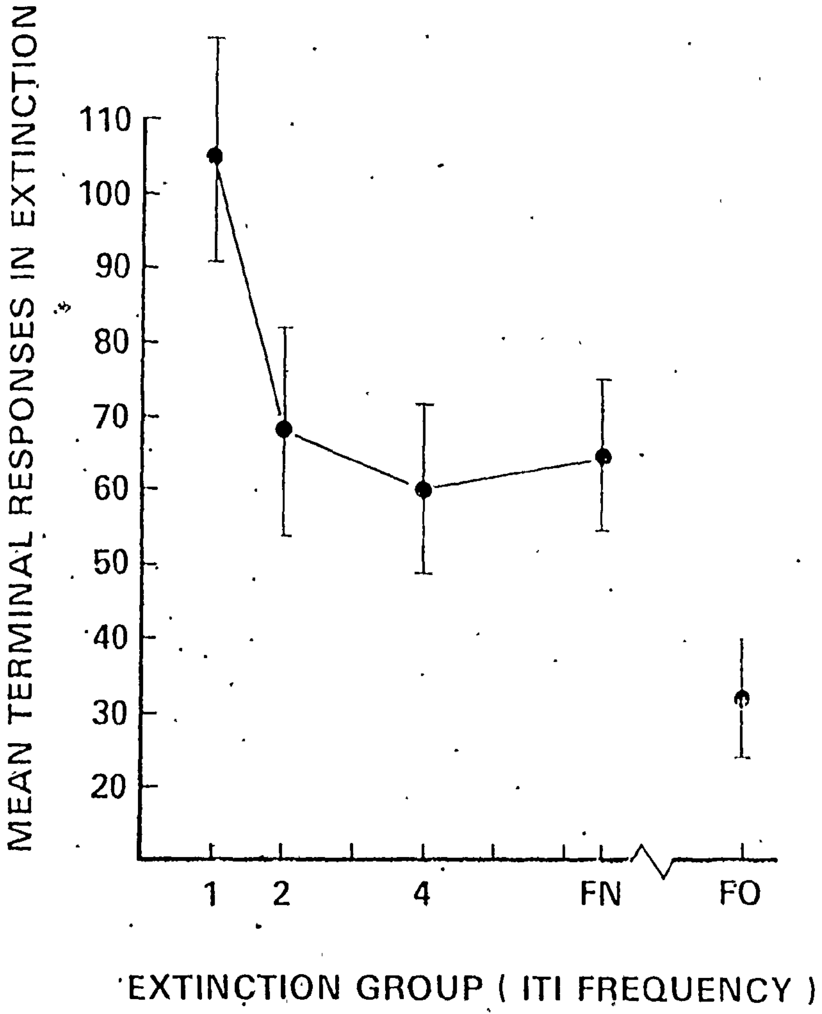


Figure 23

Experiment 3; Mean number of terminal responses in extinction, ±1 standard error, as a function of extinction group.

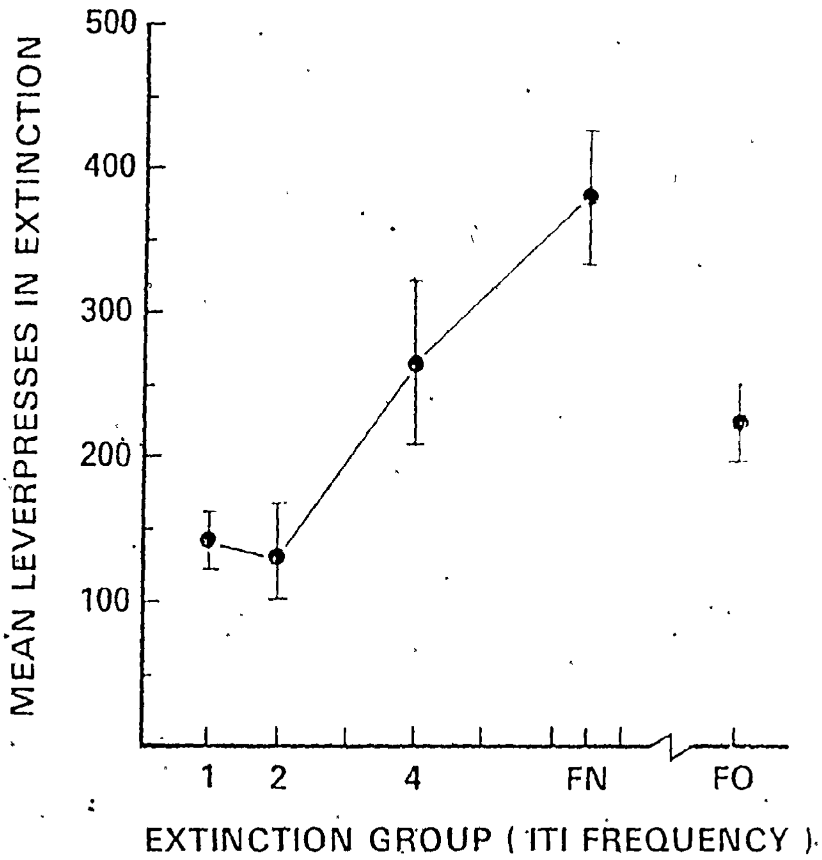


Figure 24

Experiment 3; Mean number of leverpresses in extinction, ±1 standard error, as a function of extinction group.

IN FR 1 subjects in the IT-FO conditions of Exp. 2. It was expected that mean extinction unit lengths would be equal in the FO and FN groups, since both were extinguished in the absence of reliable external cues to ratio completion. Equivalence of extinction unit lengths in these two groups would have permitted an assessment of the role of the ITI as a secondary reinforcer in maintaining terminal responding. The presence of a difference in mean unit length makes such an evaluation difficult.

If FN and FO conditions result in similar extinction unit lengths, then the difference between these groups in number of terminal responses emitted may be due to the secondary reinforcement of terminal responses provided by the ITI in the FN group, to generalization decrement in the FO group due to the absence of the ITI, or both. If FN and FO procedures do result in differences in extinction unit lengths, then the difference in number of terminal responses to extinction could equally well be accounted for by the unit-length hypothesis.

Considered as a whole, however, the terminal response data do not tend to support a secondary reinforcement account of the effects of extinction ITI schedule. In the present study, unlike Exp. 2, differences between groups in number of terminal responses emitted cannot be attributed to the differential effectiveness of the ITI as a secondary reinforcer as a function of acquisition reinforcement schedule. Furthermore, the absence of differences between FR 2, FR 4 and FN groups suggests that the contingency between terminal response occurrence and ITI presentation is not an important factor in determining resistance to extinction of the terminal response.

The terminal response data are most readily interpreted in terms of either the unit-length or generalization decrement hypotheses. The former predicts that the number of units emitted in extinction should decrease in a negatively accelerated manner with extinction unit length. The results of this study are consistent with that prediction, at least with respect to those groups which received ITI presentations in extinction. Resistance to extinction in the FO group appears lower than would be expected by this hypothesis, and is consistent with similar differences between DT and FO extinction procedures observed in Exp. 2. These differences can, however, be accounted for in terms of generalization decrement. Since all subjects were trained on a DT FR 1 schedule, decreasing ITI frequency in extinction systematically decreases acquisition-extinction similarity. Resistance to extinction should therefore be a direct function of extinction ITI frequency. It should be noted, however, that such an account cannot be applied to the DT-DT data from Exp. 2. A generalization account of the present data is therefore called into question to the extent that the similarity of the DT-DT terminal response function to that obtained in the present study indicates the operation of similar processes.

Resistance to extinction in terms of number of leverpresses emitted can be explained by hypotheses which assume the functional significance of the response unit, but is clearly inconsistent with the leverpress constancy hypothesis. The latter argues that subjects receiving the same reinforcement regiment in acquisition should emit the same number of leverpresses whether IT or FO procedures are employed in extinction. In the present study, however, number of leverpresses emitted increased with decreasing ITI frequency. The notable exception is the FO group, who emitted fewer leverpresses than the FN group, though more than either the FR 1 or FR 2 groups. If the functional significance of the response unit is assumed, these data simply reflect the fact that increases in extinction unit length as a result of ITI frequency are large enough, except in the FO group, to offset corresponding decreases in the number of units emitted. It is important to stress that a generalization decrement hypothesis which accounts for these terminal response data must assume the functional significance of the response unit; otherwise it is incapable of simultaneously accounting for the opposite relationship between ITI frequency and number of leverpresses to extinction.

The unit-length and generalization decrement hypotheses can be tested simultaneously in a shifted-IT procedure if increases in extinction unit length are unconfounded with decreases in acquisition-extinction similarity with respect to ITI frequency. Experiment 1 constituted a test of this sort. Subjects were first trained to leverpress on a IT FR 20 schedule of reinforcement, and then extinguished on IT FR 1, 5, 10, or 20 schedules of ITI presentation. Increases in extinction unit length were therefore associated with increases in the similarity between acquisition and extinction schedules of ITI presentation.

If the generalization decrement hypothesis is correct, the number of terminal responses emitted in extinction should increase with extinction FR schedule. According to the unit-length hypothesis, however, altering the relationship between acquisition-extinction similarity and extinction unit length should have little effect on resistance to extinction; it should still be the case that the number of terminal responses emitted in extinction decreases in a negatively accelerated manner with increasing extinction unit length.

Experiment 4

Subjects

The subjects for this experiment were 26 naive female hooded rats, 130-150 days old at the beginning of training, obtained from the breeding colony of the Department of Psychology at McMaster University. For three weeks prior to, and throughout the study, subjects were fed a single daily ration sufficient to maintain them at 85% of *ad lib* weight. Session reinforcements were supplemented with Purina Rat Chow to complete the daily ration.

Apparatus

The apparatus employed was that described in Exp. 1.

Procedure

Subjects were divided into four groups of six rats each such that the mean body weights of the groups were approximately equal. The two remaining subjects were designated as replacements for subjects discarded due to illness, apparatus failure, experimenter error, or failure to complete pretraining. One subject in the FR 5 group was discarded for failing to complete the first session of CRF during pretraining, and one subject from the FR 1 group was discarded for failing to complete the first session of FR 20 reinforcement.

Pretraining was carried out in the manner described in Exp. 1. Following pretraining, all subjects received 10 sessions of

FR 20 reinforcement. Each of the 30 reinforcements per session consisted of two Noyes pellets, and was accompanied by a 10-sec. ITI during which the chamber was darkened and the lever retracted.

Subjects were extinguished in a single session to a criterion of 10 min. without a leverpress. During extinction the ITI was presented following every leverpress in the FR 1 group, and following every 5th, 10th, or 20th leverpress in the FR 5, FR 10, and FR 20 groups, respectively.

Results

Figure 25 presents mean extinction unit lengths, ±1 standard error, as a function of extinction FR schedule. With the exception of the FR 20 group, mean response-unit lengths slightly exceeded the FR value in all groups. In the FR 20 group, mean extinction unit length fell slightly below the FR value. Due to the virtual absence of overlap between the FR 1, FR 5, and FR 10 groups, no statistical tests were conducted on these data.

Figure 26 presents the mean numbers of terminal responses emitted in extinction, ±1 standard error, for the four groups. The greatest number of terminal responses was emitted by the FR 1 group, and the number emitted decreased with increasing ratio size through the FR 10 group. There was an increase from the FR 10 to the FR 20 group to the extent that the mean number of terminal responses emitted was nearly identical in the FR 5 and FR 20 groups. The effect of extinction FR schedule was significant at the .05 level; F(3,20) = 3.15.

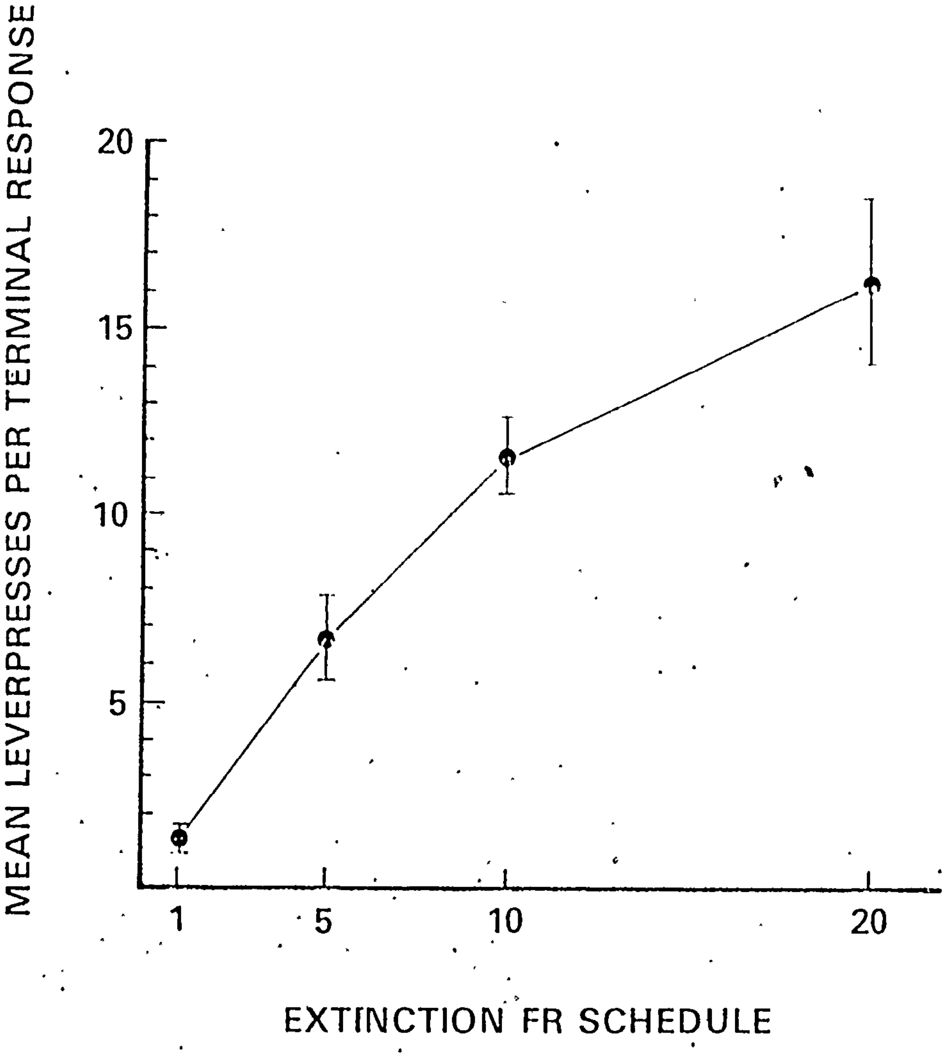


Figure 25

Experiment 4; Mean number of leverpresses per terminal response in extinction, ±1 standard error, as a function of extinction FR schedule.

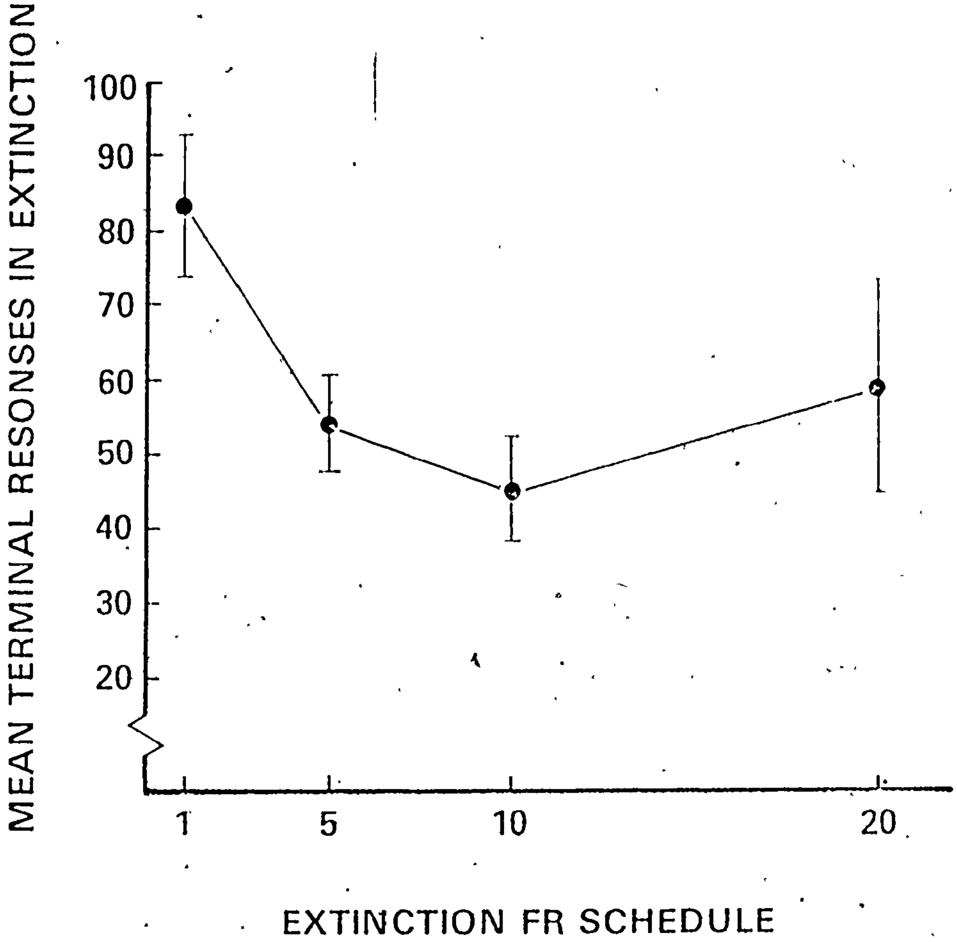


Figure 26

Experiment 4; Mean number of terminal responses in extinction, ±1 standard error, as a function of extinction FR schedule.

Figure 27 presents the mean number of leverpresses emitted in extinction, ±1 standard error, for the four groups. Mean number of leverpresses emitted increased monotonically with extinction FR requirement. Due to a linear increase in variance with group mean, an ANOVA was performed on the mean of the log-transformed scores. This test revealed the effect of extinction FR requirement to be significant at the .001 level; $\underline{F}(3,20) = 30.81$.

Discussion

With respect to mean extinction unit lengths, it is sufficient to note that the results of the present study provide an additional indication of the importance of external stimulus control of terminal responding in the FT procedure. As in Exp. 2, this control seems to be less pervasive or persistent in the FR 20 group.

The function relating number of terminal responses emitted in extinction to ITI frequency seems clearly inconsistent with the prediction of the generalization decrement hypothesis. Although differences between acquisition and extinction in ITI frequency decreased with extinction FR, so did resistance to extinction. The notable exception is the FR 20 group, whose resistance to extinction was somewhat greater than the FR 10 group. This result could be accounted for in terms of generalization decrement by positing a nonmonotonic relationship between acquisition-extinction similarity and resistance to extinction, or in terms of a combination of generalization decrement and secondary reinforcement.

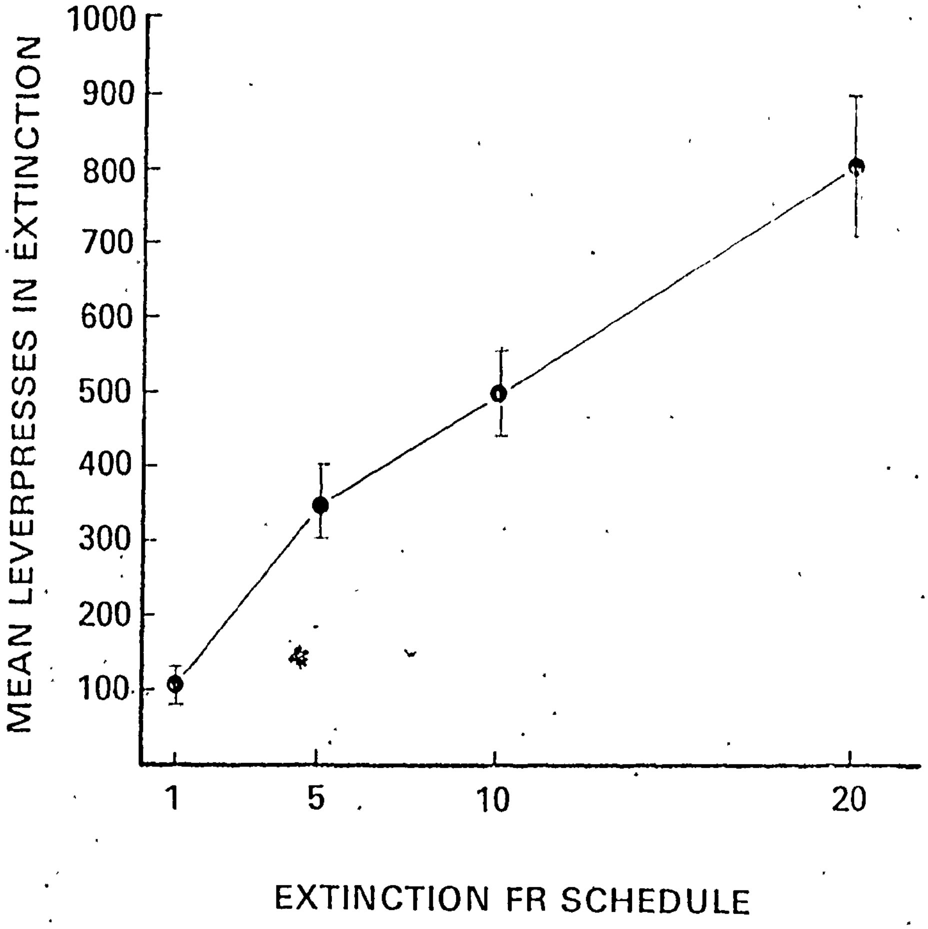


Figure 27

Experiment 4; Mean number of leverpresses in extinction, ±1 standard error, as a function of extinction FR schedule.

It appears, however, that the entire terminal response function is consistent with the unit-length hypothesis. This is clearly the case with respect to the FR 1, 5, and 10 groups; as the hypothesis predicts, increases in extinction unit length are associated with decreased resistance to extinction. Although the nonmonotonicity of the terminal response function is inconsistent with the unit-length hypothesis, an examination of individual differences in extinction unit length within the FR 20 group suggests that this discrepancy can be resolved in a manner fully consistent with the hypothesis.

First of all, it is clear that the elevated mean in the FR 20 group is due primarily to the performance of a single subject whose 109 terminal responses in extinction accounted for 11% of the range in this group. While this by itself seems to resolve the discrepancy (the remaining 5 subjects emitted a mean of 48.8 terminal responses) additional support for the unit length hypothesis was provided by the perfect rank-order correlation of -1.00 between mean extinction unit length and number of terminal responses in this group. Rank-order correlations in the remaining groups were +.38, -.31, and -.77 in the FR 1, 5, and 10 groups, respectively. The failure to observe a negative correlation in the FR 1 group is undoubtedly due to the fact that the range of unit lengths in that group was less than .50. It is apparent that the rank-order correlations approach -1.00 as within-group variability increases. Since these relationships occur within a single FR group, they are completely independent of ITI frequency.

As in Exp. 3, there was a direct relationship between acquisition FR and number of leverpresses to extinction. These data provide additional evidence inconsistent with the leverpress constancy hypothesis. While these data are compatible with a generalization decrement hypothesis applied to the leverpress response, the inadequacy of such an account is apparent from its failure to account ~~either~~ for the leverpress data from Exp. 3, or for the terminal response data in the present study.

The data from Exps. 1-4 appear to have ruled out several possible accounts of the function relating FR requirement and resistance to extinction in the IT-IT condition of Exp. 2: It is not due to generalization decrement, to differences in the secondary reinforcement provided by the ITI as a result of differences in the schedule on which subjects were trained, or to the frequency of terminal response occurrence within a constant leverpress output.

The data do not, however, rule out the possibility that the function relating extinction ITI frequency and number of terminal responses to extinction under IT conditions is due to differences in the secondary reinforcement provided by the ITI as a function of its schedule of presentation in extinction. In order to account for the terminal response data obtained in these studies, this hypothesis must assume that the rate at which the secondary reinforcing capacity of the ITI decreases with each presentation in extinction is an inverse function of the rate at which such presentations occur. Thus, the reinforcing capacity of the ITI decreases more slowly for subjects extinguished on an FR 1 as opposed to an FR 20 schedule of ITI presentation to the extent that extinction FR and ITI frequency are negatively correlated. While the literature does not speak to this assumption directly, it is clearly inconsistent with the observation that the rate at which both locomotor and operant responses extinguish increases with trial frequency (e.g., Rohrer, 1949; Teichner, 1952; Mackintosh, 1970; Krane and Ison, 1971). Furthermore, the hypothesis that the inverse relationship between extinction FR and number of terminal responses to extinction is due to differential reinforcement by the ITI does not account for the observation of a similar relationship between unit length and number of terminal responses within a single FR group.

Of the hypotheses which we have discussed, therefore, only the unit-length hypothesis appears fully consistent with all the data. There is, however, an additional hypothesis which should now be considered. Common to all of the experiments in which an inverse relationship between FR schedule and resistance of the response-unit to extinction has been obtained is the use of a DT extinction procedure. The data seem to rule out the possibility that the effects of DT extinction can be understood in terms of the reinforcing properties of the ITI, or in terms of generalization decrement arising from differences between acquisition and extinction schedules of ITI presentation. The support provided for the unit-length hypothesis suggests that it is the discriminative function of the ITI, in particular its ability to determine unit length, which is important. Control of terminal responding by ITI presentation has been a consistent feature of all those situations in which a relationship between unit length and resistance to extinction has been obtained. In Exp. 2, no such relationship was observed in those conditions in which discriminative control over terminal responding was exercised by internal stimuli, despite differences in extinction unit length. Perhaps, therefore, it is the mode of stimulus control over terminal responding, whether internal or external, which determines the nature of the relationship between FR requirement and resistance of the unit to extinction. Such an account would also explain the absence of differences in resistance to extinction in the FN and FCN studies cited in the Introduction, despite the use of a DT procedure, and the presence of between-group differences in extinction unit length, since control over terminal responding was exercised completely by internal stimuli in those studies.

The form which a mode-of-control hypothesis might take is not, however, completely clear. It would appear, however, that the most reasonable such account of these data would argue that there is an inverse relationship between extinction unit length and resistance to extinction, but only when control of unit termination is exercised by external stimuli. This hypothesis must necessarily assume that the correlation between extinction unit length and resistance to extinction observed within groups extinguished under FO conditions is unrelated to similar functions obtained between groups under DT conditions.

A test of this hypothesis against the unit-length hypothesis would require comparing resistance to extinction in groups having the same extinction unit lengths, but differing in the mode of stimulus control over unit termination. The difficulty in conducting such a test is that the extinction unit lengths employed would necessarily be determined by the length of the units emitted by subjects extinguished under internal control. Since the data indicate that such units considerably exceed acquisition FR value, both hypotheses could reasonably account for any failure to observe differences in resistance to extinction between external- and internal-control groups in terms of the proximity of these values to the asymptote of the function relating unit length to resistance to extinction. Differences in resistance to extinction should increase with differences in extinction unit length, however, and an experiment of this sort employing a sufficiently broad range of unit lengths might provide at least a provisional indication of the relative viability of these two hypotheses.

Experiment 5 consists of two studies, which, taken together, constitute a test of the sort described above. Subjects were trained on DT FR 1, 5, 10, or 20 schedules of reinforcement, but extinguished under either DT or FR-like schedules of ITI presentation. In the former condition, subjects received ITI presentations following each terminal response. Thus extinction took place under DT conditions, but with extinction unit length under internal discriminative control. In the latter condition, subjects trained on FR 1, 5, 10, and 20 schedules of reinforcement received IFI presentation following every response sequence of 5, 15, 25, or 40 leverpresses, respectively. These values approximated the extinction unit lengths emitted by subjects in the FR 1, 5, 10 and 20 groups in the IF-FO condition in Exp. 2, and were an estimate of the unit lengths to be expected from subjects extinguished under internal discriminative control. Thus extinction in the FR-like condition took place under external discriminative control of terminal responding, but at unit lengths which should be equivalent to those emitted by subjects in the FN condition. If the unit-length hypothesis is correct, subjects in both conditions should show equal resistance to extinction in terms of terminal responses, with no, or only minimal, differences between the groups within each condition. If the mode-of-control hypothesis is correct, there should be no differences in resistance to extinction between groups in the FN condition, while resistance to extinction in the FR-like condition should decrease with extinction unit length.

Experiment 5

Subjects

The subjects for this experiment were 92 naive female hooded rats, 120-150 days old at the beginning of training, obtained from the breeding colony of the Department of Psychology at McMaster University. Of these, 44 participated in the FR-like (PFR) and 48 in the FN condition. For three weeks prior to, and throughout the study, subjects were fed a single daily ration sufficient to maintain them at 85% of *ad lib* weight. Session reinforcements were supplemented with Purina Rat Chow to complete the daily ration.

Apparatus

The apparatus employed was that described in Exp. 1.

Procedure

Subjects in the FN condition were divided into four groups of 11 subjects each, and those in the PFR condition were divided into four groups of 10 subjects each, such that the mean body weights of the groups within each condition were approximately equal. The remaining four subjects in each condition were designated as replacements for subjects discarded due to injury or illness, apparatus failure, experimenter error, or failure to complete pretraining. Two subjects in the PFR condition were discarded and replaced for failure to complete magazine training. Eight subjects in the FN condition, two in each of the four groups, were discarded due to experimenter error. Three subjects, one in the FR 20 and two in the FR 10 group were discarded for failure to complete pretraining. Two replacement subjects were assigned to the FR 10 group, and one each to the FR 5 and FR 20 groups, resulting in an n of 9 in each of the four groups.

For both conditions, pretraining consisted of four days of magazine training and four days of CRF, and was carried out as described for the IT groups in Exp. 2. Each of the 30 reinforcements per session was accompanied by a 10-sec. ITI during which the chamber was darkened and the lever retracted.

Following pretraining, subjects received 10 days of IT FR reinforcement at ratio requirements of 1, 5, 10, or 20 leverpresses. All subjects were then extinguished in a single session to a criterion of 10 min. without a leverpress. In the MN condition, ITI presentation followed every terminal response regardless of the number of prior leverpresses. In the PFR condition, ITI presentation followed every sequence of 5, 10, 25, or 40 consecutive leverpresses for the FR 1, 5, 10, and 20 groups, respectively. On this modified FR schedule, ITI presentation did not occur following every 5th, 15th, 25th or 40th leverpress, but only following sequences of these lengths which were not interrupted by terminal responses. It was therefore possible for a subject to complete extinction without having received an ITI presentation, providing that each terminal response followed a sequence of leverpresses which was shorter than the programmed extinction schedule value. Had a normal FR schedule of

ITI presentation been employed, the tendency of subjects to emit terminal responses following ITI presentation would have resulted in a substantial reduction in unit length whenever a terminal response occurred within the ratio. If, for example, a subject in the FR 10 group completed a sequence of 20 leverpresses in extinction, an FR 25 schedule of ITI presentation would probably have elicited another terminal response after the next five leverpresses had been completed. This would reduce the mean unit length for these two sequences to half the programmed value. The probability of response sequences shorter than the programmed value was judged to be substantial in view of the considerable length of the higher extinction schedule values.

Results

Figure 28 presents mean extinction unit lengths, ±1 standard error, as a function of acquisition FR schedule and extinction condition. The line connects the programmed unit values for the PFR groups. Mean extinction unit lengths increased monotonically with acquisition FR in both conditions. Due to an approximately linear increase in variance with group mean, F tests were performed on the means of the log-transformed scores in both FN and PFR conditions. The effect of FR was significant in both: $F(3,32) = 12.98$, $p < .001$ in the FN condition, and $F(3,36) = 57.13$, $p < .001$ in the PFR condition. In the PFR condition, programmed and obtained mean unit lengths were identical in all but the FR 20 group which fell considerably below the programmed value. Unit lengths in the FN condition matched those in the PFR condition with the exception of the FR 10 group in which mean

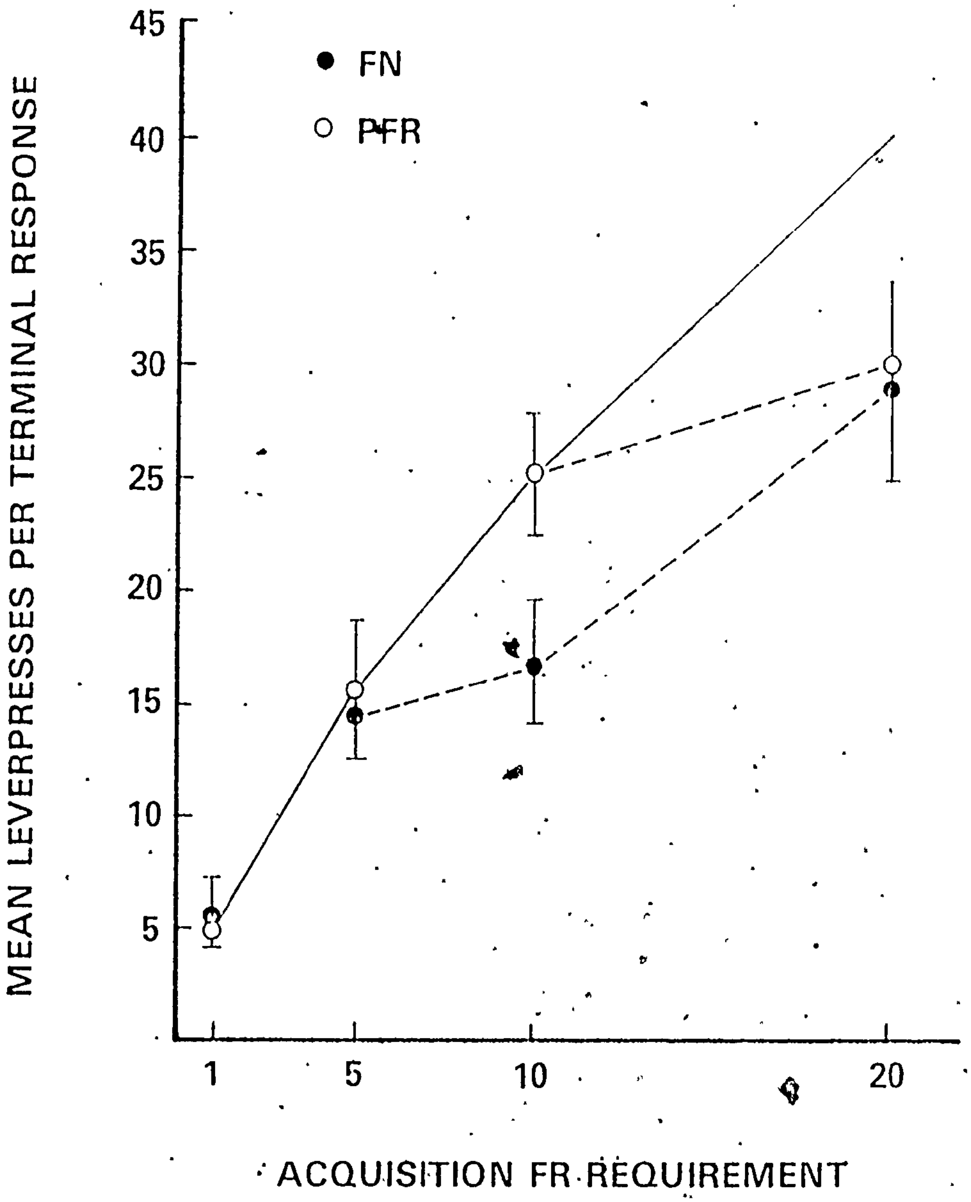


Figure 28

Experiment 5; Mean number of leverpresses per terminal response in extinction, ±1 standard error, as a function of acquisition FR requirement and extinction condition.

unit length was considerably below that of the corresponding PFR group.

Figure 29 presents the mean number of terminal responses emitted in extinction as a function of acquisition FR schedule and extinction condition. Separate F tests conducted on the means of the FN and PFR conditions failed to reveal significant between-group differences in either condition. A subsequent F test comparing only the FR 1, 5, and 10 means in the PFR condition did reveal a significant difference in number of terminal responses; $F(2,25) = 4.61$, $p < .025$. One other datum which is of interest is the proportion of terminal responses which were emitted under external control in the PFR condition. The proportion of of terminal responses which were emitted during the ITI, or following the ITI but before any additional leverpressing, was calculated for each subject. Table 3 presents the mean proportion of externally-elicited terminal responses, ±1 standard error, as a function of FR group. The figures were quite consistent in the FR 1, 5, and 10 groups, with between 55% and 65% of all sequences terminating under external control. The proportion of external control in the FR 20 group was considerably lower.

Figure 30 presents the mean number of leverpresses emitted in extinction, ±1 standard error, as a function of FR group and extinction condition. The number of leverpresses was consistently greater in the PFR than in the FN condition, but increased in an approximately linear manner with FR requirement in both conditions. No statistical tests were conducted on these data.

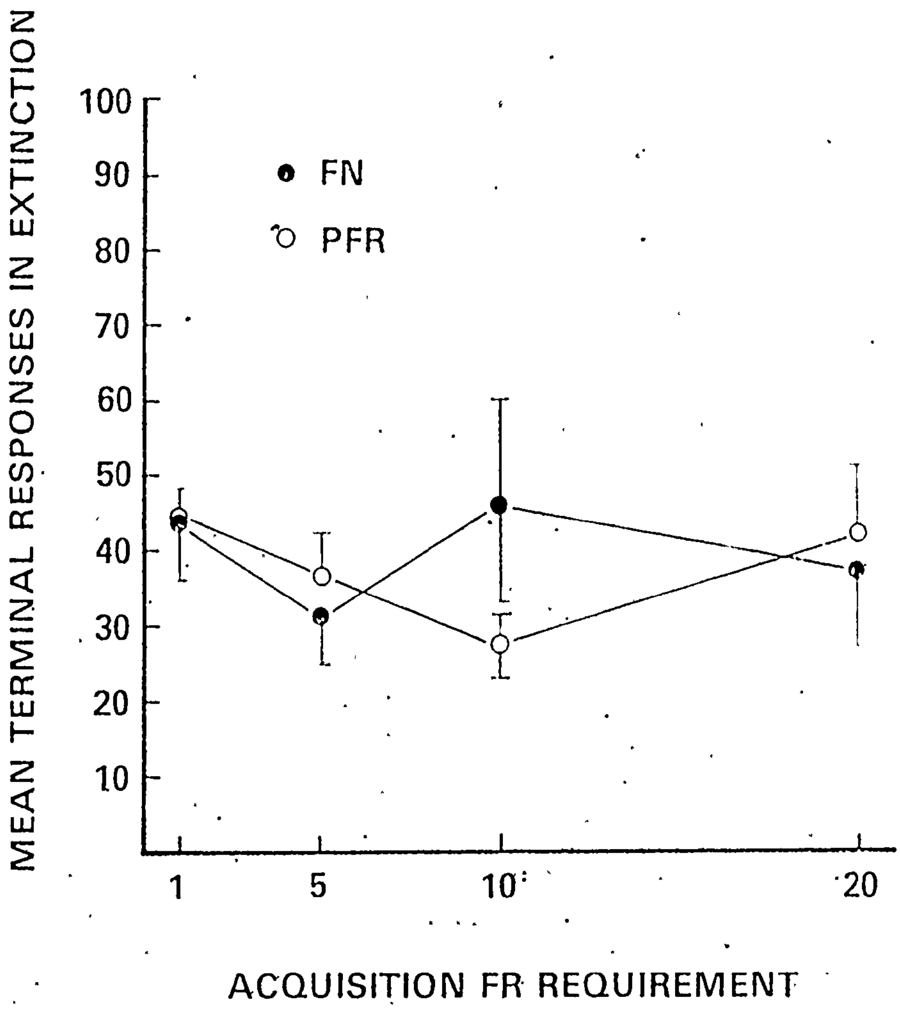


Figure 29

Experiment 5; Mean number of terminal responses in extinction, ±1 standard error, as a function of acquisition FR requirement and extinction condition.

Table 3

Experiment 5; Mean proportion of externally-elicited terminal responses in extinction, ±1 standard error, for FR groups in the PFR condition.

FR Group	Mean Proportion	±1 Standard Error
1	.62	.57-.67
5	.65	.60-.70
10	.59	.55-.63
20	.42	.38-.46

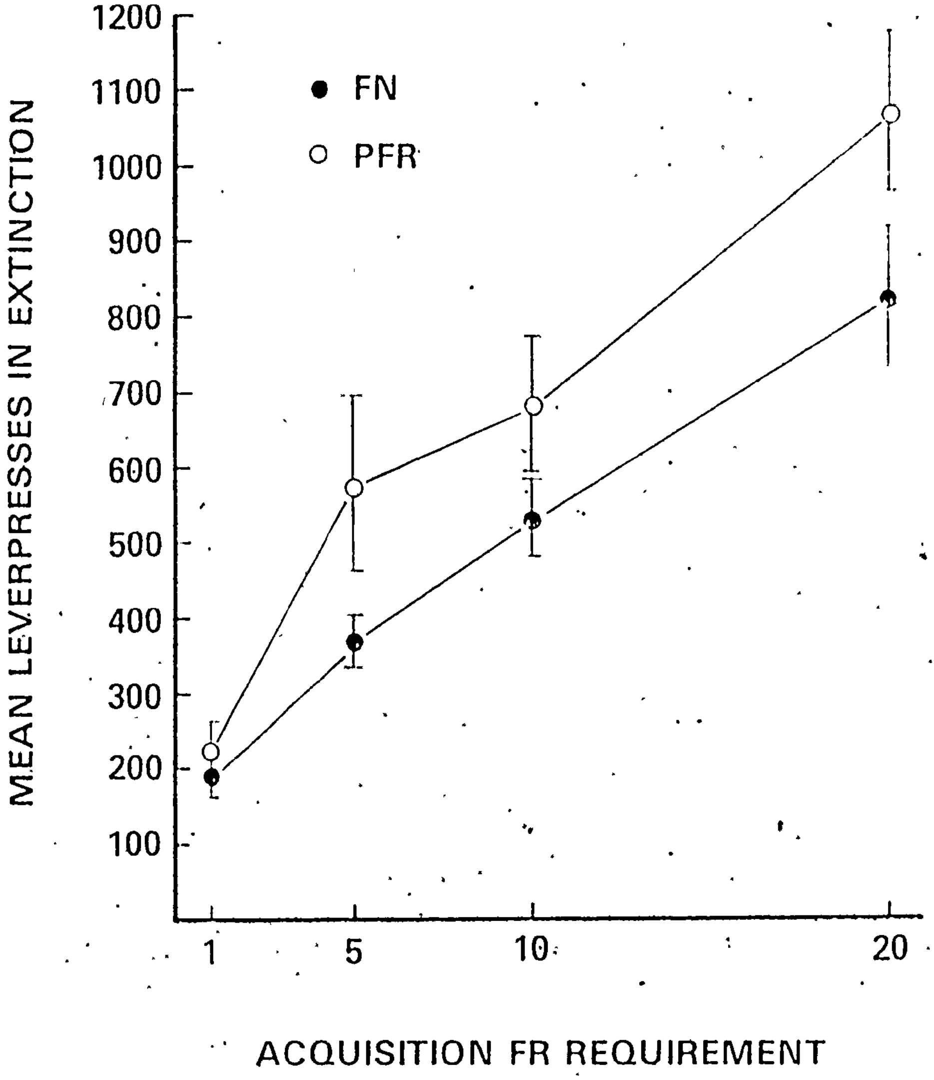


Figure 30

Experiment 5; Mean number of leverpresses in extinction, ±1 standard error, as a function of acquisition FR requirement and extinction condition.

Discussion

It was intended that mean extinction unit lengths should be equal in the corresponding groups in the FN and PFR conditions, and that these mean unit lengths should correspond to the programmed values in the PFR condition. The data in Fig. 26 indicate that neither of these objectives was completely met. The matching of unit lengths in the two conditions was the more successful, with the only departure from identity occurring in the FR 10 groups. Although it would appear that this discrepancy was due to the lower mean unit length in the FN 10 group, an examination of within-group performance does not indicate the influence of a small number of aberrant subjects. Mean unit lengths in this group were highly variable, ranging from 1.35 to 26.1, but only this latter subject had a mean unit length which equalled or exceeded the programmed PFR value. If the performance of this group is unreliable, we must attribute it to sampling error.

In the PFR group, programmed and obtained unit lengths were matched perfectly in all but the FR 20 group, whose lower mean unit length was matched perfectly by the corresponding FN group. In the FN condition, mean unit lengths in both the FR 10 and FR 20 groups fell below the programmed value.

Solely on the basis of statistical evidence, it might seem that the terminal response data obtained in this study support the mode-of-control hypothesis; there were significant differences in resistance to extinction as a function of unit length in the PFR condition (at least among the 1, 5, and 10 groups), but not in the FN condition. It is at this point that the failure to obtain equal unit lengths in the FR 10 groups is most distressing, since aside from these groups, resistance to extinction as a function of unit length is virtually identical in the two conditions. This similarity is not consistent with the mode-of-control hypothesis, and detailed consideration of both between- and within-group differences in extinction performance suggest that the present data are fully consistent with the unit-length hypothesis.

If resistance to extinction in the FN 10 group were similar to that in the corresponding PFR group, these data would provide unequivocal support for that version of the unit-length hypothesis which argues that resistance to extinction is a negatively accelerated decreasing function of extinction unit length; the exact parameters of this function varying with acquisition unit length in such a manner that at any given extinction unit length, resistance to extinction is a direct function of acquisition unit length. The equivalence of FN and PFR conditions in terms of resistance to extinction would indicate that mode of stimulus control is irrelevant to resistance to extinction, despite the fact that a considerable proportion of the terminal responses in the PFR condition were not emitted under external control. The mode-of-control hypothesis would predict that the relationship between extinction unit length and resistance to extinction becomes more pronounced as the proportion of external control increases. The probability of external control in the PFR condition was intermediate the the proportion of external control under DT-FO and DT-DT conditions in Exp. 2 (0% and 100%, respectively). The terminal response function obtained in the PFR condition is likewise intermediate to the functions obtained in these two conditions. Considered in isolation, therefore, the PFR function is readily explained by the mode-of-control hypothesis in terms of the proportion of externally-elicited terminal responses. Given equivalent performance in the PFR and FN conditions this explanation fails, since the mode-of-control hypothesis clearly predicts less resistance to extinction in the FN condition, and no relationship between terminal responses and FR requirement.

A second issue to be considered, therefore, is the existence of differences in resistance to extinction between the FR groups. Since we have chosen unit lengths which are similar to those obtained in the DT-FO condition in Exp. 2, the unit-length hypothesis seems to require that resistance to extinction be the same in both the DT-FO and the present conditions; i.e. no differences in resistance to extinction as a function of FR requirement.

A comparison of within-group performance in the DT-FO condition in Exp. 2 and in the FN and PFR conditions in the present study suggests that differences in resistance to extinction between these groups can be accounted for, consistent with the unit-length hypothesis, in terms of differences in the distribution of mean unit lengths within these groups. These differences in resistance to extinction are greatest in the FR 1 groups, and we will consider these in detail. Table 4 presents the rank-ordered mean unit lengths obtained in the three FR 1 groups under consideration. If the unit-length hypothesis is correct, we should find greater resistance to extinction associated with shorter mean unit lengths.

In the FR 1 groups in the present study, the programmed unit length of 5.00 was matched almost exactly by the mean unit lengths obtained in these groups. Mean unit length in the DT-FO FR 1 group, however, was 7.00. Of the 10 subjects in this group, 4 had mean extinction unit lengths which exceeded the lowest mean unit length obtained in the PFR group in the present study. The mean number of terminal responses emitted by these four subjects was 13.00. The remaining subjects in the DT-FO group, whose collective mean unit length was 5.73 emitted an average of 36.83 terminal responses; a value which is nearly 50% higher than the overall group mean, and considerably greater than the number emitted by the FR 5 group in the same condition (23.00). The difference in resistance to extinction between the DT-FO FR 1 group without these subjects and the FR 5 group is nearly as large as the largest difference (between the PFR 1 and PFR 5 groups) obtained in the present study.

In the FN 1 group in the present study, three subjects had mean extinction unit lengths which were shorter than the shortest mean unit length obtained in the DT-FO FR 1 group. The mean number of terminal responses emitted by these subjects was 70.3. The remaining subjects in the FN 1 group, whose mean unit length was 7.17, emitted an average of 30.17 terminal responses, much closer to

Table 4

Rank-ordered mean extinction unit lengths for subjects in the FR 1 groups in the DT-FO condition of Experiment 2, and the FN and PFR conditions of Experiment 5.

DT-FO	FN	PFR
3.46	2.87	3.77
4.05	3.07	3.80
4.25	3.26	3.86
5.44	4.02	4.50
5.61	4.91	5.19
5.61	5.05	5.30
5.96	5.11	5.61
7.40	10.50	5.92
9.00	13.35	6.09
9.43		6.33
16.85		

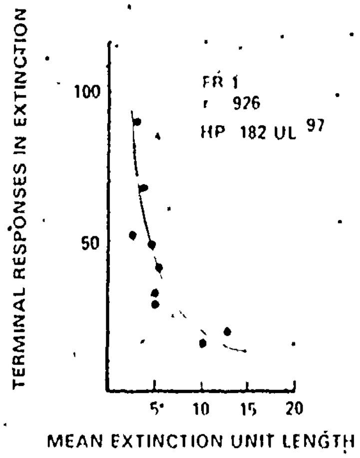
the value obtained in the DT-FO group whose mean unit length was 7.00.

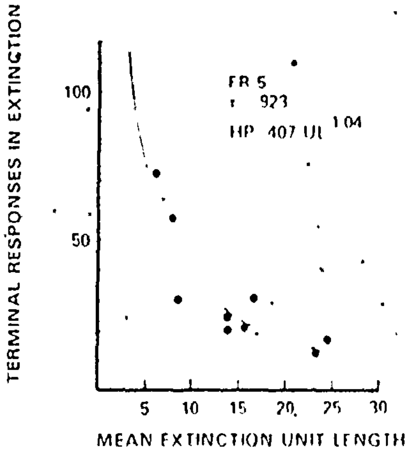
Thus it appears that when subjects emitting very long units, and few terminal responses, are omitted from the DT-FO FR 1 group, both mean extinction unit length and number of terminal responses are much closer to those observed in the present study. Likewise, if subjects emitting extremely short units, and many terminal responses, are omitted from the present FR 1 groups, both mean unit length and number of terminal responses emitted are much closer to the values obtained in the DT-FO group.

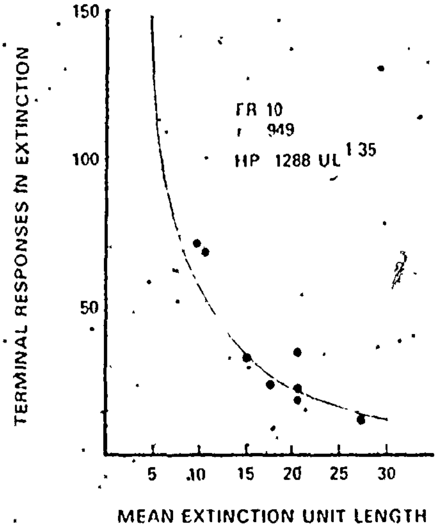
Evidence obtained from within-group analyses of extinction performance as a function of acquisition FR requirement in the present study provides further support for the unit-length hypothesis. Scatterplots of mean extinction unit length vs. number of terminal responses to extinction in the FR groups revealed a negatively accelerated decreasing relationship which was approximately linear in log-log coordinates. Pearson product-moment correlation coefficients were therefore calculated for the log-transformed scores in each group. Figure 31 presents the scatterplots of mean extinction unit length vs. terminal responses to extinction for subjects in the four FR groups. The figure also presents the correlation coefficient obtained in each group, together with the power function fitted to the data on the basis of the linear reduction equations presented in Table 5. It should be noted that power function parameters obtained in this manner are highly sensitive to variations in the position of points on the sharply-falling initial portion of the function; absolute values of these parameters must therefore be treated with

Figure 31

Experiment 5; Mean extinction unit length vs. number of terminal responses in extinction for subjects in the FR 1, 5, 10, and 20 groups of the FN condition.


FR 1
r 926
HP 182 UL 97
TERMINAL RESPONSES IN EXTINCTION
100
50
5
10
15
20
MEAN EXTINCTION UNIT LENGTH


FR 5
r 923
HP 407 UL 1 04
TERMINAL RESPONSES IN EXTINCTION
100
50
5
10
15
20
25
30
MEAN EXTINCTION UNIT LENGTH


FR 10
r 949
HP 1288 UL 1 35
TERMINAL RESPONSES IN EXTINCTION
150
100
50
5
10
15
20
25
30
MEAN EXTINCTION UNIT LENGTH

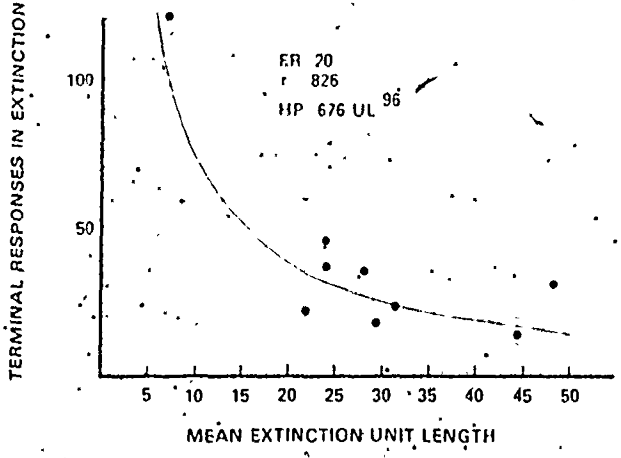

FR 20
r 826
HP 676 UL 96
TERMINAL RESPONSES IN EXTINCTION
100
50
5
10
15
20
25
30
35
40
45
50
MEAN EXTINCTION UNIT LENGTH

Table 5

Experiment 5; Linear reduction equations, obtained by the method of least squares, relating mean extinction unit length and number of terminal responses to extinction for FR groups in the FE condition.

FR 1: $\log HP = 2.26 - .97 \log UL$

FR 5: $\log HP = 2.61 - 1.04 \log UL$

FR 10: $\log HP = 3.11 - 1.35 \log UL$

FR 20: $\log HP = 2.83 - .96 \log UL$

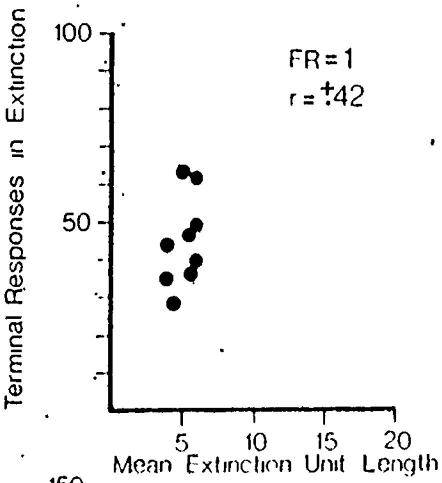
considerable caution. For comparison purposes, the scatterplots of mean extinction unit length vs. number of terminal responses for the PFR groups are presented in Figure 32. The restriction of unit lengths by the programmed ITI presentations considerably reduced within-group variability in unit length.

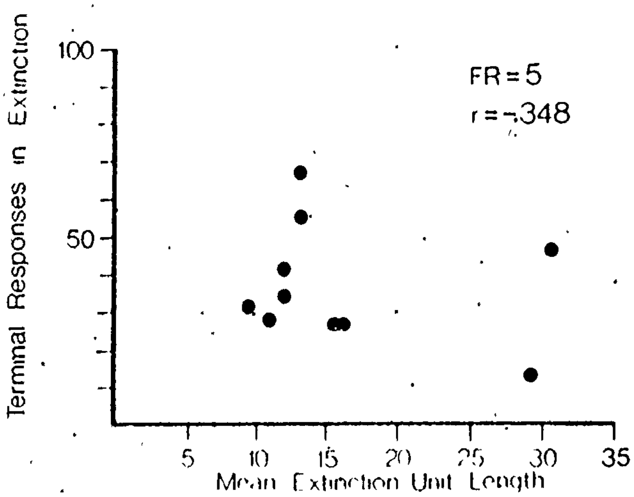
In the FN condition, correlations were quite high, indicating that from 69% to 90% of the variance in number of terminal responses to extinction could be accounted for in terms of variations in mean extinction unit length. In the PFR condition, the restricted range of unit lengths reduced correlations considerably, especially in the FR 1 group in which variability was least. It is apparent from a comparison of the points obtained in the two conditions that the performance of subjects in the PFR groups was fully consistent with the functions obtained in the corresponding FN groups. Furthermore, differences in the distribution of mean unit lengths in the FR 10 groups indicated that higher resistance to extinction in the FN 10 group can be fully explained in terms of the presence in this group of several subjects whose mean unit lengths were in the rapidly descending portion of the unit-length function.

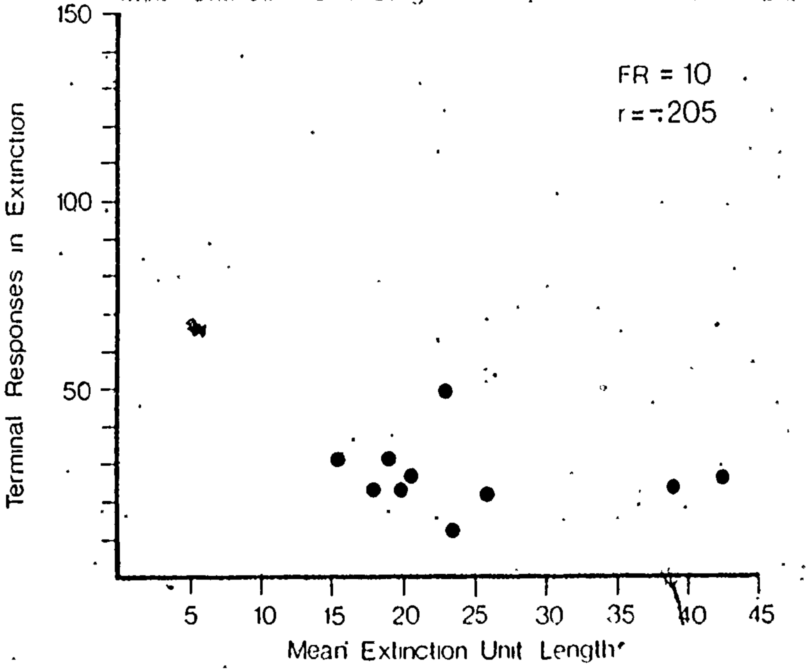
These functions support the hypothesis that acquisition reinforcement schedule is an important determinant of resistance to extinction. In general, it appears that the relationship between mean extinction unit length and resistance to extinction becomes shallower and shifts upward and to the right with increasing acquisition FR requirement. Thus resistance to extinction at any given extinction unit length is a direct function of acquisition unit length.

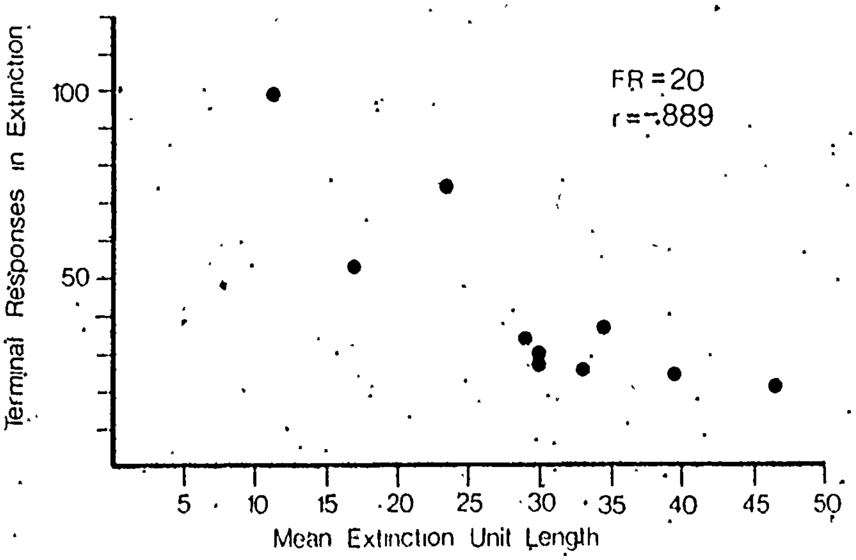
Figure 32

Experiment 5; Mean extinction unit length vs. number of terminal responses in extinction for subjects in the FR 1, 5, 10, and 20 groups of the PFR condition.


FR = 1
r = +.42
Terminal Responses in Extinction
100
50
5
10
15
20
Mean Extinction Unit Length


FR = 5
r = -.348
Terminal Responses in Extinction
100
50
5
10
15
20
25
30
35
Mean Extinction Unit Length


FR = 10
r = -.205
Terminal Responses in Extinction
150
100
50
5
10
15
20
25
30
35
40
45
Mean Extinction Unit Length


FR = 20
r = -.889
Terminal Responses in Extinction
100
50
5
10
15
20
25
30
35
40
45
50
Mean Extinction Unit Length

General Discussion

The response-unit hypothesis proposed by Mowrer and Jones (1945) contains two logically independent assumptions. The first and more important of these is that the individual responses which precede reinforcement during acquisition form an integrated functional response. This implies that control over the termination of such sequences is exercised by stimuli provided by the execution of the sequence. Studies in which reinforcement of response sequences took place in the absence of external cues to sequence completion (Day, 1972a, 1972b, 1973) clearly indicated both the development of internal control over terminal responding in acquisition, and the persistance of such control in extinction. Despite the support for the response-unit hypothesis provided by these studies, it remained unclear whether, or to what extent, a similar process of response integration occurs in operant schedules in which reinforcement of response sequences is accompanied by salient external stimuli which might block or retard the acquisition by internal stimuli of discriminative control over terminal responding. With respect to this question, the present studies demonstrate that internal stimuli do form a part, together with available external stimuli, of the stimulus complex which acquires discriminative control over terminal responding in acquisition.

In acquisition, the development of control over terminal responding by stimuli associated with ratio completion is indicated by the relatively rapid elimination of nonrewarded terminal responses, and their virtual absence by the end of acquisition. Extinction data indicate that this control is predominantly exercised by external correlates of ratio completion: When external cues continue to be provided in extinction, mean response-unit lengths tend to match the schedule of external stimulus presentation, even when it is inconsistent with the schedule employed during acquisition, and thus with the cues provided by internal stimuli. Even in the presence of external stimuli, however, the existence of internal control of terminal responding is indicated by the fact that subjects experiencing an inconsistency between external and internal cues emit units whose mean length differs in the direction of acquisition unit length from that dictated by the schedule of external stimulus presentation (Day and Platt, 1974). Further evidence of the existence of internal control, and of the strength of external control, is provided by the performance of subjects deprived in extinction of those external stimuli which accompanied reinforcement during acquisition. In such cases, mean extinction unit lengths are a direct function of acquisition unit lengths, even though the transition from predominantly external to fully internal control is characterized by a tendency to emit extremely long response sequences indicating the extent to which external control may initially override the cues provided by internal stimuli. That this tendency is not inherent in internal control is indicated by the fact that it does not occur to any appreciable extent when subjects are both trained and extinguished under fully internal control; in such studies differences between acquisition and extinction unit lengths are much less pronounced than in the present studies.

Mowrer and Jones' view of the response unit included the assumption that its length remained unchanged from acquisition to extinction. The present studies indicate that response-unit length, defined as the number of leverpresses preceding each terminal response, not only may change from acquisition to extinction, but may also show progressive changes in extinction. While these changes are of undoubted interest, they do not necessarily vitiate the concept of the response unit as an integrated functional unit. The unit can be said to be integrated, regardless of its length, to the extent that the terminal response is associated only with those stimuli which are produced by unit completion, and not with those stimuli produced by any one of its constituent responses. That this integration is maintained even when unit lengths change from acquisition to extinction is indicated by the consistent direct relationship between acquisition and extinction unit lengths. Changes in unit length from acquisition to extinction, and within extinction itself, may well result not from any qualitative change in the association between stimuli produced by unit completion and reinforcement, but rather from the difficulty of discriminating these stimuli. When these stimuli are quite salient, as in DF extinction, response-unit lengths change very little from acquisition to extinction, and remain relatively constant through extinction. Changes in unit length are typically observed only under FO extinction conditions, in which salient external cues which were available during acquisition are unavailable, and in which the relative difficulty of discriminating the appropriate internal cues might well be increased by alterations in response rate.

In summary, the present studies support the primary assumption of the response-unit hypothesis that response sequences followed by reinforcement form integrated response units whose termination is controlled by internal stimuli produced by execution of the unit.

The response-unit hypothesis proposed by Mowrer and Jones (1945) contains a second assumption: that the resistance of a response-unit to extinction is independent of its length. In the present studies, however, between-group comparisons consistent with this prediction were obtained only when control over terminal responding in extinction was exercised by internal stimuli. Whenever the use of IT procedures provided external cues to ratio completion, the mean number of units emitted in extinction decreased in a negatively accelerated manner with the mean unit length of the group. These data are most readily interpreted as indicating the existence of an inverse relationship of the form described between resistance to extinction and mean extinction unit length. Before considering this unit-length hypothesis in detail, however, we shall review the evidence bearing on several alternative explanations of this relationship.

Accounts of the inverse relationship between unit length and resistance to extinction which appeal to the differential secondary reinforcement supplied by the ITI as a function of either its acquisition or extinction presentation schedule suffer from both empirical and theoretical difficulties. It is clear, for example, that the effect of the ITI on resistance to extinction is not a function of the acquisition schedule on which it was established: Number of units emitted in extinction decreases with extinction FR in a similar manner whether subjects were trained at these values or shifted to them following training on a common schedule. The hypothesis that the secondary reinforcement imparted by the ITI increases with its frequency of presentation in extinction also appears implausible. The hypothesis that the number of responses emitted increases with the probability of response-reinforcer pairings in extinction is both inapplicable to the present terminal response data and inconsistent with the available literature. In the present studies, the probability of terminal response-ITI pairings was essentially independent of extinction ITI schedule, and cannot therefore account for differences in resistance to extinction as a function of extinction FR Furthermore, the literature suggests quite the opposite relationship between resistance to extinction and probability of response-reinforcer pairings (v. Dutch, 1974a,b). While the data do not rule out the possibility that the secondary reinforcement provided by the ITI increases with the frequency of terminal response-ITI pairings, there is nothing in the literature to suggest such a relationship, and it would be inconsistent with the frequent observation that massing of extinction trials reduces resistance to extinction (e.g, Krane and Ison, 1971; Teichner, 1952). In addition to these empirical difficulties, the data provide a theoretical obstacle to secondary reinforcement interpretations in that the temporal sequence of response _followed_ by reinforcer which is held to be a necessary condition for reinforcement is absent from all studies in which a reliable relationship between extinction ITI schedule and resistance to extinction was observed.

As an account of the operant PREE in general, and of the present results in particular, the generalization decrement hypothesis also fares poorly. According to this view, decreases in resistance to extinction as a function of acquisition or extinction FR schedule are the result of concommitant decreases in the similarity of acquisition and extinction stimulus conditions. This hypothesis is most directly applicable to those studies in which subjects trained on a common DT FR schedule are shifted to different DT schedules in extinction. In such cases the generalization decrement hypothesis predicts that the number of terminal responses emitted will be an inverse function of the difference between acquisition and extinction FR values. The present data indicate, however, that the inverse relationship between extinction FR value and resistance to extinction is independent of the relationship between acquisition and extinction FR values. It should be noted that while the generalization decrement hypothesis has typically been applied only to resistance to extinction in terms of the total number of individual responses emitted, the results of shifted-DT studies are also incompatible with this position: Regardless of the relationship between acquisition and extinction FR values, number of leverpresses to extinction increases with extinction FR value.

Several hypotheses suggested by certain features of the present results also do not appear to provide a completely adequate account of all available data. The leverpress-constancy hypothesis, for example, argues that acquisition response-unit length determines the total number of leverpresses which will be emitted in extinction, and that the frequency with which the terminal response is elicited while this reserve is being exhausted is responsible for the relationship observed in extinction between response-unit length and number of terminal responses emitted. This hypothesis was based on the similarity in Exp. 2 between the several extinction conditions in the number of leverpresses emitted as a function of acquisition FR requirement. In addition, the equations relating number of terminal responses to extinction and extinction unit length within FR groups are consistent with a reciprocal relationship between terminal responses and extinction unit length: If total leverpresses to extinction is constant for a given acquisition unit length, then that constant total (A) can be expressed as the product of extinction unit length and number of terminal responses to extinction: A = HP x UL. Rearranging terms, we find that the relationship between terminal responses and unit length should be $HP = A \times (1/UL)$, or $HP = A \times UL^{-1}$. The best-fitting functions relating terminal responses to unit length are, in fact, equations of the form $HP = A \times UL^{-B}$, and computed values of B are sufficiently close to -1.00 to be consistent with the hypothesis that for any acquisition unit length, the product of extinction unit length and number of terminal responses is a constant.

As we have indicated, however, considerable caution must be exercised in interpreting power function parameters obtained via a least-squares curve-fitting procedure. The values obtained for the exponent are also consistent with an increase in total leverpresses emitted with extinction unit length (exponents between -1.00 and 0). The data also support this position: In shifted-IT studies, number of leverpresses to extinction is consistently a direct function of extinction unit length. It is also the case that within a given extinction FR group there is generally a positive correlation between extinction unit length and number of leverpresses to extinction.

A second hypothesis derived from the data argues that the relationship between extinction unit length and number of units emitted depends upon the mode of stimulus control over unit termination: When control is predominantly internal, unit length and resistance to extinction are independent; when control is predominantly external, resistance to extinction decreases with extinction unit length. The data from Exp. 5, however, indicate that extinction performance as a function of extinction unit length does not differ appreciably under internal and external control. In both cases, the data tend to suggest an inverse relationship between unit length and resistance to extinction.

Of those we have discussed, only the unit-length hypothesis appears to be fully consistent with the results of the present studies. Before considering this hypothesis in detail, however, we should consider the possible relevance to these data of the two major theories which, as we indicated in the introduction, seem to provide an adequate account of the instrumental PREE: Capaldi's sequential theory and Amsel's frustration theory.

Both theories are primarily concerned with discrete-trial procedures in which reinforcement is contingent upon the completion of what Platt and Senkowski (1970) have referred to as homogeneous behaviour sequences in which "... a series of substantially identical S-R units (is) followed by some terminal reinforcing event (S^R)." (p. 195). There are, therefore, obvious similarities between the instrumental runway situation from which these theories have been derived and the DT operant procedures employed in the present studies. The nature of these similarities, however, also alerts us to the difficulty involved in applying these theories to the present data.

Both theories have much to say concerning the effects of partial reinforcement in extinction. In the runway situation, however, partial reinforcement is defined in terms of the probability that a given behaviour sequence, or trial, will be followed by reinforcement. In the case of the FR schedule, each response sequence is invariably followed by reinforcement, and partial reinforcement is defined in terms of the probability of reinforcement for each of the individual responses comprising the sequence. Thus, in the runway partial reinforcement is defined in terms of the frequency with which a sequence of fixed length is followed by reinforcement. In the operant situation, partial reinforcement is defined in terms of the length of the response sequence which terminates with reinforcement. The operant FR schedule would not, therefore, be viewed as a partial reinforcement paradigm from the instrumental point of view, but rather as analogous to the manipulation of runway length (Platt, 1971).

Given these differences between the procedures defining partial reinforcement in the instrumental and operant situations, it is plausible to argue that the response-unit hypothesis and the theoretical accounts of the instrumental PREE are not competing but complementary accounts of phenomena which may be related. The response-unit hypothesis is concerned with the processes which serve to integrate into a functional unit the sequence of behaviours which precede reinforcement. The frustration and sequential theories begin with the assumption of a unitary sequence and concern themselves with the extent to which disconfirmation of the expectancy of reward increases the persistance of the unit.

It is not surprising, therefore, that neither sequential theory nor frustration theory provides a useful framework within which to organize the results of the present studies of the analogy between the operant ratio and the instrumental trial is accepted. Both theories can be applied to the present data, however, if we assume the functional equivalence of the individual leverpress and the instrumental trial. On this assumption, sequential theory would view acquisisition FR requirement as a manipulation of the number of nonreinforced trials preceding a reinforced trial, or N-length. According to sequential theory, number of responses to extinction should be a direct function of N-length, or acquisition FR requirement. This prediction is confirmed only in those experiments in which either FO or matched-DT extinction procedures were employed.

Beyond this prediction, it is difficult to apply the tenets of sequential theory to our data. Firstly, the status of the terminal response is unclear. Viewed simply as one of several concurrent responses, each of which is independently affected by reinforcement contingencies, the terminal response is continuously reinforced during all but the first few sessions of partial reinforcement. During this transition period the number of nonreinforced terminal responses per reinforcement is directly related to FR requirement. Applying the N-length postulate to the terminal response we would predict that either (1) number of terminal responses to extinction should increase with acquisition FR, or (2) this early and minimal partial reinforcement is insufficient to affect the resistance of the terminal response to extinction, which should therefore be independent of acquisition FR. The first prediction is clearly contradicted by the data, and the second is supported only in those cases in which FO rather than DT extinction procedures were employed.

Secondly, the uniqueness of sequential theory lies primarily in its explanation of the effects of acquisition reinforcement parameters such as magnitude and delay of reward, and of the spacing and ordering of reinforced and nonreinforced trials. In dealing with the extinction stimulus manipulations which characterize much of our data, sequential theory must rely on those generalizations concerning the properties of stimuli paired with reinforcement which are the common property of general behaviour theory, and which were discussed earlier in our consideration of the generalization decrement and secondary reinforcement hypotheses.

The tenets of frustration theory likewise do not provide a satisfactory account of our data. According to frustration theory, continuous reinforcement in pretraining results in the development of an expectancy of reward following a response. Subjects shifted from continuous to partial reinforcement experience frustration on each occasion on which a response fails to produce reward. Initially, this frustration may disrupt performance. If frustrative nonreward occurs repeatedly in the context of ongoing reinforcement, the stimuli it produces become part of the context in which the reinforced response occurs. The greater the proportion of responses which go unrewarded, the greater the frustration, and the greater the conditioning of frustration-produced stimuli to the ongoing response. When reinforcement is omitted in extinction, continuously reinforced subjects have their performance disrupted by the resulting frustration, while partially reinforced subjects continue to respond to the extent that frustration-produced stimuli have been conditioned to the response. Since the proportion of nonreinforced leverpresses increases with acquisition FR requirement, frustration theory predicts that number of leverpresses to extinction will increase with acquisition ratio requirement. As was the case with sequential theory, the data consistent with this prediction comes from studies in which FO or matched-IF extinction procedures were employed.

On the assumption that the terminal response in an independent operant, frustration theory makes the same predictions concerning its resistance to extinction as a function of acquisition FR requirement as sequential theory; the former interpreting the effects of early partial reinforcement in terms of the conditioning of frustration-produced stimuli rather than in terms of N-length. Both theories, therefore, are unable to provide an explanation of the relationship between acquisition FR requirement and number of terminal responses to extinction under matched-IF extinction conditions. Furthermore, we find that the tenets of frustration theory, like those of sequential theory, deal primarily with the effects of acquisition reinforcement parameters on extinction, and make no predictions concerning the manipulation of extinction stimulus conditions which are not implied by the generally accepted properties of reinforcement-paired stimuli.

Sequential theory and frustration theory both rely on a specific elaboration of the generalization decrement hypothesis to account for the PREE. They argue that the difference between continuous and partial reinforcement lies in the extent to which the response of interest becomes conditioned to stimuli arising from nonreinforcement. As an operation, nonreinforcement can be considered to be the omission of reinforcement from a stimulus context which is indiscriminable from that in which reinforcement has been presented, but which is discriminable from other stimulus contexts in which reinforcement has never been presented. A number of runway studies have demonstrated that the effect of nonreinforced trials on resistance to extinction decreases if reinforced and nonreinforced trials are discriminable. For example, regular alternation of reinforced and nonreinforced trials produces less resistance to extinction than random 50% reinforcement (Tyler, Wortz, and Bitterman, 1953; Capaldi and Minkoff, 1967; Bloom and Capaldi, 1961). Furthermore, resistance to extinction decreases with increased training on alternating schedules, but increases with training on random schedules (Capaldi, 1958). Rudy (1971) has demonstrated that this effect is not due to the greater variability of N-length on random schedules: Subjects reinforced following every second or third trial were less resistant to extinction when reinforced and nonreinforced trials were discriminable than were subjects receiving random 50% reinforcement.

It is the importance of the discrimination between reinforced and nonreinforced stimulus contexts which renders implausible the equation of the leverpress and the runway trial. To argue that subjects on partial reinforcement schedules experience nonreinforcement following each leverpress implies that the stimuli accompanying a leverpress and those accompanying reinforcement cannot be, or are not, discriminated. This is unlikely on both a priori and empirical grounds. It is clear, for example, that the two sets of stimuli are eminently discriminable. Those accompanying a leverpress consist primarily of proprioceptive stimuli (which presumably change with each successive press), while those accompanying reinforcement also include salient external stimuli which may encompass several sensory modalities. Furthermore, the characteristics of FR performance are clearly consistent with the rapid development of such a discrimination: While the transition from continuous to partial reinforcement is characterized by frequent pauses and terminal responses, within the first few sessions nonreinforced terminal responses disappear almost completely.

In summary, it appears that attempts to apply either sequential theory or frustration theory to the present data fail not only because the manipulations employed fall outside the domains of these theories, but also because the functional correspondence of the ratio and the runway trial preclude any consideration of FR reinforcement schedules in terms of the effects of nonreinforcement of trials.

With the elimination of the most plausible alternatives, the unit-length hypothesis provides the only clear and integrated account of the available data. According to this hypothesis, variations in the number of terminal responses emitted in extinction as a function of extinction FR schedule are due to an inverse relationship between mean extinction unit length and resistance to extinction. The most direct support for this hypothesis is provided by the evidence obtained within experimental groups of a negative correlation between mean extinction unit length and number of terminal responses to extinction. This relationship, which is independent of ITI frequency, has been observed in every case in which a sufficiently broad range of unit lengths were represented within an FR group. While it is possible that unidentified factors are responsible for the covariation of unit length and resistance to extinction when these variables are not under experimental control, our confidence in the existence of a causal relationship between them is increased by the observation of a similar function when extinction unit lengths are directly manipulated. Least-squares fits to the within-group data suggest that the relationship between mean unit length and resistance to extinction is best represented by a power function of the form $HP = A \times UL^{-B}$. The reliability of the A and B parameters obtained via curve-fitting procedures is suspect, but the data support several cautious generalizations: Firstly, data obtained both within and between extinction FR groups indicates an increase in total number of individual responses emitted with increasing extinction unit length. This relationship is governed by the exponent (-B) applied to mean unit length, and is satisfied by a value of B between 1.00 and 0.00, and a value of the exponent between -1.00 and 0.00. Secondly, the progressive flattening of the unit length/ terminal response function with increasing acquisition FR requirement would be consistent with a concomitant decrease in the absolute value of the exponent. Finally, the function also appears to shift upward and to the right as acquisition unit length increases. This increase in overall resistance to extinction with acquisition unit length should be reflected by the parameter A, and is consistent with a direct relationship between A and acquisition unit length.

The data therefore suggest that number of response units emitted in extinction is a function both of the length of the unit reinforced in acquisition, and of the mean length of the units emitted in extinction. For any given acquisition unit length, the number of units emitted in extinction decreases in a negatively accelerated manner as mean extinction unit length increases. The slope of this function decreases with increasing acquisition unit length, and is such that the total number of individual responses emitted, the product of mean unit length and number of units emitted, increases with mean extinction unit length. For any given extinction unit length, however, resistance to extinction increases with acquisition unit length.

The extent to which these generalizations are supported by the data is attested to by the consistency across studies and conditions in the relationships obtained between mean extinction unit length and resistance to extinction as a function of acquisition unit length. This consistency is graphically illustrated in Figure 33, which presents the scatterplots of mean extinction unit length vs.

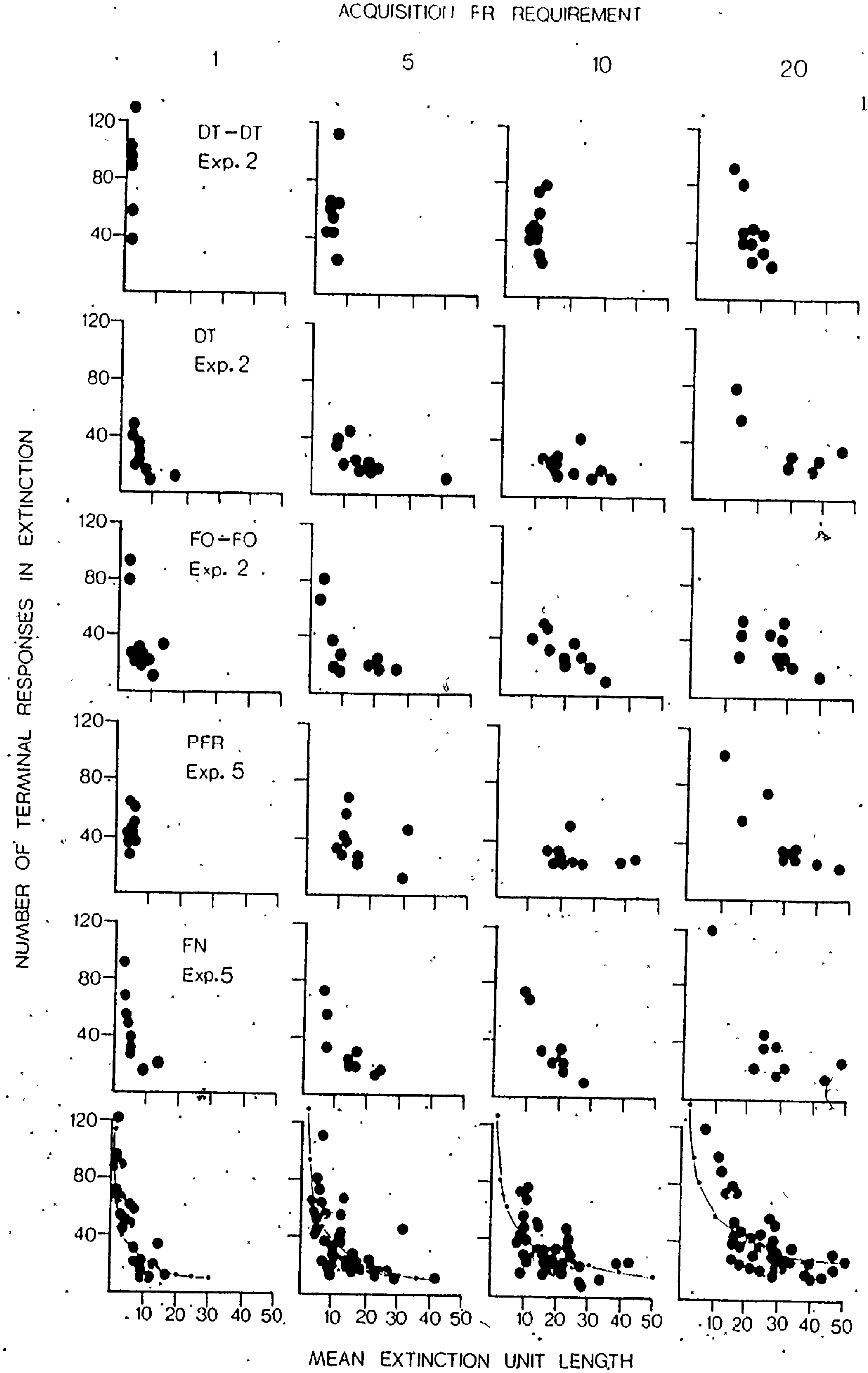
number of terminal responses to extinction from each of the acquisition FR groups represented in the several conditions of Exps. 2 and 5. Each row in the figure contains scatterplots obtained from the several FR groups within a single experimental condition. Each column consists of scatterplots obtained from subjects trained at the same FR value, but extinguished under different conditions. The bottom row of the figure plots all of the points in the column above it on the same axes.

In experimental conditions in which sufficient within-group variability was obtained, both the negatively accelerated decreasing form of the function and its progressive rightward shift and flattening with increasing acquisition unit length are apparent. While these features cannot clearly be discerned in those conditions in which direct experimental control of extinction unit lengths minimized within-group variability, the summary plots indicate that these points are compatible with the relationship observed in the remaining conditions. These summary plots, to which power functions have been fitted by eye, also suggest the extent to which differences in resistance to extinction between groups trained at the same unit length can be accounted for in terms of differences between conditions in the within-group distribution of extinction unit lengths along a common underlying function.

It is also possible to explain differences in resistance to extinction between groups within a condition by referring the extinction unit lengths of each group to the unit length/terminal

Figure 33

Mean extinction unit length vs. number of terminal responses in extinction for subjects in the FR 1, 5, 10, and 20 groups in the DF-DF, DF-FO, and FO-FO conditions in Experiment 2; and the [illegible] and PFR conditions in Experiment 5.


ACQUISITION FR REQUIREMENT
1
5
10
20
DT-DT
Exp. 2
DT
Exp. 2
FO-FO
Exp. 2
PFR
Exp. 5
FN
Exp. 5
NUMBER OF TERMINAL RESPONSES IN EXTINCTION
120
80
40
10
20
30
40
50
MEAN EXTINCTION UNIT LENGTH

response function appropriate to its acquisition requirement. To accomplish this for the studies represented in Fig. 33, assumptions must be made concerning the shape of the unit length/terminal response functions at each of the four acquisition unit length values employed. For this purpose, the power function fitted by eye to the summary plots were abstracted, and are presented in Figure 34f. The equations for these functions are as follows:

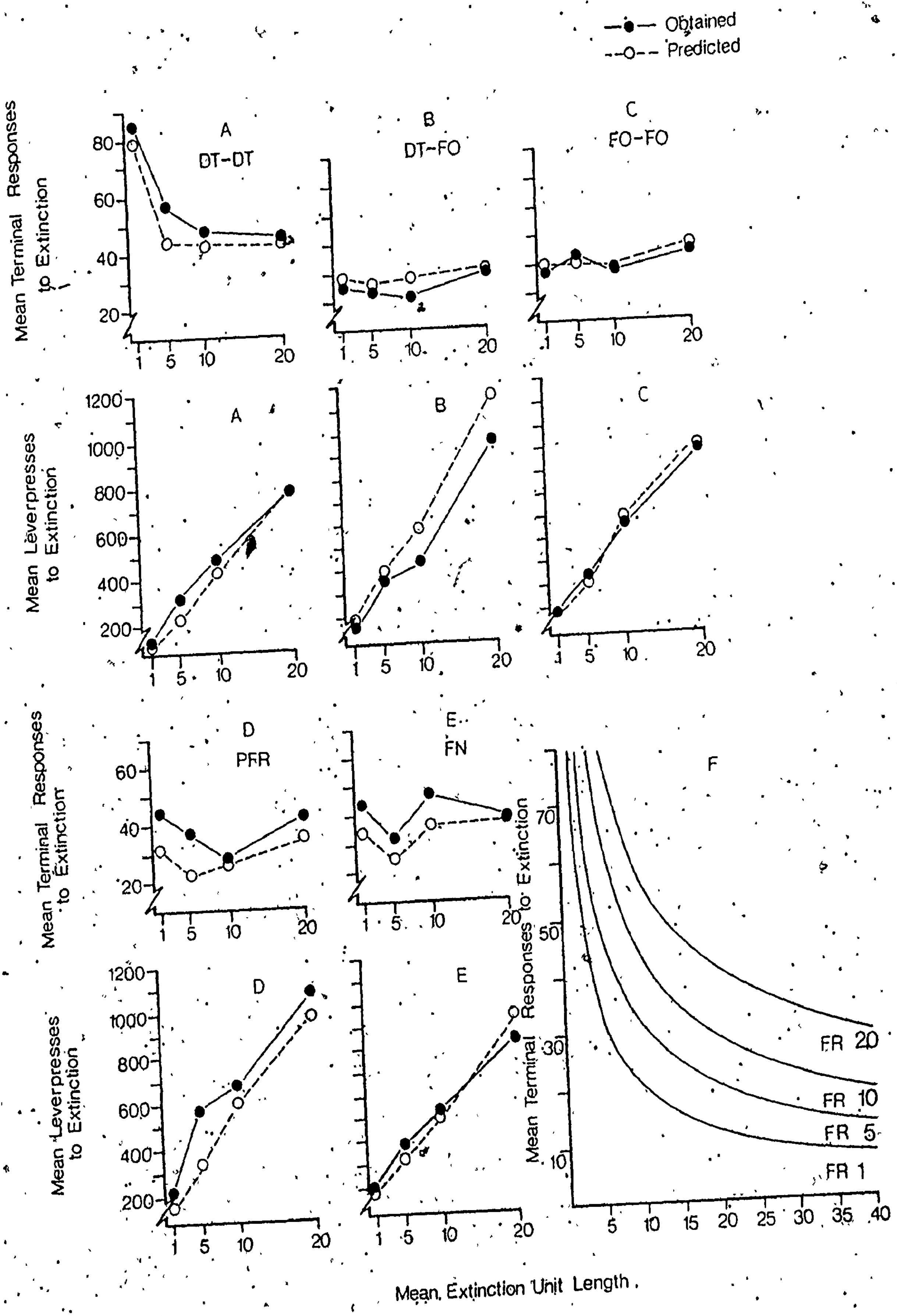
1. FR 1: $HP = 100 \times UL^{-.71}$
2. FR 5: $HP = 130 \times UL^{-.65}$
3. FR 10 $HP = 170 \times UL^{-.60}$
4. FR 20: $HP = 180 \times UL^{-.50}$

These curves and their equations illustrate the changes in the relationship between extinction unit length and resistance to extinction which are presumed to occur as a function of acquisition unit length. Since they are derived, albeit informally, from the available data, these functions may also be taken as a reasonable approximation of the functions which actually underly extinction performance in these studies. Thus it should be possible to demonstrate that differences in resistance to extinction between the groups within the five conditions represented in Fig. 33 can be adequately accounted for, at least in form, by referring the mean extinction unit lengths obtained in each group to the function in Fig. 34 appropriate to its acquisition FR requirement.

In deriving predicted resistance to extinction within each condition, the following procedure was employed:

Figure 34

Power functions fitted to mean extinction unit length vs. number of terminal responses in extinction as a function of acquisition FR requirement; Predicted and obtained mean numbers of terminal responses and leverpresses in extinction for groups in the IT-IT, IT-FO, and FO-FO conditions in Experiment 1, and in the IT and PFR conditions in Experiment 5.


—●— Obtained
--○-- Predicted
A
DT-DT
B
DT-FO
C
FO-FO
Mean Terminal Responses to Extinction
80
60
40
20
1
5
10
20
A
B
C
Mean Leverpresses to Extinction
1200
1000
800
600
400
200
D
PFR
E
FN
F
60
40
20
D
E
1200
1000
800
600
400
200
Mean Terminal Responses to Extinction
70
50
30
10
FR 20
FR 10
FR 5
FR 1
5
10
15
20
25
30
35
40
Mean Extinction Unit Length

1. The mean extinction unit length obtained by each subject within a group was inserted into the formula for the appropriate acquisition FR function in Fig. 34f.
2. Solution of the equation thus produced the predicted number of terminal responses to extinction for each subject in the group.
3. The predicted number of terminal responses to extinction for each subject was then multiplied by the mean extinction unit length obtained by that subject to produce the predicted number of leverpresses to extinction for that subject.
4. Finally, the predicted group mean for each measure was obtained by taking the mean of the predicted scores for all subjects in the group.

Figures 34a-34e present mean number of terminal responses and mean number of leverpresses to extinction, both predicted and obtained, as a function of acquisition FR group for the five extinction conditions represented in Fig. 33. The results of these comparisons for the DT-DT, DT-FO, and FO-FO conditions of Exp. 2 are presented in Figs. 34a-34c, respectively. The most important of these is the DT-DT condition. The matched-DT procedure employed in this condition resulted in a negatively accelerated decreasing relationship between acquisition FR and number of units emitted in extinction. According to the unit-length hypothesis, this relationship resulted from the negatively accelerated decreasing form of the functions underlying extinction performance at each acquisition FR value, together with the fact that the overall increase in resistance to extinction with acquisition FR value was not of sufficient magnitude to outweigh increases in mean extinction unit length across FR groups. Thus the predicted relationship between acquisition FR and number of terminal responses to extinction is of the same form as the individual functions, but considerably shallower. As Fig. 34a indicates, predicted group means for number of terminal responses matched the obtained means fairly well. The largest discrepancy occurred in the FR 5 group, in which the predicted mean was only 79% of that actually obtained. The remaining predicted means were all at least 90% of those actually obtained.

In all of the conditions, including DT-DT, total number of leverpresses to extinction was an approximately linear function of acquisition FR requirement. A similar relationship is predicted by the unit-length hypothesis, and the fit between predicted and obtained means for this measure in the DT-DT condition was fairly good. The largest discrepancy again occurred in the FR 5 group in which the predicted mean was only 79% of the obtained. Remaining predicted means were at least 88% of obtained, and in the FR 20 group predicted and obtained means were identical.

In the DT-FO and FO-FO conditions of Exp. 2, the number of terminal responses in extinction did not differ significantly as a function of acquisition FR requirement. According to the unit-length hypothesis this is due to the long mean extinction unit lengths in these conditions, together with the existence of a direct relationship between acquisition FR and the discrepancy between acquisition and extinction unit lengths. When mean extinction unit lengths equal acquisition FR requirement, the DT-DT terminal response function is obtained. When extinction units exceed acquisition FR by a constant proportion, the predicted terminal response function becomes both lower and slightly flatter than the DT-DT function as this proportion increases. In the DT-FO and FO-FO conditions, however, extinction unit lengths exceeded FR requirement by a proportion which was inversely related to FR requirement. The predicted terminal response functions in these conditions are therefore both lower and considerably flatter than the DT-DT function.

Figs. 34b and 34c present the comparison of predicted and obtained means in the DT-FO and FO-FO conditions, respectively. With respect to terminal responses, the fits are quite good. The largest discrepancy occurs in the FR 10 group of the DT-FO condition in which the predicted mean is 33% larger than actually obtained. The fit between predicted and obtained resistance to extinction in terms of total leverpresses emitted was excellent in the FO-FO condition, and fairly good in the DT-FO condition. In the latter, predicted means exceeded obtained in the FR 10 and FR 20 groups by 34% and 20% respectively.

The PFR and FN conditions of Exp. 5 were expected to produce results essentially identical to those observed in the DT-FO and FO-FO conditions of Exp. 2. In discussing differences between the former two groups, and between them and the DT-FO and FO-FO conditions, it was suggested that they could be accounted for in terms of within-group distributions of mean extinction unit lengths. Figs. 34d and 34e present predicted and obtained means in the PFR and FN conditions, respectively. In the PFR condition, predicted and obtained means matched fairly well in the FR 10 and FR 20 groups, while predicted fell short of obtained means in the FR 1 and FR 5 groups. The shape of the predicted and obtained terminal response functions were similar except that the former did not reflect the observed decrease in resistance to extinction between the FR 5 and FR 10 groups, and turned upward at FR 10 rather than at FR 20. In the FN condition, predicted resistance to extinction was consistently lower than obtained, although the shape of the predicted and obtained terminal response functions were virtually identical. In our earlier discussion of Exp. 5, we concluded that the FN and PFR conditions produced identical extinction performance, and that the discrepancy between the FR 10 groups in these conditions was due to a similar discrepancy in their mean extinction unit lengths. The predicted terminal response functions support this analysis in that predicted resistance to extinction is identical in both conditions save for the FR 10 groups in which the predicted difference matches that actually observed.

With respect to total number of leverpresses to extinction, the fit between predicted and obtained means is quite good in the FN condition, and fair in the PFR condition. In the latter, the predicted group means are consistently below those actually obtained. The actual differences between predicted and obtained means are moderate in all but the FR 5 group, in which the obtained was considerably higher than the predicted mean. The departure of the obtained FR 5 mean from an otherwise linear relationship between mean number of leverpresses and FR requirement is due to a single subject who emitted 46 units of 30 leverpresses, for a total number of leverpresses greater than that emitted by any other subject in the experiment.

It should be emphasized that the fit between predicted and obtained means depends solely on the extent to which the extinction performance of all subjects trained at a given FR value can be characterized by a common unit length/terminal response function of the form described earlier. The correspondence between predicted and obtained means in the present comparisons clearly supports this hypothesis, and demonstrates that the derived functions adequately explain extinction performance in conditions in which direct experimental control of extinction unit lengths eliminated the possibility of detecting within-group relationships between unit length and resistance to extinction.

The success of the unit-length hypothesis in accounting for the results of the present studies indicates that the response-unit hypothesis propsed by Mowrer and Jones must be reexamined and modified. We noted earlier that this hypothesis contained two independent assumptions. The first and most fundamental of these is that reinforcement of a sequence of responses during acquisition results in the integration of this sequence into a functional response unit whose termination is controlled by proprioceptive and other internal consequences of its execution. The unit-length hypothesis also rests on this assumption, which finds considerable support in the results of the present studies. The second assumption made by Mowrer and Jones was that resistance to extinction in terms of response units is independent of acquisition response-unit length. As a purely empirical generalization applied to FO procedures such as those with which Mowrer and Jones were concerned, this assumption also finds support in the present studies. To the extent that the results of the present studies can be generalized to all acquisition unit lengths, they suggest that independence of acquisition unit length and resistance to extinction should be observed whenever control of extinction unit length is exercised by internal stimuli. However, as a statement of the general relationship which obtains between response-unit length and resistance to extinction this assumption must be discarded.

What the unit-length hypothesis suggests, therefore, is modification rather than rejection of Mowrer and Jones' original response-unit hypothesis. This modification would add to the original assumption concerning the functional significance of the response unit the several assumptions concerning the relationship between extinction unit length and resistance to extinction as a function of acquisition unit length described above. The postulates of this revised response-unit hypothesis might take the following form:

1. Reinforcement of sequences comprising n individual responses strengthens the tendency for stimuli associated with the completion of n responses to control the termination of response sequences.

2. The strength of the discriminative control over terminal responding exercised by stimuli associated with completion of the reinforced response sequences is a direct function of the number of pairings of those stimuli and reinforcement.

3. The length of response sequences emitted in extinction is a direct function of the rate at which those stimuli exercising discriminative control over terminal responding, whether internal or external, occur in extinction.

4. When terminal responding is controlled by internal stimuli, the ratio of extinction to acquisition mean unit length decreases as acquisition unit length increases.

5. The number of response sequences emitted in extinction is a negatively accelerated decreasing function of mean extinction response-unit length. The equation expressing this relationship is of the form $HP = A \times UL^{-B}$, where B is greater than 0 and less than 1.00.

6. The relationship between mean extinction unit length and resistance to extinction changes with acquisition unit length such that A increases and B decreases with increasing acquisition unit length.

One issue which is not addresses by these postulates concerns that aspect of the response unit which is responsible for the inverse relationship between its length and resistance to extinction. One possibility, suggested by Mowrer and Jones (1945) is that there is an inverse relationship between the effort involved in making a response and its resistance to extinction. Longer units, which presumably require more effort, would therefore be less resistant to extinction. Such a view finds theoretical support in Hull's behaviour theory in which extinction is viewed as the result of the combination ofreactive and conditioned inhibition, both of which are directly related to the effortfulness of the response. In dealing with the relationship between mean extinction unit length and resistance to extinction at a single acquisition unit length, both reactive and conditioned inhibition may be important. Resistance of a response to extinction is a direct function of its excitatory potential, from which the sum of reactive and conditioned inhibition is subtracted. Since both are incremented upon each occurrence of a response by an amount which is directly related to the effortfulness of the response, a direct relationship between extinction unit length and effort implies an inverse relationship between mean extinction unit length and resistance to extinction.

The possible role of response effortfulness and inhibition in the relationship between acquisition unit length and resistance to extinction is less clear. According to the unit-length hypothesis, resistance to extinction at any given extinction unit length increases with acquisition unit length. Without additional assumptions, Hull's conception of reactive and conditioned inhibition does not appear capable of accounting for this relationship.

The empirical relationship between response effortfulness and resistance to extinction is no clearer. A number of studies have reported an inverse realtionship between response effortfulness and resistance to extinction when response effortfulness was the same during acquisition and extinction (Mowrer and Jones, 1943; Solomon, 1948; Applezweig, 1951; Stanley and Aamodt, 1954; Capehart et al, 1958; Weiss, 1961; Young, 1966). Others, however, have failed to observe such a relationship (Maatsch et al, 1954; Aiken, 1957; Johnson and Viney, 1970). Furthermore, studies indicating a relationship between response effortfulness and resistance to extinction have been criticized on the grounds that manipulation of effort by altering the force required to register a response confounds effort and response criterion. Thus resistance to extinction of subjects emitting the same distribution of response forces in extinction will vary with the minimum force necessary to register a response.

The evidence concerning the relationship between acquisition response effortfulness and resistance to extinction is less ambiguous. Several studies have indicated that when subjects are extinguished on the same response, resistance to extinction is a direct function of acquisition response effortfulness (Grusec and Bower, 1965; Stachnik, 1967). The results of these studies, which are free of the response criterion bias present when extinction response effortfulness is manipulated, parallel the data in the present studies which indicate a direct relationship between acquisition response-unit length and resistance to extinction.

It appears, therefore, that there is some indication in the literature of relationships between acquisition and extinction response effortfulness and resistance to extinction consistent with those observed in the present studies between unit length and resistance to extinction. Deficiencies in the effort literature, however, make any assessment of the general role of effort in resistance to extinction, or of its relationship to unit length both difficult and highly speculative.

The results of the present studies raise, or leave unanswered, a number of interesting questions in addition to that concerning the source of the relationship between unit length and resistance to extinction.

One important issue is the extent to which the modified response-unit hypothesis outlined earlier, or response-unit analysis in general, is applicable to operant schedules other than those on which reinforcement is explicitly contingent upon completion of a response sequence of fixed length. The response-unit hypothesis identifies response-unit formation with the development of discriminative control over terminal responding by internal stimuli produced by the execution of the reinforced response sequence. It is not clear to what extent such control develops in the absence of specific contingencies between the number of responses executed and reinforcement. In variable-ratio schedules, for example, there exists a contingency between number of responses and reinforcement, but trial by trial alterations in the number of responses required for reinforcement presumably reduces the extent to which internal stimuli associated with any given unit length are paired with reinforcement. Preliminary studies from our laboratory suggest, however, that response-unit formation does occur under such circumstances, and that the relationship between unit length and resistance to extinction is similar to that observed in DT FR studies.

Fixed-interval (FI) or variable-interval (VI) schedules, deliver reinforcement on the basis of time since the previous reinforcement, and do not provide any explicit contingency between number of responses and reinforcement. In the FI case, however, there may be a fair degree of consistency across trials in the number of responses occurring prior to reinforcement to the extent that response rates in each interval are consistent. Whether or not internal stimuli do become associated with reinforcement in such cases, Buchman and Zeiler (1975) have shown that subjects can respond differentially on the basis of the number of responses completed in an FI interval.

The development of response units under VI reinforcement schedules is more questionable in view of the absence of a contingency between response number and reinforcement, and of a consistent relationship between the number of responses emitted in an interval and reinforcement. However, to the extent that response rates remain constant, and the number of intervals employed is small, sufficient consistency in the internal stimuli associated with reinforcement may exist to permit response-unit development akin to that observed in VR schedules.

A second unanswered question concerns the effects on response-unit formation and extinction of acquisition parameters such as reinforcement magnitude and delay, ITI, and amount of training; all of which have proven to be of considerable importance in instrumental partial reinforcement paradigms. While these variables have been manipulated within the context of operant reinforcement schedules, the absence from such studies of measures of terminal responding obviates any evaluation of the extent to which these factors are relevant to acquisition or extinction performance considered in terms of integrated units rather than individual responses. Response-unit analysis, employing a measure of terminal responding, would make possible a precise determination of the extent to which a given variable affects one or more of the parameters of response-unit length and persistence. For example, within broad limits, increasing amounts of FR training result in increases in the number of individual responses emitted in extinction. Preliminary studies from our laboratory indicate that this relationship reflects increases in the length, but not in the number, of response units emitted in extinction. The latter appears to be constant, at least to the point at which further training produces no further increases in response-unit length.

Perhaps the most important question left unanswered by these studies concerns the effects on response-unit formation and resistance to extinction of partial reinforcement of the response unit itself. This issue was addressed directly by Day (1973), in which FCN units were placed on an FR schedule of reinforcement. The results of this study, described at some length in the introduction, suggested that such a procedure might lead to the integration of response units into still more complex second-order units. As we indicated earlier, however, the extent to which these results can be generalized to traditional operant reinforcement schedules is not clear.

The importance of the partial reinforcement of response units derives from the fact that in considering this question we come to a point at which the possibility of a theoretical integration of disparate operant and instrumental partial reinforcement procedures is apparent. In shifting the focus of theoretical interest from the individual response to the reinforced sequence of which it is a part, the response-unit hypothesis implicitly suggests the functional equivalence of this sequence and the instrumental trial as units of analysis. The identification of the response unit and the trial as equivalent functional units provides a ready solution to the problem of comparing FO and DT procedures, an issue which has been a focus of the debate concerning the relationship between operant and instrumental paradigms. Not only does the terminal response serve to identify successive functional units under both DT and FO conditions, but it also constitutes, as does the instrumental goal response, the point at which the operations of reinforcement and nonreinforcement have their effects on behaviour.

Response-unit analysis not only provides a means of identifying equivalent functional units in operant and instrumental paradigms, but also suggests the way in which operant and instrumental reinforcement schedules may be integrated into a single conceptual schema. The primary obstacle to such a conceptual or theoretical integration has been the view that number of operant responses per reinforcement and number of instrumental trials per reinforcement both measure partial reinforcement in the same sense. Both the response-unit hypothesis and current conceptions of instrumental behaviour reject this view. They argue instead that simple operant reinforcement schedules, like manipulations of runway length, determine the nature of the functional behaviour sequence rather than its probability of reinforcement. Partial reinforcement occurs only when reinforcement is omitted following the functional response; i.e. following a response unit or a trial. According to this view, operant and instrumental reinforcement schedules affect separate, though perhaps related behavioural processes. In general, operant partial reinforcement procedures are most directly concerned with the extent to which acquisition and extinction performance are dictated by the parameters of the behavioural unit required for reinforcement, while instrumental partial reinforcement procedures are primarily concerned with the effects on acquisition and extinction performance of the parameters of reinforcement applied to this functional unit. Our question concerning the effects of partially reinforcing the operant response unit therefore represents the conceptual and theoretical interface between these two sets of procedures, and the answer to it is of considerable theoretical interest.

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APPENDIX

Table 1

Experiment 1: Total terminal responses on Day 10 of acquisition as a function of extinction FR requirement and replication.

Extinction FR Requirement

	5		10		15	
	S#		S#		S#	
Replication 1	2	32	1	32	4	33
	8	30	3	36	5	35
	10	30	6	30	9	30
	12	29	11	31	15	33
	14	31	13	30	16	30
	17	29	18	26	19	30
	22	29	23	32	21	30
	S#		S#		S#	
Replication 2	1	32	2	33	28	38
	4	36	5	30	6	34
	7	30	8	29	9	32
	10	33	11	31	12	31
	13	41	14	34	15	45
	16	33	17	32	18	31
	19	32	20	32	21	30
	22	32	23	32	24	35
	25	33	26	34	27	30
	S#		S#		S#	
Replication 3	1	32	2	31	3	32
	28	36	5	40	30	35
	7	30	8	30	9	30
	10	33	11	60	33	30
	13	30	14	30	15	31
	16	29	17	30	18	32
	19	30	20	32	32	32
	22	30	23	36	24	34
	25	28	29	30	27	31

Table 2

Experiment 1: Data employed in, and summary of, ANOVA performed on log session time, in seconds, on Day 10 of acquisition, as a function of extinction FR requirement and replication.

Extinction FR Requirement

	5		10		15	
	S#		S#		S#	
Replication 1	2	522	1	362	4	271
	8	252	3	730	5	470
	10	234	6	248	9	214
	12	221	11	132	15	233
	14	194	13	212	16	298
	17	243	18	407	19	360
	22	202	23	326	21	144
	S#		S#		S#	
Replication 2	1	323	2	543	28	474
	4	368	5	271	6	548
	7	332	8	221	9	220
	10	564	11	244	12	285
	13	335	14	525	15	343
	16	394	17	432	18	766
	19	505	20	211	21	240
	22	291	23	427	24	301
	25	326	26	678	27	220
	S#		S#		S#	
Replication 3	1	262	2	493	3	206
	28	458	5	590	30	671
	7	365	8	383	9	203
	10	461	11	1307	33	261
	13	166	14	446	15	191
	16	283	17	329	18	503
	19	589	20	232	32	371
	22	283	23	459	24	383
	25	277	29	429	27	330

Source	df	SS	MS	F
Groups	2	123,867.71	61,933.80	1.98
Replications	2	143,493.10	71,746.55	2.30
G x R	4	75,966.70	18,991.67	1.00
Error	66	2,061,954.44	31,241.73	
Total	74	2,405,281.95		

Table 3

Experiment 1: Data employed in, and summary of, ANOVA performed on log leverpresses per HP in extinction, as a function of extinction FR schedule and replication.

Extinction FR Schedule

	S#	5	log	S#	10	log	S#	15	log
Replication 1	2	5.78	.76	1	12.33	1.09	4	16.50	1.22
	6	5.60	.75	3	16.30	1.21	5	16.41	1.22
	10	4.31	.63	6	7.76	.89	9	12.17	1.09
	12	6.31	.80	11	9.04	.96	15	16.20	1.21
	14	4.79	.68	13	17.54	1.24	16	13.00	1.11
	17	5.43	.73	18	9.34	.97	19	11.43	1.06
	22	5.87	.77	23	13.65	1.13	21	22.67	1.35

	S#		log	S#		log	S#		log
Replication 2	1	5.24	.72	2	14.52	1.16	28	14.64	1.17
	4	5.96	.78	5	15.68	1.19	6	13.68	1.14
	7	7.98	.90	8	6.15	.79	9	10.15	1.01
	10	6.24	.80	11	9.13	.96	12	11.89	1.08
	13	5.98	.78	14	5.86	.77	15	14.76	1.17
	16	8.55	.93	17	10.89	1.04	18	15.75	1.20
	19	[illegible].58	.82	20	9.88	.99	21	14.08	1.15
	22	9.67	.99	23	11.37	1.06	24	12.62	1.10
	25	7.58	.88	26	10.27	1.01	27	10.94	1.04

	S#		log	S#		log	S#		log
Replication 3	1	5.91	.77	2	8.73	.94	3	10.92	1.04
	28	5.75	.76	5	10.00	1.00	30	12.56	1.09
	7	7.12	.85	8	12.46	1.09	9	14.33	1.16
	10	6.01	.78	11	10.43	1.02	33	12.42	1.09
	13	6.60	.82	14	10.67	1.03	15	14.56	1.16
	16	6.01	.78	17	6.20	.79	18	15.29	1.18
	19	5.77	.76	20	9.46	.97	32	12.81	1.11
	22	6.08	.78	23	9.22	.96	24	9.72	.99
	25	3.98	.60	29	10.01	1.00	27	12.26	1.09

Source	df	SS	MS	F
Groups	2	1.526	.763	87.11
Replications	2	.027	.014	1.55
G x R	4	.085	.021	2.42
Error	66	.578	.009	
Total	74	2.22		

Table 4

Experiment 1: Data employed in, and summary of, ANOVA performed on log leverpresses per TP in extinction as a function of extinction FR requirement and replication.

Extinction FR Schedule

	5			10			15		
	S#		log	S#		log	S#		log
Replication 1	2	4.51	.65	1	10.88	1.04	4	11.00	1.04
	8	4.34	.64	3	6.58	.82	5	12.76	1.10
	10	1.94	.29	6	4.66	.67	9	8.05	.90
	12	5.32	.73	11	5.04	.70	15	7.81	.89
	14	1.98	.30	13	13.30	1.12	16	7.01	.84
	17	2.95	.47	18	4.53	.66	19	5.56	.74
	22	3.91	.59	[illegible]3	10.13	1.00	21	17.36	1.24

	S#		log	S#		log	S#		log
Replication 2	1	3.91	.59	2	10.96	1.04	28	8.91	.95
	4	3.50	.54	5	8.21	.91	6	7.00	.84
	7	6.19	.79	8	3.59	.56	9	5.07	.70
	10	3.59	.55	11	4.47	.65	12	8.38	.92
	13	3.96	.59	14	3.04	.48	15	12.20	1.09
	16	3.72	.57	17	8.24	.92	18	9.84	.99
	19	5.00	.70	20	8.29	.92	21	8.97	.95
	22	6.90	.84	23	8.74	.94	24	9.14	.96
	25	4.64	.67	26	7.60	.88	27	6.97	.84

	S#		log	S#		log	S#		log
Replication 3	1	2.56	.41	2	5.85	.77	3	5.18	.71
	28	2.73	.44	5	5.19	.72	30	9.92	.99
	7	4.16	.62	8	9.81	.99	9	10.86	1.04
	10	5.46	.74	11	5.45	.74	33	5.44	.73
	13	4.97	.70	14	5.00	.70	15	11.51	1.06
	16	4.46	.65	17	2.79	.44	18	11.14	1.05
	19	3.14	.50	20	3.85	.58	32	5.26	.72
	22	4.19	.62	23	6.78	.83	24	4.29	.63
	25	2.01	.30	29	6.28	.80	27	6.23	.79

Source	df	SS	MS	F
Groups	2	1.381	.690	27.20
Replications	2	.098	.049	1.94
G x R	4	.127	.032	1.25
Error	66	1.675	.025	
Total	74	3.281		

Table 5

Experiment 1: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction, as a function of extinction FR requirement and replication.

Extinction FR Schedule

	5			10			15		
	S#		log	S#		log	S#		log
Replication 1	2	370	2.57	1	370	2.57	4	495	2.69
	8	291	2.46	3	750	2.88	5	804	2.91
	10	384	2.58	6	629	2.80	9	1594	3.20
	12	612	2.79	11	343	2.54	15	648	2.81
	14	930	2.97	13	1210	3.08	16	897	2.95
	17	277	2.44	18	467	2.67	19	800	2.90
	22	505	2.70	23	628	2.80	21	816	2.91
	S#		log	S#		log	S#		log
Replication 2	1	215	2.33	2	581	2.76	28	615	2.79
	4	340	2.53	5	345	2.54	6	301	2.48
	7	415	2.62	8	449	2.65	9	690	2.84
	10	312	2.49	11	420	2.62	12	654	2.82
	13	293	2.47	14	328	2.52	15	915	2.96
	16	171	2.23	17	305	2.48	18	630	2.80
	19	270	2.43	20	257	2.41	21	718	2.86
	22	290	2.46	23	341	2.53	24	530	2.72
	25	455	2.66	26	380	2.58	27	558	2.75
	S#		log	S#		log	S#		log
Replication 3	1	455	2.66	2	480	2.68	3	1016	3.01
	28	350	2.54	5	410	2.61	30	377	2.58
	7	520	2.72	8	461	2.66	9	945	2.98
	10	415	2.62	11	240	2.38	33	795	2.90
	13	1023	3.01	14	480	2.68	15	495	2.69
	16	397	2.60	17	614	2.79	18	780	2.89
	19	248	2.39	20	643	2.81	32	615	2.79
	22	310	2.49	23	332	2.52	24	515	2.71
	25	279	2.44	29	791	2.90	27	748	2.87

Source	df	SS	MS	F
Groups	2	.896	.448	19.06
Replications	2	.3409	.170	7.25
G x R	4	.022	.005	1.00
Error	66	1.555	.023	
Total	74	2.81		

Table 6

Experiment 1: Data employed in, and summary of, ANOVA performed on log HP to extinction, as a function of extinction FR schedule and replication.

Extinction FR Schedule

	5			10			15		
	S#		log	S#		log	S#		log
Replication 1	2	64	1.81	1	30	1.48	4	30	1.48
	8	52	1.72	3	46	1.66	5	49	1.69
	10	89	1.95	6	81	1.91	9	131	2.12
	12	97	1.99	11	38	1.58	15	40	1.60
	14	194	2.29	13	69	1.84	16	69	1.84
	17	51	1.71	18	50	1.70	19	70	1.84
	22	86	1.93	23	46	1.66	21	36	1.56
	S#		log	S#		log	S#		log
Replication 2	1	41	1.61	2	40	1.60	28	42	1.62
	4	57	1.75	5	22	1.34	6	22	1.34
	7	52	1.72	8	73	1.86	9	68	1.83
	10	50	1.70	11	46	1.66	12	55	1.74
	13	49	1.69	14	56	1.75	15	62	1.79
	16	20	1.30	17	28	1.45	18	40	1.60
	19	41	1.61	20	26	1.41	21	51	1.71
	22	30	1.48	23	30	1.48	24	42	1.62
	25	60	1.79	26	37	1.57	27	51	1.71
	S#		log	S#		log	S#		log
Replication 3	1	77	1.89	2	55	1.74	3	93	1.97
	28	63	1.80	5	41	1.61	30	30	1.48
	7	73	1.86	8	37	1.57	9	66	1.82
	10	69	1.84	11	23	1.36	33	64	1.81
	13	155	2.19	14	45	1.65	15	34	1.53
	16	66	1.82	17	99	1.99	18	51	1.71
	19	43	1.63	20	68	1.83	32	48	1.68
	22	51	1.71	23	36	1.56	24	53	1.72
	25	70	1.84	29	79	1.90	27	61	1.78

Source	df	SS	MS	F
Groups	2	.238	.119	4.11
Replications	2	.364	.182	6.30
G x R	4	.107	.027	1.00
Error	66	1.908	.029	
Total	74	2.617		

Table 7

Experiment 1: Data employed in, and summary of, ANOVA performed on log OP to extinction, as a function of extinction FR schedule and replication.

Extinction FR Schedule

Replication 1		5			10			15	
	S#		log	S#		log	S#		log
	2	18	1.26	1	4	.60	4	15	1.18
	8	15	1.18	3	68	1.83	5	14	1.15
	10	109	2.04	6	54	1.73	9	67	1.83
	12	18	1.26	11	30	1.48	15	43	1.63
	14	276	2.44	13	22	1.34	16	59	1.77
	17	43	1.63	18	53	1.72	19	74	1.87
	22	43	1.63	23	16	1.20	21	11	1.04

Replication 2	S#		log	S#		log	S#		log
	1	14	1.15	2	13	1.11	28	27	1.43
	4	40	1.60	5	20	1.30	6	21	1.32
	7	15	1.18	8	52	1.72	9	68	1.83
	10	37	1.57	11	48	1.68	12	23	1.36
	13	25	1.40	14	52	1.72	15	13	1.11
	16	26	1.41	17	9	.95	18	24	1.38
	19	13	1.11	20	5	.70	21	29	1.46
	22	12	1.08	23	9	.95	24	16	1.20
	25	38	1.58	26	13	1.11	27	29	1.46

Replication 3	S#		log	S#		log	S#		log
	1	101	2.00	2	27	1.43	3	103	2,01
	28	65	1.81	5	38	1.58	30	8	.90
	7	52	1.72	8	10	1.00	9	21	1.32
	10	7	.84	11	21	1.32	33	82	1.91
	13	51	1.71	14	51	1.71	15	9	.95
	16	23	1,36	17	121	2.08	18	19	1.28
	19	36	1.56	20	99	1.99	32	69	1.84
	22	23	1.36	23	13	1.11	24	67	1.83
	25	69	1.84	29	47	1.67	27	59	1.77

Source	df	SS	MS	F
Groups	2	.147	.074	1.00
Replications	2	.753	.376	2.93
G x R	4	.136	.034	1.00
Error	66	8.49	.129	
Total	74	9.526		

Table 8

Experiment 1: Data employed in, and summary of, ANOVA performed on log TP to extinction, as a function of extinction FR schedule and replication.

Extinction FR Requirement

	5			10			15		
	S#		log	S#		log	S#		log
Replication 1	2	82	1.91	1	34	1.53	4	45	1.65
	8	67	1.83	3	114	2.06	5	63	1.80
	10	198	2.30	6	135	2.13	9	198	2.30
	12	115	2.06	11	68	1.83	15	83	1.92
	14	470	2.67	13	91	1.96	16	128	2.11
	17	94	1.97	18	103	2.01	19	144	2.16
	22	129	2.11	23	62	1.79	24	47	1.67
	S#		log	S#		log	S#		log
Replication 2	1	55	1.74	2	53	1.72	28	69	1.84
	4	97	1.99	5	42	1.62	6	43	1.63
	7	67	1.83	8	125	2.10	9	136	2.13
	10	87	1.94	11	94	1.97	12	78	1.89
	13	74	1.87	14	108	2.03	15	75	1.88
	16	46	1.66	17	37	1.57	18	64	1.81
	19	54	1.73	20	31	1.49	21	80	1.90
	22	42	1.62	23	39	1.59	24	58	1.76
	25	98	1.99	26	50	1.70	27	80	1.90
	S#		log	S#		log	S#		log
Replication 3	1	178	2.25	2	82	1.91	3	196	2.29
	28	128	2.11	5	79	1.90	30	38	1.58
	7	125	2.10	8	47	1.67	9	87	1.94
	10	76	1.88	11	44	1.64	33	146	2.16
	13	206	2.31	14	96	1.98	15	43	1.63
	16	89	1.95	17	220	2.34	18	70	1.84
	19	79	1.90	20	167	2.22	32	117	2.07
	22	74	1.87	23	49	1.69	24	120	2.08
	25	139	2.14	29	126	2.10	27	120	2.08

Source	df	SS	MS	F
Groups	2	.200	.100	2.18
Replications	2	.534	.267	5.84
G x R	4	.106	.027	1.00
Error	66	3.021	.046	
Total	74	3.862		

Table 9

Experiment 2: Mean number of leverpresses per terminal response on Day 10 of acquisition in the FT-FT condition, as a function of FR requirement.

FR Requirement							
	1		5		10		20
S# 23	1.00	S# 14	5.17	S# [illegible]	10.34	S# 13	20.69
25	1.00	21	4.84	24	10.34	20	20.69
3	1.03	26	5.17	[illegible]	10.34	[illegible]	[illegible]
8	1.00	22	5.17	29	9.38	27	20.69
9	1.00	5	5.00	1	10.00	4	20.69
14	1.03	11	5.17	6	10.00	10	20.00
20	1.00	18	5.00	12	10.00	12	20.00
22	1.00	21	4.84	15	10.00	19	20.69
25	1.00	27	5.00	17	10.34	24	20.00
				23	10.34	26	20.69
				28	10.34		

Table 10

Experiment 2: Mean number of leverpresses per terminal response on Day 10 of acquisition in the DF-FO condition, as a function of FR requirement.

FR Requirement							
	1		5		10		20
S# 1	1.00	S# 4	5.17	S# 3	10.34	S# 2	16.22
6	1.00	5	4.55	8	10.34	7	20.69
11	1.03	10	4.69	9	10.34	12	20.69
15	1.00	16	5.17	14	10.34	13	19.35
17	1.00	20	5.17	19	9.68	23	20.69
27	1.00	26	5.00	24	10.00	29	20.00
30	1.00	31	4.69	25	10.34	4	20.69
1	1.03	2	5.17	3	10.34	5	20.69
11	1.00	7	5.00	8	10.34	10	20.69
16	1.03	12	5.17	9	10.00	15	19.35
17	1.03	13	5.17	14	10.00		

Table 11

Experiment 2: Mean number of leverpresses per terminal response on Day 10 of acquisition in the FO-FO condition, as a function of FR requirement.

FR Requirement							
1		5		10		20	
S# 3	1.07	S# 2	5.00	S# 6	10.00	S# 4	20.00
6	1.15	5	5.00	9	8.57	10	20.00
14	1.00	12	5.00	16	9.68	20	21.43
17	1.03	18	4.41	19	10.34	26	19.35
24	1.20	21	3.49	22	10.34	29	18.75
27	1.03	28	4.41	25	9.68	30	17.14
1	1.11	2	5.17	3	11.11	31	20.69
8	1.00	5	4.69	6	9.68	4	20.69
11	1.07	12	5.17	9	11.54	10	20.69
14	1.36	15	4.41	16	10.00	13	19.35
17	1.11			19	10.34	20	22.22

Table 12

Experiment 2: Number of leverpresses per terminal response in extinction, in the DF-DF condition.

FR Requirement

1		5		10		20	
S#		S#		S#		S#	
23	1.50	14	5.05	15	10.23	13	18.68
25	1.18	21	4.67	24	10.00	20	22.17
3	1.61	28	6.60	26	10.80	22	12.31
8	1.38	2	6.54	29	9.76	27	24.05
9	1.07	5	4.21	1	10.51	4	18.69
14	1.45	11	7.06	6	9.58	10	14.95
20	1.23	18	5.00	12	11.06	13	15.71
22	1.56	21	4.38	15	11.45	19	15.51
25	1.88	27	4.64	17	9.14	24	17.31
				23	7.95	26	21.88
				28	9.46		

Table 13

Experiment 2: Data employed in, and summary of, ANOVA performed on log leverpresses per terminal response, in the IF-FO condition.

FR Requirement

1			5			10			20		
S#		log	S#		log	S#		log	S#		log
1	3.46	.54	4	8.50	.93	3	22.90	1.36	2	16.09	1.21
6	9.00	.95	5	15.06	1.18	8	12.37	1.09	7	60.70	1.78
11	7.40	.87	10	9.90	1.00	9	30.10	1.48	12	31.20	1.49
15	5.61	.75	16	13.54	1.13	14	21.41	1.33	13	32.28	1.51
17	16.85	1.23	20	18.19	1.26	19	27.42	1.44	23	46.70	1.67
27	5.61	.75	26	17.68	1.25	24	16.37	1.21	29	14.40	1.16
30	4.25	.63	31	11.39	1.06	25	24.07	1.38	4	38.69	1.59
1	4.05	.61	2	15.41	1.19	3	17.87	1.25	5	65.52	1.82
11	5.44	.74	7	14.24	1.15	8	16.67	1.22	10	81.07	1.91
16	9.43	.97	12	20.23	1.31	9	16.82	1.23	15	40.08	1.60
17	5.96	.78	13	41.90	1.62	14	33.10	1.52			

Source	df	SS	MS	F
Groups	3	3.30	1.10	27.53
Error	39	1.44	.04	
Total	42	4.74		

Table 14

Experiment 2: Data employed in, and summary of, ANOVA performed on log leverpresses per terminal response in extinction, in the FO-FO condition.

FR Requirement

1			5			10			20		
S#		log	S#		log	S#		log	S#		log
1	2.91	.46	2	21.94	1.34	6	14.20	1.15	4	27.61	1.44
8	3.33	.52	5	7.81	.89	9	16.16	1.21	10	41.21	1.62
14	6.38	.80	12	22.30	1.35	16	23.68	1.37	20	28.36	1.45
17	14.03	1.15	18	18.89	1.28	19	63.11	1.80	26	16.96	1.23
24	9.43	.97	21	3.39	.53	22	11.18	1.05	29	32.05	1.50
27	4.67	.67	28	27.29	1.44	25	19.76	1.29	30	27.85	1.44
1	4.11	.61	2	8.17	.91	3	32.73	1.51	31	28.98	1.46
8	5.00	.70	5	4.91	.69	6	25.11	1.40	4	15.27	1.18
11	5.36	.73	12	9.60	.98	9	27.95	1.45	10	29.43	1.47
14	10.54	1.02	15	9.86	.99	16	19.78	1.30	13	25.13	1.40
17	7.09	.85				19	15.33	1.19	20	16.70	1.22

Source	df	SS	MS	F
Groups	3	2.777	.926	19.21
Error	39	1.880	.048	
Total	42	4.657		

Table 15

Experiment 2: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction in the DF-DF condition.

FR Requirement

1			5			10			20		
S#	LPs	log	S#	LPs	log	S#	LPs	log	S#	LPs	log
23	57	1.76	14	217	2.34	15	583	2.77	13	467	2.67
25	92	1.96	21	196	2.29	24	300	2.48	20	665	2.82
3	106	2.03	28	165	2.22	26	270	2.43	22	1120	3.05
8	99	2.00	2	412	2.61	29	449	2.65	27	505	2.70
9	96	1.98	5	278	2.44	1	410	2.61	4	860	2.93
14	139	2.14	11	791	2.90	6	460	2.66	10	1181	3.07
20	43	1.63	18	220	2.34	12	520	2.72	13	660	2.82
22	251	2.40	21	245	2.39	15	859	2.93	19	605	2.78
25	243	2.39	27	246	2.39	17	384	2.58	24	623	2.79
						23	302	2.48	26	941	2.97
						28	681	2.83			

Source	df	SS	MS	F
Groups	3	3.66	1.19	29.66
Error	35	1.23	.04	
Total	38	4.89		

Table 16

Experiment 2: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction in the DF-FO condition.

FR Requirement

1			5			10			20		
S#	LPs	log	S#	LPs	log	S#	LPs	log	S#	LPs	log
1	135	2.13	4	306	2.49	3	481	2.68	2	692	2.84
6	90	1.95	5	241	2.38	8	334	2.52	7	607	2.78
11	112	2.05	10	199	2.30	9	512	2.71	12	657	2.82
15	157	2.20	16	325	2.51	14	364	2.56	13	904	2.96
17	219	2.34	20	291	2.46	19	329	2.52	23	1448	3.16
27	146	2.16	26	389	2.59	24	262	2.42	29	1072	3.03
30	204	2.31	31	501	2.70	25	963	2.98	4	619	2.79
1	81	1.91	2	339	2.53	3	268	2.43	5	1376	3.14
11	185	2.27	7	356	2.55	8	450	2.65	10	1135	3.05
16	132	2.12	12	344	2.54	9	370	2.57	15	1002	3.00
17	155	2.19	13	461	2.66	14	398	2.60			

Source	df	SS	MS	F
Groups	3	3.47	1.16	57.91
Error	39	.75	.02	
Total	42	4.22		

Table 17

Experiment 2: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction in the FO-FO condition.

FR Requirement

1			5			10			20		
S#	LPs	log	S#	LPs	log	S#	LPs	log	S#	LPs	log
1	93	1.97	2	395	2.60	6	724	2.86	4	773	2.89
8	80	1.90	5	281	2.45	9	501	2.70	10	577	2.76
14	204	2.31	12	513	2.71	16	829	2.92	20	1163	3.07
17	477	2.68	18	359	2.56	19	568	2.75	26	890	2.95
24	217	2.34	21	224	2.35	22	447	2.65	29	673	2.83
27	140	2.15	28	464	2.67	25	494	2.69	30	724	2.86
1	115	2.06	2	147	2.17	3	360	2.56	31	1507	3.18
8	150	2.18	5	398	2.60	6	703	2.85	4	443	2.65
11	118	2.07	12	144	2.16	9	559	2.75	10	824	2.92
14	137	2.14	15	286	2.46	16	455	2.66	13	1131	3.05
17	149	2.17				19	736	2.87	20	718	2.86

Source	df[a]	SS	MS	F
Groups	3	3.41	1.14	37.90
Error	39	1.11	.03	
Total	42	4.52		

Table 18

Experiment 2: Data employed in, and summary of, ANOVA performed on total terminal responses to extinction in the FT-FT condition.

FR Requirement

1		5		10		20	
S#		S#		S#		S#	
23	38	14	43	15	57	13	25
25	78	21	42	24	30	20	30
3	66	28	25	26	25	22	91
8	72	2	63	29	46	27	21
9	90	5	65	1	39	4	46
14	96	11	112	6	48	10	79
20	35	18	44	12	47	13	42
22	161	21	56	15	75	19	39
25	129	27	53	17	42	24	36
				23	38	26	43
				28	72		

Source	df	SS	MS	F
Groups	3	9,504.95	3,168.32	4.45
Error	35	24,938.70	712.53	
Total	38	34,443.65		

Table 12

Experiment 2: Data employed in, and summary of, ANOVA performed on total terminal responses to extinction in the DT-WO condition.

FR Requirement

1		5		10		20	
S#		S#		S#		S#	
1	39	4	36	3	21	2	51
6	10	5	16	8	27	7	10
11	15	10	20	9	17	12	21
15	28	16	24	14	17	13	28
17	13	20	16	19	12	23	31
27	26	26	22	24	16	29	74
30	48	31	44	25	40	4	16
1	20	2	22	3	15	5	21
11	34	7	25	8	27	10	14
16	14	12	17	9	22	15	25
17	26	13	11	14	12		

Source	df	SS	MS	F
Groups	3	406.92	135.64	1.00
Error	39	6,434.98	164.99	
Total	42	6,841.90		

Table 20

Experiment 2: Data employed in, and summary of, ANOVA performed on total terminal responses to extinction in the FO-FO condition.

FR Requirement							
1		5		10		20	
S#		S#		S#		S#	
1	32	2	18	6	51	4	28
8	24	5	36	9	31	10	14
14	32	12	23	16	35	20	41
17	34	18	19	19	0	26	53
24	23	21	66	22	40	29	21
27	30	28	17	25	25	30	36
1	28	2	18	3	11	31	52
8	30	5	81	6	28	4	20
11	22	12	15	9	20	10	28
14	13	15	29	16	23	13	45
17	21			19	48	20	43

Source	df	SS	MS	F
Groups	3	512.04	170.68	
Error	39	8,578.15	219.96	
Total	42	9,090.19		

Table 21

Experiment 3: Data employed in, and summary of, ANOVA performed on log leverpresses per terminal response in extinction, as a function of extinction group.

Extinction Group

1		2		4		10		[illegible]	
S#		S#		S#		S#		S#	
1	1.07	2	2.00	3	3.01	[illegible]	10.[illegible]	5	6.51
11	1.09	7	1.77	8	[illegible]	9	5.40	15	7.00
16	1.04	12	1.91	1[illegible]	4.41	[illegible]	5.10	[illegible]	[illegible]
21	1.67	17	2.20	28	6.70	24	6.[illegible]	25	[illegible]
		27	2.08	32	5.05	29	24.70		

Source	df	SS	MS	F
Groups	4	1.785	.446	17.92
Error	18	.449	.0249	
Total	22	2.234		

Table 22

Experiment 3: Data employed in, and summary of, ANOVA performed on number of terminal responses to extinction as a function of extinction group.

Extinction Group									
1		2		4		FO		IE	
S#		S#		S#		S#		S#	
1	134	2	105	3	96	4	20	5	70
11	100	6	52	8	44	9	46	15	63
16	73	12	44	13	49	19	32	20	84
21	116	17	91	28	43	24	48	25	42
		27	48	32	60	29	13		

Source	df	SS	MS	F
Groups	4	12,371.98	3,092.99	6.17
Error	18	9,030.07	501.67	
Total	22	21,402.05		

Table 23

Experiment 3: Total leverpresses to extinction as a function of Extinction group.

Extinction Group

1		2		4		FO		FN	
S#		S#		S#		S#		S#	
1	[illegible]	[illegible]	[illegible]	3	[illegible]	4	216	[illegible]	386
11	[illegible]	7	[illegible]	8	103	9	[illegible]	15	447
[illegible]	[illegible]	12	[illegible]	13	216	19	166	20	272
21	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	24	305	25	[illegible]
		[illegible]	[illegible]	[illegible]	348	[illegible]	191		

Table 24

Experiment 4: Mean number of leverpresses per terminal response in extinction, as a function of extinction FR requirement.

Extinction FR Schedule							
1		5		10		20	
S#		S#		S#		S#	
5	1.21	6	5.88	7	9.42	8	17.68
15	1.48	11	9.36	13	14.80	9	16.19
20	1.35	16	5.95	18	10.99	14	9.17
21	1.36	17	9.74	23	12.72	19	13.69
26	1.24	27	5.12	28	11.09	24	26.30
29	1.48	30	4.29	12	10.15	25	11.83

Table 25

Experiment 4: Data employed in, and summary of, ANOVA performed on number of terminal responses to extinction, as a function of extinction FR schedule.

Extinction FR Schedule

1		5		10		20	
S#		S#		S#		S#	
5	59	6	49	7	53	8	57
15	120	11	55	13	25	9	32
20	89	16	73	18	58	14	109
21	81	17	38	23	36	19	65
26	87	27	41	28	33	24	20
29	65	30	69	12	66	25	70

Source	df	SS	MS	F
Groups	3	4,841.83	1,613.94	3.37
Error	20	9,570.00	478.50	
Total	23	14,411.83		

Table 26

Experiment 4: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction, as a function of extinction FR schedule:

Extinction FR Schedule

1			5			10			20		
S#		log	S#		log	S#		log	S#		log
5	69	1.84	6	288	2.46	7	499	2.70	8	1008	3.00
15	178	2.25	11	515	2.71	13	370	2.57	9	582	2.76
20	120	2.08	16	432	2.64	18	632	2.80	14	1000	3.00
21	110	2.04	17	370	2.57	23	458	2.66	19	903	2.96
26	108	2.03	27	210	2.32	28	366	2.56	24	526	2.72
29	96	1.98	30	296	2.47	12	670	2.83	25	828	2.93

Source	df	SS	MS	F
Groups	3	2.39	.80	49.76
Error	20	.32	.016	
Total	23	2.71		

Table 27

Experiment 5: Data employed in, and summary of, ANOVA performed on log leverpresses to extinction, as a function of FR requirement, in the FN condition.

FR Requirement.

1			5			10			20		
S#		log	S#		log	S#		log	S#		log
1	5.11	.71	13	8.84	.95	3	28.40	1.45	4	31.32	1.50
6	3.07	.49	18	16.62	1.22	14	9.72	.99	15	24.22	1.38
17	4.02	.60	23	16.70	1.22	19	4.35	.64	20	27.86	1.44
22	3.26	.51	28	6.24	.80	25	10.61	1.03	26	28.62	1.46
27	5.05	.70	29	13.85	1.14	30	21.11	1.32	31	24.08	1.38
32	2.87	.46	34	24.47	1.39	35	20.97	1.32	36	7.27	.86
33	10.50	1.02	39	14.04	1.15	41	15.00	1.18	37	43.80	1.64
38	4.91	.69	44	7.56	.88	45	20.77	1.32	42	21.54	1.33
43	13.35	1.13	48	23.14	1.36	47	17.96	1.25	46	48.15	1.68

Source	df	SS	MS	F
Groups	3	3.50	1.17	12.98
Error	20	1.72	.09	
Total	23	5.22		

Table 26

Experiment 5: Data employed in, and summary of, ANOVA performed on log leverpresses per terminal response in extinction, as a function of FR requirement, in the PFR condition.

FR Requirement

1			5			10			20		
S#		log	S#		log	S#		log	S#		log
1	6,33	.80	2	29.46	1.47	3	23.37	1.37	4	29.32	1.47
6	5.61	.75	7	11.11	1.05	8	38.67	1.59	5	17.24	1.25
11	4.50	.65	12	13,21	1.12	9	22.84	1.36	15	30.00	1.48
16	6.09	.78	13	12.37	1.09	14	20.39	1.31	20	25.38	1.40
17	5.39	.73	18	9.55	.98	19	26.14	1.42	21	11.76	1.07
22	5.92	.77	23	12.00	1.08	24	42.58	1.63	26	30.10	1.48
27	3.86	.59	28	30.67	1.49	25	15.55	1.19	31	34.64	1.54
32	3.80	.58	29	15.46	1.19	30	20.44	1.31	36	46.38	1.67
33	3.77	.58	34	16.26	1.21	35	19.16	1.28	41	33.72	1.53
38	5.19	.72	39	12.93	1.11	40	18.13	1.26	42	39.62	1.60

Source	df	SS	MS	F
Groups	3	3.43	1.14	57.13
Error	36	.79	.02	
Total	39	4.22		

Table 29

Experiment 5: Data employed in, and summary of, ANOVA performed on terminal responses to extinction, in the FN condition.

FR Requirement

1		5		10		20	
S#		S#		S#		S#	
1	28	13	32	3	10	4	22
16	67	18	21	14	71	15	46
17	48	23	30	19	140	20	36
22	54	28	72	25	67	26	16
27	38	29	20	30	18	31	36
32	90	34	17	35	34	36	118
33	16	39	24	41	32	37	15
38	32	44	55	45	22	42	22
43	20	48	14	47	25	46	27

Source	df	SS	MS	F
Groups	3	1,185.86	395.29	1.00
Error	32	29,018.44	906.83	
Total	35	30,204.30		

Table 30

Experiment 5: Data employed in, and summary of, ANOVA performed on terminal responses to extinction in the PFR condition.

FR Requirement							
1		5		10		20	
S#		S#		S#		S#	
1	61	2	13	3	24	4	34
6	36	7	28	8	24	5	53
11	28	12	67	9	49	15	27
16	49	13	35	14	23	20	74
17	46	18	31	19	22	21	99
22	39	23	41	24	26	26	30
27	43	28	46	25	31	31	36
32	35	29	27	30	27	36	21
33	43	34	27	35	31	41	26
38	63	39	55	40	23	42	24

Source	df	SS	MS	F
Groups	3	1,600.00	533.43	1.96
Error	36	9,788.50	271.90	
Total	39	11,388.50		

Table 31

Experiment 5: Total leverpresses to extinction, as a function of acquisition FR requirement, in the FW condition.

FR Requirement							
1		5		10		20	
S#		S#		S#		S#	
1	138	13	283	3	284	4	689
16	206	18	349	14	690	15	1114
17	193	23	501	19	609	20	1003
22	176	28	449	25	711	26	458
27	192	29	277	30	380	31	867
32	258	34	416	35	713	36	858
33	168	39	337	41	480	37	657
38	157	44	416	45	457	42	474
43	267	48	324	47	449	46	1300

Table 32

Experiment 5: Total leverpresses to extinction as a function of acquisition FR requirement, in the PFR condition.

FR Requirement

1		5		10		20	
S#		S#		S#		S#	
1	386	2	383	3	561	4	997
6	202	7	311	8	928	5	914
11	126	12	885	9	1119	15	810
16	298	13	433	14	469	20	1878
17	248	18	296	19	575	21	1164
22	231	23	492	24	1107	26	903
27	166	28	1411	25	482	31	1247
32	133	29	402	30	552	36	974
33	162	34	439	35	594	41	877
38	327	39	711	40	417	42	951