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The undersigned recommend to the Faculty
of Graduate Studies acceptance of the thesis
"Some Determinants of the Reinforcing and Aversive
Functions of Timeout"

submitted by

Lorne S. Cousins

in partial fulfilment of the requirements for
the degree of Doctor of Philosophy

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April, 1978

Some Determinants of the Reinforcing and
Aversive Functions of Timeout

by

Lorne Stanley Cousins

A thesis submitted to
the Faculty of Graduate Studies
in partial fulfillment of the requirements for
the degree of Doctor of Philosophy

Department of Psychology
Carleton University
Ottawa, March, 1978

Abstract

The present research was designed to assess the role of reinforcement frequency and frequency of timeout as controlling variables of the effects of timeout. In order to accomplish this, pigeons' choices and response rates were studied in concurrent chains schedules. In these schedules preference for two mutually exclusive terminal-link stimuli is measured by the relative number of responses emitted on concurrently available schedules that constitute the initial links. One terminal link was a schedule of reinforcement containing timeouts; the other was a similar schedule, free of timeout periods, but containing an equal number of un-signalled extinction periods. In Experiment 1, 1-min timeouts or extinction periods were presented at a rate of 30/hr and the scheduled reinforcement density in the respective terminal link was either 30, 60 or 120 reinforcements/hr. In Experiment 2 the rate of timeout and extinction was increased to 240/hr and the reinforcement density was either 60, 120 or 240 reinforcements/hr.

Analyses of the choice data revealed that in Experiment 1 preferences were in the direction of the timeout component and these preferences were greatest at 120 reinforcements/hr. Minimal effects occurred at the remaining rein-

forcement densities. Response rates in the timeout-terminal link increased over baseline and the increases were monotonically related to increasing reinforcement density. Similar consistency was not observed in the extinction-terminal link.

In Experiment 2 preferences were also observed for the timeout-terminal link and in most instances were greater in magnitude than in Experiment 1. However, there was no consistent pattern in changes in preferences from baseline as a function of scheduled reinforcement density. Response rates in the timeout-terminal link increased over baseline at the higher reinforcement densities and either decreased or did not change at 60 reinforcements/hr. Response rates in the extinction-terminal link mostly decreased with the greatest effects occurring at 120 reinforcements/hr.

Detailed analyses revealed that in both experiments relative response rate in the initial links was proportional to the relative density of obtained reinforcements if the latter were calculated omitting the total duration of the timeout periods. However, the functions relating relative responding and reinforcement were best described as "undermatching" in that the slopes of the best fitting lines were consistently less than one. Also, a greater degree of undermatching occurred in Experiment 2, possibly due to the higher rate of timeout presentations.

The results suggested that preferences were a joint function of both indirect and direct effects of timeout. The indirect effect of timeout was to increase relative rate of reinforcement in that terminal-link stimulus. The direct effect was to prevent preferences from reaching the magnitude expected from the matching law suggesting an aversive function of timeout. The data were also discussed in terms of hypotheses not predicated on the assumption that the matching law is the theoretical standard against which the effects of timeout should be assessed.

To my friend Robert F. Lisak
who always cared.

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I. INTRODUCTION

Temporary withdrawal of positive reinforcement or timeout is a common method for controlling behaviour. Withholding allowance, removal from the classroom, suspension of drivers' licences and interruptions of sporting contests are but a few examples. Most of these procedures are predicated on the assumption that withdrawal of reinforcement is aversive and they are designed to eliminate, or at least to reduce the behaviour they are made contingent upon. Accordingly, a large part of the research in experimental psychology on the effects of withdrawal of reinforcement has attempted to answer the question of whether or not this operation is indeed aversive (Leitenberg, 1965). Some studies have found, paradoxically, that timeout has appetitive rather than aversive properties. Data are now available that strongly suggest the effects of timeout depend on a number of factors.

That the effects of timeout should depend on conditions such as the context in which it occurs makes sense, intuitively. Consider, for example, the use of "timeout" by either team in a sporting contest such as a game of basketball. A "timeout" (or calling "time") may be sought during a point in a game in which one team is carrying the

play and scoring most of the points at a high rate. In these cases it is most often, though not always, called by the team being scored against and is designed to interrupt the "momentum" of the dominant team. Consider timeout as a consequence for both teams. For the dominant team, the timeout represents the removal of very positive conditions and it is reasonable to assume that such a delay, if extended, would become aversive or at least frustrating. However, for the losing team, the timeout represents momentary escape from the aversive (or frustrating) condition of giving up points at an undesirable rate as well as a period of time to reconsider strategies, etc. For this team the calling of "timeout" is probably reinforced by temporary removal of the adverse game conditions. Thus, from the context of winning, timeout might be aversive but from the context of losing, timeout from the same conditions would most likely be reinforcing.

Historically, in animal psychology, timeout has been considered in a "static" sense, simply as a period of time that separates the opportunities to obtain reinforcement. For example, in discrete trial procedures such as runways, alleys, and choice paradigms timeout is designated as an inter-trial interval. In free operant procedures timeout may serve both as the beginning and end of an

experimental session. The possible dynamic properties of this inter-trial interval were not realized until Herrnstein's (1955) experiments. Herrnstein arranged timeouts of varying durations to follow responses intermittently and examined their effects on responding in variable interval (VI) schedules of reinforcement. Since Herrnstein's (1955) original work, a substantial amount of research in both experimental and applied behaviour analysis has focused on the "dynamic" properties of timeout. In attempting to answer the question of whether timeout is aversive, several studies have compared and contrasted its effects to those of electric shock (e.g. McMillan, 1967). Data suggesting that timeout may have reinforcing properties (Dardano, 1974), however, argue strongly for a shift in experimental emphasis towards the identification of the controlling variables, rather than simply attempting to determine whether or not timeout has aversive properties.

The combined purpose of the two experiments in this dissertation was to investigate the role of reinforcement frequency and frequency of timeout as controlling variables of the effects of timeout. In order to accomplish this, pigeons' choices and rates of responding were measured when the alternatives were a schedule of reinforcement containing timeout, and a similar schedule, free of timeout periods but

adjusted for reinforcement frequency. Several determinations were made of the effects of timeout over a limited range of overall reinforcement densities. In the first experiment the occurrence of timeout was both irregular and low in frequency; in the second, timeout was also irregular but high in frequency.

Prior to a more detailed treatment of the rationale for these experiments, an introduction to the topic will be presented including both a general and specific definition of timeout, a discussion of the necessity for context and paradigm specific effects of timeout, a presentation of the basic paradigms in which timeout has been studied together with empirical effects, and finally, a consideration of some theoretical issues in timeout.

I.1 Definition of Timeout (TO)

In its most general sense, timeout (TO) refers to a discriminable interval of time in which the variables controlling behaviour in a particular context are temporarily suspended. In the area of animal learning, TO usually consists of the temporary withdrawal of reinforcement or punishment, and their correlated stimuli. The number of behavioural contexts from which TO can occur is virtually unlimited. It can occur from an appetitive or an aversive context, TO can be experimenter or subject

imposed, it can be produced through removal of the subject from the environment or through removal of part of the environment from the subject, or TO can involve withdrawal of the opportunity to respond as well as withdrawal of reinforcement or punishment. The common unifying factor in this seemingly diverse set of situations is that a discriminable suspension of the controlling variables occurs.

The experiments conducted for the present dissertation are concerned with a specific variation of TO, notably, that which occurs when positive reinforcement is made temporarily unavailable. Within this context there are a number of experimental operations that can suitably be classified as instances of TO; procedures such as removal of the response manipulandum, blackout of the apparatus or removal of the subject from the environment qualify as TO. The common property that procedures classified as TO have, is that they provide a signal to the subject that reinforcement will be withheld for a period of time.

I.2 TO as an Event

TO is discriminable and therefore has properties that are separable from the context in which it occurs. In most experimental instances TO involves the temporary replacement of stimuli correlated with reinforcement with

some other stimulus or stimuli, which are in turn correlated with non-reinforcement. For example, in pigeon key pecking experiments it is customary to administer TO by "blacking out" the apparatus thereby removing all sources of illumination, including stimuli correlated with reinforcement (Ferster and Skinner, 1957).

Defined as an event such as blackout, TO can be manipulated like any other stimulus. It may have a discrete onset allowing for the control of its duration and rate of occurrence. Moreover, since TO can be manipulated, its effects as a stimulus can be studied in schedules of reinforcement. For instance consider the effects of blackouts in a study employing a percentage reinforcement (PR) schedule (Neuringer and Chung, 1967). Under this schedule a sequence of behaviour was occasionally reinforced by food and sometimes followed by blackout. No discriminative stimuli distinguished which of the two events would follow any given sequence of responding. When behaviour emitted under two different PR schedules was compared to that emitted under a number of control conditions, with rate of reinforcement virtually the same in all conditions, the PR schedules were found to increase the rate of responding and to change the pattern of responding. Both pattern and rate of responding under the PR schedules were comparable to that in similar

schedules in which the same behaviour sequence was always followed by primary reinforcement. On the basis of these and other results Neuringer and Chung (1967) concluded:

"Thus the blackout stimulus when presented on a PR schedule appears to approximate the function of a primary reinforcer."

1.3 Effects of TO

For the most part, the significance of stimuli in an organism's environment depend upon the conditions in which such stimuli are presented. The effectiveness of reinforcers, for example, depends upon such factors as deprivation, the time elapsed since the last presentation of reinforcement and their relationship to behaviour. Similarly, the effects of aversive stimuli are dependent upon their intensity, their relationship to responding and whether or not they serve as discriminative stimuli for more positive events. It should not be surprising, then, to find that the effects of TO are dependent upon the circumstances in which it occurs. The following two sections describe two sets of conditions upon which the effects of TO ought to be dependent. These are the stimulus context into which TO is introduced and the paradigm determining its relationship to responding. The intention is not to present exhaustively all possible context and paradigm specific effects of TO but rather to illustrate why the effects of TO as defined, should be

dependent on these conditions.

Context Dependent Effects of TO. It is reasonable that the effects of TO should be context dependent. TO is the mutually exclusive counterpart of the prevailing conditions maintaining responding so its effects must, to some extent, depend on the nature of those conditions. If the controlling conditions are aversive, the effects of TO should be positive; if the former are positive the effects of TO should be aversive. Furthermore, the effects of TO should vary in an orderly fashion with the strength of the variables controlling behaviour, whether they are positive or negative. An example will serve to illustrate this point. TO from a context of relatively high reinforcement density should have different effects than TO from a context of low reinforcement density. Other things being equal, the reduction in reinforcement density occasioned by TO from a high density schedule should be much greater than that from a low density schedule. At least to the extent that changes in responding vary with changes in absolute reinforcement density (Catania and Reynolds, 1968) one would expect the behavioural effects of TO on responding in the two situations to differ from one another. A similar argument can be made for parameters of reinforcement other than density such as magnitude and underlying motivational conditions (e.g. amount of

deprivation).

The stronger the relationship between responding and its controlling variables the greater should be the effects of TO. Generally, the effects of TO should vary at least to the extent that comparable changes in the maintaining conditions produce variations in responding. As we shall see this assumption has rarely been tested.

Paradigm Dependent Effects of TO. If TO has properties similar to other controlling variables, its effects should depend not only on the context in which it occurs but also on the nature of the relationship between TO and responding. In a given context, TOs that are positively correlated with responding should produce effects opposite from TOs which are negatively correlated with responding. Suppose, for example, TOs are presented in the context of a high density reinforcement schedule. It has already been suggested that TO under these conditions should function as an aversive stimulus. In addition, suppose that the correlation between TO and responding is varied. In one set of conditions TO could be presented contingent upon responding according to the requirements of an $IRT > t$ schedule. That is, whenever a response is preceded by an inter-response time (IRT) greater than t sec, TO would be delivered. If the assumption concerning the aversiveness of TO is correct, a diminishing

frequency of IRTs greater than t sec would be expected in conjunction with an increase in response rate.

In a subsequent set of conditions the contingency could be reversed such that TO is presented on an $IRT < t$ schedule. That is, TO would occur whenever a response is preceded by an IRT less than t sec. If TO is aversive, the opposite result would be expected, namely, a decrease in the frequency of $IRTs < t$ sec and a corresponding decrease in response rate. In summary, conditions can be described under which TO could produce either an increase or decrease in response rate. The variable controlling the expected change in response rate is the correlation between the TO and responding. This correlation is dictated by the paradigm that schedules TOs contingent upon responding. The following section presents a delineation of the paradigms in which TO has been studied and the empirical effects of TO in each.

II. PARADIGMS AND THEIR EMPIRICAL EFFECTS

Most of the research in the area of TO has been designed to determine whether or not TO from positive reinforcement is aversive (Leitenberg, 1965; Coughlin, 1973). A few studies have examined the effects of TO from negative reinforcement (e.g. Baron and Trenholme, 1971). The emphasis on TO from positive reinforcement is probably due to its potential attractiveness as an alternative form of punishment (Skinner, 1953; Azrin, 1961).

The notion that TO from positive reinforcement might have aversive properties has some theoretical roots. The most developed theory of the aversive properties of a stimulus correlated with extinction is Amsel's analysis of frustrative non-reward (Amsel, 1958; 1962). Amsel has argued that the consequences of non-reinforcement may be similar to the consequences of negative reinforcement. Specifically, he assumes that stimuli associated with the experience of non-reinforcement establish a drive which he refers to as conditioned frustration (rf-sf). Amsel assumes that the drive of conditioned frustration is similar to other primary negative drives in that the organism will seek to diminish its intensity. Other theories have also appealed to the aversiveness of non-reinforcement (e.g. Terrace, 1971).

in attempting to develop an integrated theoretical account of the empirical by-products of successive discrimination learning, including behavioural contrast (Reynolds, 1961a), the peak shift (Terrace, 1964), emotional responses to S⁻ (Terrace, 1966a) and inhibitory stimulus control (Terrace, 1966b).

While a substantial amount of research has been carried out, on the effects of TO from positive reinforcement, the effects of TO from negative reinforcement have not gone totally ignored. Several theorists (e.g. Mowrer, 1960) have proposed that stimuli correlated with time free from aversive stimuli will themselves have reinforcing properties. Mowrer (1960) postulated a second type of secondary reinforcement in which the reinforcing properties of the stimulus are based on its capacity to act as a fear reducer. Studies have indicated such safety signals do in fact have positive conditioned reinforcing properties (Rescorla and Lolordo, 1965; Weisman and Litner, 1969a).¹

In the next few sections the various paradigms in which the effects of TO have been studied will be considered. Paradigms involving TO from positive reinforcement will be

¹Mowrer in fact referred to such a state as "conditioned relief".

presented first, followed by those examining the effects of TO from negative reinforcement. Each section is intended to familiarize the reader with the effects of TO in each situation by considering studies that serve as benchmarks for descriptive purposes. Readers already familiar with the empirical effects of TO may wish to skip to Chapter III (p.37), where the major theoretical issues in the area of TO are discussed.

II.1 Avoidance of TO

The avoidance paradigm was one of the first to be used to test whether or not TO has aversive properties. In this context an aversive stimulus is identified by the S's performance of a response where the sole consequence of that response is the omission or postponement of the onset of that stimulus. Both the unsignalled and signalled avoidance paradigms have been utilized to determine the effectiveness of TO as a negative reinforcer. In the TO-variant of the unsignalled avoidance procedure (Sidman, 1953) two response alternatives are usually concurrently available to Ss (Morse and Herrnstein, 1956; Ferster, 1958; Mechner and Ray, 1959; Thomas, 1964). A schedule of food reinforcement is programmed on one of the response keys while responses to the alternative key postpone TOs from this schedule. Not only is the occurrence of TO sufficient to maintain avoid-

ance behaviour, but also, response rate on the avoidance key varies inversely with the duration of the response-timeout (R-TO) interval (Ferster, 1958). This suggests that under some conditions TO has functional properties which are similar to known aversive stimuli such as electric shock (Sidman, 1966).

Responses whose consequence is the avoidance of TO are also susceptible to a high degree of stimulus control (Thomas, 1965). When an external clock, that varies systematically with the R-TO interval, serves as the warning stimulus, avoidance responding increases from the earlier to the later portions of that stimulus. The control exerted by the warning stimulus is similar to that of warning stimuli used in electric shock avoidance studies (e.g. Sidman, 1955; Ulrich, Holz and Azrin, 1964).

A viable explanation of the TO avoidance results is that TO functions like an aversive stimulus since organisms respond to terminate stimuli signalling its occurrence. In unsignalled avoidance of TO it is assumed that response produced stimuli, which precede the loss of positive reinforcement, acquire secondary negative reinforcing properties (Leitenberg, 1965). That is, animals respond to terminate these stimuli. In signalled TO avoidance, it is the warning stimulus that acquires conditioned negative

reinforcing properties. In view of these considerations it is reasonable to suggest that the effects of TO in the avoidance paradigm demonstrate an aversive function of TO.

II.2 Escape from TO and stimuli signalling TO.

The escape procedure also has been used, rather extensively, in attempts to demonstrate the aversive properties of TO. In this context an aversive stimulus is one that produces an increase in the rate of a response that terminates it. For example, rats will escape from a situation in which non-reinforcement (TO) has occurred (an empty goal box) even though the escape response does not lead to further food reinforcement (Adelman and Maatsh, 1956). Furthermore rats have been observed to escape stimuli that previously signalled TO (Wagner, 1963). Wagner trained two groups of rats to run down an alley on a 50% partial reinforcement schedule. The experimental group received either an auditory or a visual CS (S^-) in both the alleyway and goal box on non-reinforced trials. The control group received the CS in the retaining cage and it was uncorrelated with extinction. During testing, experimental Ss learned to jump over a hurdle faster than control Ss when this response served to terminate the CS. As training progressed the experimental group's escape latencies decreased while those of the control group increased

slightly.

The effects of stimuli signalling TO in the escape paradigm can even be more powerful if the following conditions are upheld (Daly, 1969a): 1) a twenty-four (24) hour delay occurs between training and testing and 2) the goal box of the training apparatus is used as the start box of the hurdle jump. These findings have been replicated in a situation in which an instrumental response was not necessary during training (Daly, 1969b) and one in which cues are correlated with partial reinforcement (Daly, 1969c). Also the effects of shock and non-reward (S^-) have been shown to summate (Daly, 1970).

The fact that animals will acquire responses whose only apparent consequence is to terminate a stimulus (CS) previously correlated with TO from positive reinforcement, suggests that TO under these conditions functions as an aversive stimulus.

II.3 Punishment by TO

In the punishment paradigm a positive contingency is arranged between a certain response and the punisher. The behavioural process identified as punishment is the subsequent decline in the frequency of emission of the punished response (Azrin and Holz, 1966). This procedure has been used extensively to investigate the effects of

TO from positive reinforcement.

In the earliest studies of the punishing effects of TO, responding during a pre-TO stimulus was shown to be completely suppressed provided that the occurrence of a response during this time period produced a TO and the non-occurrence of a response avoided TO (Ferster, 1958; Ferster, 1960; Ferster, Appel and Hiss, 1962). Typically, in these experiments responding is reinforced on either an interval or ratio schedule. Periodically, a signal (usually a key colour change) is presented for a fixed duration and precedes a scheduled TO. However, an $IRT > t$ contingency allows for the omission of the TO provided that no response occurs during the last 5 sec of the signal ($t = 5$ sec). With chimpanzees, responding increases during the early portions of the pre-TO stimulus and then totally suppresses during the critical IRT (Ferster, 1960). In contrast, pigeons typically suppress their responding throughout the full duration of the pre-TO signal. The procedures used by Ferster are clearly distinguishable from the CER or conditioned suppression paradigm (Estes and Skinner, 1941). In the CER procedure changes in behaviour in the presence of the signal (CS) have no programmed consequence on the delivery of the unconditioned stimulus (US).

TO has also been shown to suppress responding in

the matching to sample paradigm (Ferster and Appel, 1961). In this procedure, pigeons are required to first peck at a centre key containing the sample stimulus. A response to the sample turns it off and simultaneously presents two comparison stimuli. A peck to the comparison stimulus that is the same as the sample is intermittently reinforced on an interval schedule (Zimmerman and Ferster, 1963). In some procedures, every correct response produces a brief flash of the magazine lights and pecks to the incorrect comparison stimulus occasion a TO in the form of a blackout. A non-correction procedure is typically employed so that a trial terminates once S makes a choice (Ferster and Appel, 1961). When correct responses are reinforced on a CRF schedule, TOs for incorrect responses have no measureable effect on overall matching accuracy. However, when correct matching performance is maintained on an intermittent schedule of reinforcement, brief durations of TO contingent on responses to S^- , the incorrect matching stimulus, are effective in producing accurate matching. As Ferster and Appel (1961) suggested, interval schedules are perhaps more sensitive to independent variables than CRF or FR schedules.

When matching is maintained on an interval schedule, longer TO durations have disruptive effects on responding to S^+ , the correct matching stimulus (Ferster and Appel, 1961).

The disruptive effects of long TO durations (2-min) are probably on the birds' overall disposition to respond. Zimmerman and Ferster (1963) reported similar findings with different TO durations.

Matching accuracy is also influenced by TO frequency. At intermediate values of TO duration (e.g. 10-sec or 1-min) matching accuracy improves substantially as the frequency of TO increases; maximal performance is obtained when intermediate TO durations are presented according to the requirements of a CRF schedule (Zimmerman and Ferster, 1963).

The matching to sample data illustrate that TO punishment for responses to S^- can expedite the acquisition of the conditional discrimination. TO has also been shown to have more specific effects such that individual responses in a sequence can be suppressed (Kaufman and Baron, 1968). These effects were observed in a modified ratio schedule in which every third bar press (R_3) in a sequence of three was initially non-reinforced. During punishment, R_3 was followed by a stimulus that previously had been correlated with non-reinforcement (S^-). These TO periods were presented for 2-min, during which responding was not reinforced. Sizeable increases in the IRTs between R_2 and R_3 were obtained with little or no change in IRTs between R_3 and R_1 or R_1 and R_2 . Additionally, the amount of suppression

varied with TO duration; longer TOs increased the suppressive effects of TO punishment. Finally, the suppressive effects of TO increased with increases in percentage maintained body weight (or simply, decreases in deprivation).

Baron and Kaufman (1969) followed up these results by determining the effect of: (a) prior discrimination training with TO as S^- and (b) the availability of the response lever during TO. Response suppression developed and was maintained over many sessions of TO. Suppression of R_3 was maximized when responding was possible during the TO period and when Ss had not been given prior discrimination training with TO as S^- . However, these effects disappeared with continued training. Carlson (1970) also found no difference in the effect of TO whether responding was available during TO or not.

Punishing effects of TO have also been studied in $IRT > t$ schedules of reinforcement. When reinforcement density is reduced in VI schedules by adding an $IRT > t$ requirement for reinforced responses, the effects of TO remain relatively unchanged (Ferster, 1960). Ferster found that TO punishment during the last 5-sec of a pre-TO stimulus suppressed responding to an equivalent degree across a wide range of reinforcement densities. However relative response rate in the earlier portion of the pre-TO

stimulus increased with decreasing reinforcement density.

The effects of TO in $IRT > t$ schedules seem to be localized to the elimination of short IRTs (Kraemer and Rilling, 1969). Also, the effects of TO at $IRT > 20$ -sec appear to be long lasting since performance on the baseline $IRT > 20$ -sec improves after removal of the TO condition.

The punishment paradigm is one which has been used extensively for comparisons between the effects of TO and electric shock (McMillan, 1967; Kaufman and Baron, 1968). Generally, the effects of the two procedures are remarkably similar. For instance, response produced TO and response produced shock suppress responding in VI schedules of reinforcement almost immediately and to about the same extent (McMillan, 1967). However, responding was observed to recover within a session during the TO component. McMillan also found that responding suppressed by either shock or TO increased when pentobarbital was administered. Finally, McMillan (1967) observed that under both procedures response rate increased when the density of punishment decreased from FR 1 to FR 3. Other similarities between the effects of shock punishers and TO are: 1) With both TO (Kaufman and Baron, 1968) and electric shock (Azrin, Holz and Hake, 1963) response suppression increases with increasing body weight, and decreases with decreasing body weight. Thus

variations in motivation to perform a punished response have generally similar effects regardless of whether punishment is by shock or TO. 2) The suppressive effects of TO punishment increase with increasing TO duration (Kaufman and Baron, 1968). This is analogous to the direct relation between the suppressive effects of shock punishment and shock intensity. 3) Pre-exposure to TO reduces its subsequent effectiveness as a punisher (Baron and Kaufman, 1969). This is also true for punishment by electric shock (Baron and Antonitis, 1961).

To summarize, the results of studies of the punishing effects of TO in pre-TO stimuli, matching to sample, IRT > t schedules and modified ratio schedules suggest that TO can function as an aversive stimulus. That is, TO from positive reinforcement, appears to suppress the rate of responding it is made contingent upon. Also, variables which have been shown to influence the suppressive effects of punishment by electric shock have remarkably similar effects when TO is used as the punishing stimulus.

II.4 TO Punishment and Choice

Not all studies of TO punishment have unequivocally demonstrated its suppressive effects. For instance, Holz, Azrin and Ayllon (1963) found little or no suppression in the behaviour of two of four mental patients when responding

on VI schedules of cigarette reinforcement was punished on a FR 10 schedule of TO. Mild suppression was observed in the remaining Ss. However, when an alternative unpunished response was made available, responding immediately reduced to near zero levels in all subjects. Thus TO was mildly effective in reducing response rates in single VI schedules but totally effective in concurrent VI schedules.² Holz et al., (1963) suggested that with mild forms of punishment, such as TO, it may be necessary to teach the organism an alternative unpunished response in order to obtain suppression in the punished response.

Generally, TO has been shown to produce consistent punishment effects in concurrent schedules of reinforcement (Nigro, 1966; Thomas, 1968; Carlson and Aroksaar, 1970; Todorov, 1971). In concurrent appetitive-avoidance schedules, TO punishment is more effective in increasing the rate of extinction in the avoidance component than is punishment by electric shock (Nigro, 1966). This finding is surprising in view of the high degree of resistance to extinction that

²In concurrent schedules of reinforcement two or more responses are available for obtaining reinforcement. The schedules controlling reinforcement delivery operate independently and simultaneously and S is free to switch from one alternative to another.

avoidance responses are known to possess (Solomon, Kamin and Wynne, 1953). In concurrent schedules of positive reinforcement, response contingent TO for one alternative produces suppression of that response and simultaneously increases the rate of the unpunished response (Thomas, 1968; Carlson and Aroksaar, 1970). Behavioural interactions of this nature are not uncommon in concurrent schedules (Catania, 1966). The increase in the rate of unpunished behaviour when other behaviour decreases as a result of punishment, may be classified as a type of behavioural contrast (e.g. Brethower and Reynolds, 1962) which is not directly related to changes in reinforcement frequency. The net result of this type of behavioural interaction is, of course, pronounced preference for the unpunished concurrent component (Thomas 1968; Carlson and Aroksaar, 1970; Carlson, 1972).

Other findings when TO is scheduled in one component of a concurrent schedule of positive reinforcement include:

- 1) Response suppression in the TO component is inversely related to the size of the FR producing TO (Thomas, 1968). Similar results have been obtained with TO in the matching to sample paradigm (Zimmerman and Ferster, 1963). Also, this finding systematically replicates those obtained with electric shock. That is, the greater the number of shocked

responses, the greater the response suppression (Azrin, Holz and Hake, 1963). 2) When changeover responses are punished by TO in concurrent schedules (Todorov, 1971) changeover rates decrease; the proportion of responses emitted in the component with the highest rate of reinforcement increases with increasing TO duration; relative time spent responding in the high density component increases with increasing TO duration; local response rate in the high density component increases with increasing TO duration while local response rate in the alternate component decreases; and, as Stubbs Pliskoff and Reid (1977) have shown from Todorov's (1971) data, interchangeover time increases monotonically with increases in TO duration. These results essentially replicate those obtained with electric shock as the punishing stimulus (Todorov, 1971).

The effects of TO punishment in concurrent schedules support the conclusion reached with single schedules, namely, that TO seems to function as an aversive stimulus. Concurrent schedules appear to be ideal for the study of the effects of TO owing to their high sensitivity to the effects of mild stimuli.

IX.5 Conditioned Suppression and TO

The CER or conditioned suppression paradigm (Estes and Skinner, 1941) was suggested by Leitenberg (1965) as a

possible defining paradigm for an aversive stimulus. In the typical CER procedure a stable baseline of appetitively reinforced responding is obtained. Usually a VI schedule of reinforcement is employed. Then, a neutral stimulus (CS) followed by an aversive stimulus (UCS), is imposed upon this operant baseline. When shock is employed as a UCS, responding in the presence of the CS is suppressed below the baseline level. Presumably, the CS tends to elicit some component of the shock produced emotional behaviour (e.g. freezing, defecating) which is termed "fear" and which consequently interferes with ongoing responding (Hunt and Brady, 1955).

The results of studies using TO as the UCS in the conditioned suppression paradigm generally do not concur with those obtained in studies where shock is employed as the UCS. Suppression may be observed in a pre-TO stimulus if a response contingent variant of the CER paradigm is used in which the first response occurring during the latter part of the CS produces a TO from a high density reinforcement schedule (Herrnstein, 1955). However, if responding is maintained by a low density reinforcement schedule, an increase in pecking rate during the CS may be observed (Ferster, 1958; Herrnstein, 1955). Herrnstein (1955) interpreted the increased pre-TO responding as evidence

that the stimulus correlated with the low frequency VI schedule of reinforcement became aversive and thus TO from this schedule became reinforcing. This hypothesis received no support from a study by Ferster (1960) in which responding during the latter part of a pre-TO stimulus remained invariant with respect to changing overall reinforcement densities.

Attempts to resolve the problem of what controls response rates during pre-TO stimuli have met with little success. Leitenberg (1966) compared TO and electric shock using both the response dependent procedure (Herrnstein, 1955) and the regular response independent procedure (Estes and Skinner, 1941). Conditioned acceleration with TO and conditioned suppression with shock were obtained, regardless of whether a response contingent or response independent procedure was used. While no adequate explanation for the conditioned acceleration effect was advanced, these results suggested that some of the functional properties of shock and TO are different.

Recent data have contributed little in the way of clarification of the above problem. Leitenberg, Bertsch and Coughlin (1968) using rats in a bar pressing situation found some suppression in the presence of a pre-TO stimulus. This finding directly contradicted those of

earlier studies (e.g. Herrnstein, 1955) since Leitenberg et al., used the same low density VI schedule of reinforcement which Herrnstein (1955) employed. Kaufman (1969) using a high density VI schedule also found conditioned suppression in rats but it was only significant when TO was response contingent. Little or no suppression occurred when the direct analogue of the CER paradigm was used. Also, Carman (1969) found no suppression when TO was accompanied by a decrease in ambient illumination. Mild suppression gradually developed when no stimulus change other than bar retraction occurred. To further complicate matters, Holmes (1972) obtained complete suppression in the presence of a CS signalling TO (presentation of an S^-). Suppression developed in a gradual and cyclical manner with response rate first decreasing then increasing before suppressing altogether.

To summarize, one study which employed an S^- as TO found complete and maintained suppression in the presence of the pre- S^- signal. In contrast, while some studies have found mild suppression during a CS followed by TO, the one study which employed the direct TO analogue of the CER paradigm (Leitenberg, 1966) found reliable and sustained response acceleration in the presence of the CS.

II.6 Escape into TO.

Up to this point the empirical effects of TO in the various paradigms studied, provide some evidence that it may function as an aversive event. This conclusion notwithstanding, several conditions exist in which Ss may respond to produce periods of TO. That is, TO has been observed to function as a positive reinforcer. The most powerful demonstrations of the reinforcing function of TO have been in shock avoidance procedures (Verhave, 1962; Sidman, 1962; Baron and Trenholme, 1971; Baron, De Waard and Lipson, 1977). In all studies cited, TO consists of a signal correlated with time free from shocks on an unsignalled (Sidman, 1953) avoidance schedule. The effects of TO in this paradigm have been to increase the probability of the response it is contingent upon. The reinforcing effects of TO have been observed when it is contingent upon the same response that serves to avoid shock. However this effect is more potent when TO presentation is dependent upon a separate response (Baron and Trenholme, 1971). Additionally, TO producing responses have been maintained by ratio and interval schedules of TO onset (Verhave, 1962) suggesting that it shares functional properties with other positive reinforcers. Finally, the effects of TO from shock avoidance schedules are enhanced if TO includes the opportunity to escape to a

safe place (Baron, De Waard and Lipson, 1977). This suggests that the effects of TO partially depend on the extent to which they remove conditioned stimuli correlated with the primary aversive event.

As indicated earlier, it is both logically consistent and theoretically reasonable that the effects of TO are inversely related to favorability of the context into which it is introduced. The data marshalled thus far strongly support this contention: TO from a context of positive reinforcement appears to be aversive, whereas, TO from a context of negative reinforcement has the earmarks of a positive reinforcer. Unfortunately, the situation is not quite this simple, for an organism will sometimes acquire and maintain a response which changes or even removes conditions associated with positive reinforcement. Self-imposed TOs have been observed in fixed and progressive ratio schedules (Azrin, 1961; Appel, 1963; Thompson, 1964; Zimmerman and Ferster, 1964; Dardano, 1973; 1974), fixed interval schedules (Brown and Flory, 1972) and multiple schedules (Rilling, Askew, Ahlskog, and Kramer, 1969; Rilling, Kramer, and Richards, 1973; Terrace, 1971 and Coughlin, 1973).

In fixed ratio (FR) schedules the frequency and duration of self-imposed TOs increase as the size of the ratio increases, depending on the range of values studied

(Azrin, 1961; Appel, 1963). If the range of FR values is sufficiently expansive, the relation between ratio size, frequency and duration of TOs may not be monotonic (Zimmerman and Ferster, 1964). In progressive ratio schedules³ where ratio size reaches the point of "ratio strain" within one session, the frequency of TO-producing responses is a bitonic function of ratio size (Dardano, 1973; 1974). Similar results have been observed in FI schedules as the interval between reinforcements increases (Brown and Flory, 1972). Although relevant parametric data are not available from multiple schedules, a higher frequency of self-imposed TOs occurs during an extinction component than during a component of lower reinforcement density (Rilling et al., 1969). Also, TO-producing responses are more likely to occur during the earlier portion of an extinction component than later (von Sturmer, Beale and Davison, 1975).

One striking commonality between the three paradigms presented is that TO-producing responses almost invariably occur when reinforcement probability is at its lowest. In FR and PR schedules, TOs are most likely to occur during the post reinforcement pause (Azrin, 1961; Appel, 1963; Thompson, 1964; Dardano, 1973; 1974). In fixed interval (FI) schedules TOs occur most often in the early part of the interval (Brown

³In these schedules the ratio requirements are successively increased after each reinforcement by some fixed amount until performance becomes extremely strained.

and Flory, 1972) and in multiple schedules TOs occur in the component which has the lower relative reinforcement density (Rilling, Askew, Ahlskog and Kramer, 1969; Rilling, Kramer, and Richards, 1973; Terrace, 1971; von Sturmer et al., 1975). Thus, in all three paradigms, TO-producing responses have the greatest likelihood of occurrence soon after reinforcement. This observation, in one situation or another, has prompted several authors to hypothesize that self-imposed TOs are escape responses from momentarily aversive schedule conditions (Azrin, 1961; Thompson, 1964; Terrace, 1971). That is, reduction in local rate of reinforcement is assumed to be aversive for Ss responding on schedules of reinforcement. Self-imposed TOs allow for the removal of these aversive conditions.⁴

Unfortunately, the phenomenon of self-imposed TO is probably more complex than is implied by the escape hypothesis. First, a non-monotonic relationship between reinforcement density and frequency of self-imposed TOs (Zimmerman and Ferster, 1964; Dardano, 1973; 1974) is not consistent with this hypothesis because schedules with the lowest reinforcement density would be expected to be the

⁴This hypothesis of the aversive properties of a schedule of positive reinforcement is very consistent with Amsel's (1958) theory of conditioned frustration discussed earlier.

most aversive. Secondly, this hypothesis has difficulty in accounting for the finding that fewer TO-producing responses are observed when the duration of TO is not under Ss control (Zimmerman and Ferster, 1964). Further complicating matters is the observation that the occurrence of TO-producing responses seems to depend, to some extent, on the degree of stimulus change that is occasioned by the presentation of TO (Appel, 1963; Coughlin, 1973). Nevertheless, stimulus change alone is probably not sufficient to maintain self-imposed TOs if it does not result in removal of the stimulus originally controlling responding (Terrace 1971). For example, in multiple schedules, if a TO-response serves to alter the stimulus controlling TO responses, but does not remove S⁻ in that component of the schedule, TO-producing responses are not maintained (Terrace, 1971). Conversely, removal of the stimulus controlling responding (e.g. S⁻ in a multiple schedule) may not be sufficient if it is unaccompanied by an additional stimulus change such as blackout (Coughlin, 1973).

Although the escape hypothesis is intuitively appealing and may be tailored to account for most of the data, it does not go unchallenged. A viable alternative hypothesis is that TO-producing responses occur as a result

of weak control by the prevailing schedule of positive reinforcement (Zimmerman and Ferster, 1964). It could be argued that the occurrence of low probability behaviours such as pecking a non food key, preening, etc. would be most likely when local rate of reinforcement is at its lowest immediately following reinforcement - exactly the point at which TOs are observed to occur. Thus self-imposed TOs are hypothesized to emerge at a point in time when the schedule's controlling variables temporarily lose control.

As Dardano (1974) aptly points out, it is difficult to distinguish between the escape hypothesis and the hypothesis implying loss of schedule control (Zimmerman and Ferster, 1964) because both are predicated on "unfavorable" reinforcement conditions and both predict the temporal characteristics of self-imposed TOs. However, there are at least two aspects of the data gathered thus far which neither hypothesis can explain. First, neither appear to account for the bird's eventual reinstatement of the time-in (TI) condition (i.e. the schedule of positive reinforcement when the experimental procedure allows the subject to control the TO duration). The question remains as to why local conditions of reinforcement should function as a negative reinforcer at one time (occasion TO) and a positive reinforcer at another (occasion TI). Secondly, it remains for

either or both hypotheses to explain why Ss consistently emit an alternative response to a stimulus to remove the schedule of positive reinforcement rather than simply turning away from the food key. Perhaps the correct hypotheses will emerge when further research produces the answers to these questions.

II. 7 Summary and Conclusions

Thus far, a general definition of TO has been presented which characterized it as a temporary discriminable suspension of the variables controlling responding. The specific definition of TO that is germane to the present dissertation is that which occurs from a context of positive reinforcement. It was then illustrated that, because TO is discriminable, it must have stimulus properties. Subsequently, it was argued that the effects of TO, like other stimuli should be dependent on both context and paradigm. Finally, the paradigms in which TO has been studied were discussed highlighting the empirical effects of TO in each. The findings in the avoidance, escape and punishment paradigms suggest that TO can function as an aversive stimulus. In some instances, remarkable parallels were described between the effects of TO and other aversive stimuli such as electric shock. However, the effects of TO in the CER paradigm are somewhat equivocal in that some studies report response

suppression in the presence of a stimulus signalling TO whereas others report response acceleration. The remaining two paradigms, i.e. self-imposed TOs from contexts of either positive or negative reinforcement, constitute conditions under which TO functions as a positive reinforcer. In conclusion, there appears to be empirical support for the contention that the effects of TO are dependent either on contextual factors, or its correlation with responding or both. Research which is directed at determining whether or not TO is aversive would, in view of this conclusion, be conceptually oversimplistic.

III. THEORETICAL AND METHODOLOGICAL ISSUES IN TO

By definition, TO from reinforcement involves a stimulus-correlated reduction in reinforcement density. That is, when TO is presented in a schedule of reinforcement other things being equal, the absolute density of reinforcement in that schedule must decline. Consequently, any pattern of responding which modifies the rate of TO will, in turn, modify the overall density of reinforcement. This introduces a problem of interpretation of the effects of TO in schedules in which the rate of TO is correlated with rate of responding (Leitenberg, 1965). The problem is that the behaviour changes used to indicate the aversiveness of TO when avoidance, escape and punishment procedures are employed, may have the consequence of increasing the density of reinforcement.⁵ By avoiding or escaping TO the subject replaces periods of TO with periods when reinforcement can be obtained and, as a consequence, obtains a higher density of reinforcement or, possibly, greater numbers of reinforcements than if TO had occurred. Similar increases

⁵ Similar reasoning can be applied to behaviour changes indicating the appetitiveness of TO such as self-imposed TOs from shock avoidance schedules.

in reinforcement may occur in situations where organisms can switch from the response punished by TO to an alternative unpunished response (Holz et al, 1963). Thus, the results of these and similar studies may be interpreted in terms of increased positive reinforcement. However, as Leitenberg (1965) pointed out, this interpretation in no way negates the alternative possibility that TO from positive reinforcement is an aversive event.⁶

An obvious way to circumvent the above problem, at least in TO punishment, would be to remove the correlation between rate of responding and frequency of TO. That is, response contingent TOs themselves could be presented on interval schedules such that the probability of TO over time remains relatively constant. Thus, the reductions in response rate would not produce reductions in the rate of TO. However, a solution of this nature would be accompanied by the introduction of yet another problem. This has to do with changes in relative density of reinforcement. If TOs themselves were to occur in interval schedules, the absolute

⁶Since the publication of Leitenberg's paper several studies (e.g. Kaufman and Baron, 1968; Baron and Kaufman, 1969 and Carlson, 1970; 1972) have indicated that punishment by TO produces response rate reductions even when such reductions result in either loss of positive reinforcement or no change in rate of positive reinforcement.

density of reinforcement in the presence of the schedule- (e.g. VI) stimulus would remain the same as in baseline. However, the density of reinforcement in the presence of the VI-stimulus, relative to the frequency during all of the stimuli that successively control the organism's behaviour (e.g. TOs), would increase (Reynolds, 1961a). For instance, taking an example similar to the one used by Reynolds, (1961a) suppose that responding during baseline is reinforced on a Mult (VI 3-min VI 3-min) schedule of reinforcement in which one component is a green stimulus and the other a red stimulus. Subsequently, TOs (e.g. blackout of the apparatus) are substituted for the red stimulus periods. The relative frequency of reinforcement associated with the green stimulus increases. Before the change in schedules 0.5 of the total reinforcers per session occur when the key is green. After the change the same absolute number of the total reinforcers per session occurs in green, but since none occurs in TO the relative frequency in green increases to 1.0.⁷

Thus, when TOs are presented in such a way as to control for increases in absolute density of reinforcement the relative density of reinforcement in the schedule can

⁷ TOs have rarely been studied in multiple schedules but the same reasoning applies when TOs are presented on interval schedules in single VI schedules of reinforcements.

still increase. Increases in relative density of reinforcement have been shown to result in behavioural contrast (Reynolds, 1961c; Sadowsky, 1973), an increase in the rate of responding in the unchanged VI-component. It would seem, then, that in studies of escape and avoidance of TO or punishment by TO, it is important to note that the effects of TO in most cases must be assessed against a background of either an increase in absolute and/or relative reinforcement depending on whether or not responding modifies the rate of TO.

III.1 Control Possibilities in Choice Paradigms

An effective method for controlling increases in absolute density of reinforcement would be to present TO in concurrent schedules such that choosing the non-TO component would result in a schedule that presents the same density of reinforcement as in the TO component, but without presenting TO. This would entail adjusting the reinforcement frequency in the non-TO schedule so that it delivers reinforcements at the same frequency as the TO schedule (Carlson and Arokbaar, 1970; Carlson, 1972). However, as with single schedules of reinforcement, controlling for absolute density of reinforcement results in a higher relative density of reinforcement in the TO component. Thus, choice for the TO component might be expected, but it would be misleading to conclude

that TO was not aversive if this were to occur. It should be emphasized that the effects of TO must be assessed against a background of changes in relative reinforcement density produced by its occurrence.

Since the present research was conducted exclusively with concurrent schedules of reinforcement it may be helpful to consider the formal aspects of concurrent scheduling, per se, as well as the quantitative relationships that have been observed among concurrent operants. This discussion of concurrent schedules will be followed by a detailed presentation of the concurrent chains procedure and the rationale for the two experiments that follow.

IV. FORMAL ASPECTS OF CONCURRENT SCHEDULING

Ferster and Skinner (1957) have defined concurrent operants as "two or more responses of different topography at least with respect to locus, capable of being executed with little mutual interference at the same time or in rapid alternation under the control of separate programming devices." An experimental situation in which concurrent operants have been widely investigated is the two-key pigeon chamber. In this experimental situation three classes of responses may be identified: 1) Responses that occur on one of the two keys, 2) responses that occur to the other key and 3) responses involved in switching from one key to the other. Thus, the analysis of concurrent operants must take into account not only the absolute rates of the two responses but the relative frequency of occurrence of each and the frequencies of changeovers from one to the other (Catania, 1966).

It has been customary to study concurrent operants which are topographically independent of one another (Herrnstein, 1961). The use of mutually incompatible operants minimizes the development of superstitious behaviour in concurrent schedules. Concurrent

superstitions develop generally whenever the two responses can be emitted simultaneously and the consequences of one thus have an effect on both. This control of one operant by the reinforcement schedule for another has been demonstrated in a number of studies (Sidman, 1958; Catania and Cutts, 1963).

Even when concurrent operants are incompatible, concurrent superstitions may be established if the operants can occur in rapid succession. Simply, the temporal contiguity of one response with the subsequent reinforcement of the other may be sufficient to strengthen the first. Thus, it is often necessary to program concurrent schedules to make topographically incompatible responses more incompatible, at least with respect to their relationship with their respective reinforcement schedules. One technique for accomplishing this is the changeover delay (COD) procedure (Herrnstein, 1961). With this procedure a response is reinforced only if a certain interval of time has passed since the last changeover (CO) from the alternate response. This technique has proved quite effective in eliminating concurrent superstitions (Catania and Cutts, 1963).

There are two basic methods for programming concurrent operants. In one, the organism switches between the two schedules on the two operants by physically moving

from one to the other. In the other, the separate schedules are programmed on one manipulandum, each correlated with a different discriminative stimulus, and switching between schedules is occasioned by a response to a second "switching" or changeover (CO) manipulandum. In both procedures, each of the concurrent schedules of reinforcement operates continuously. Thus, in a concurrent VI schedule the timing of the intervals occurs in one component even though the organism is emitting the other operant.

The concurrent performance of pigeons in schedules where they switch back and forth between two keys is characterized by sequences of pecks on one key (runs) followed by sequences of pecks on the other. The duration of a CO is the time from the last peck on one key to the first peck on the other. The COD is usually timed from the first response on a given key after a CO has occurred.

In the changeover-key or CO-key procedure (Findlay, 1958) each peck on one key changes the schedule and associated stimuli on a second key. As in the two-key procedure, runs of responses on one schedule are typically followed by runs on the other (Catania, 1966). The CODs programmed in CO-key procedures are usually timed from the occurrence of a response on the CO-key. Thus, at least two pecks

are required for reinforcement when S moves from one schedule to another: a peck on the CO-key and a peck on the schedule key following the COD.

IV.1 Quantitative Relations among Concurrent Operants

It has been known for some time, that the rate of responding maintained by a given schedule is determined not only by the rate of reinforcement provided by that schedule but also by the reinforcement rate provided by alternate schedules for other operants (Findlay, 1958; Reynolds, 1961c). For example, in concurrent interval schedules, if the rate of reinforcement provided by one of the schedules is increased, the rate of responding maintained by the other schedule decreases while the rate maintained by the first schedule increases. Catania (1963a) and Herrnstein (1964) have attempted to quantify the relationship described above by deriving mathematical equations from several features of concurrent VI performances. These features were: (a) the total output or rate of responding maintained by two schedules is a monotonically increasing, negatively accelerated function of the total reinforcements/hr provided by the two schedules; (b) this total output is independent of the way in which reinforcements are distributed between the two operants; and (c) the proportion of the total number of responses emitted in

either schedule matches the proportion of the total number of reinforcements received in that schedule (Catania 1963a). Another way of stating this last relationship is that relative rates of responding match relative rates of reinforcement. Mathematically, this matching has been expressed by the equation: $\frac{R_a}{R_a + R_b} = \frac{r_a}{r_a + r_b}$ where R and r represent response and reinforcement rates for operants a and b respectively (Catania, 1966, Herrnstein, 1970).

These relationships appear to hold with both the two-key and CO-key methods of programming concurrent schedules. In addition it has been found using the CO-key procedure (Catania, 1963a) that the relative amount of time spent in the presence of a discriminative stimulus in a concurrent VI schedule matches the relative rate of reinforcement in the schedule correlated with that stimulus. In this same experiment the matching relation was also obtained with relative rate of responding. On the basis of these findings one could argue that local response rates in concurrent schedules are constant and that matching is a consequence solely of the relative time spent in each schedule. That is, pigeons in concurrent VI schedules are simply responding to equalize local rates of reinforcement (Rachlin, 1973). This interpretation would seem to indicate that relative

time measures are more reflective of choice behaviour than relative response rates (Baum and Rachlin, 1969). However, it has been customary to employ relative rates of responding as the operational definition of choice in concurrent schedules.

IV.2 Concurrent Chains Schedules

Concurrent chains schedules (Astor, 1969) are most easily viewed as concurrent schedules of conditioned reinforcement. In these schedules the preference for two mutually exclusive terminal link schedules is measured by the relative number of responses emitted on concurrently available VI schedules that constitute the initial links. Figure 1 presents a diagram of a concurrent chains schedule. The mutually exclusive terminal links are produced by responding in the initial links when the appropriate VI timer has completed operating. For example, responding in the left initial link key, as diagrammed on the left side of Figure 1, occasionally results in an entry into the left terminal link. Usually the initial link stimuli are correlated with VI schedules of conditioned reinforcement. When a terminal link is entered, both initial link timers stop operating and the alternate key, is darkened and becomes inoperative (see Figure 1, top). Also, the terminal link

Figure 1. A schematic representation of a concurrent chains schedule showing the sequence of events during a cycle from one initial link to the next.

Figure 1

stimulus is a different colour than the respective initial link stimulus. As can be seen in Figure 1, at the top, the left key light has changed to red and the right key is darkened indicating a left terminal link entry. Responding in the terminal link eventually leads to reinforcement according to some schedule. The type of terminal link schedule employed depends on the nature of the experiment. In most schedules, but not all, the choice period is restored after each terminal link reinforcement. This is shown at the right side of Figure 1. Similar conditions occur when responding on the right initial link stimulus leads to a right key terminal-link entry (see Figure 1 bottom).

Herrnstein (1961, 1964) compared the concurrent chains procedure with the standard procedure in which concurrent responding leads to primary reinforcement. This comparison showed that variations in either the frequency of primary reinforcement or in the frequency with which a conditioned reinforcer is paired with a primary reinforcer had essentially identical effects. In either case relative rate of responding matched relative rate of reinforcement. Subsequent experiments have shown that the matching relation does not generally hold true in concurrent schedules of conditioned reinforcement. For

example, Fantino (1969) and Wardlaw and Davison (1974) have shown that initial link length is also a critical determinant of preference in concurrent chains schedules. It is only at intermediate values of initial link schedules (e.g. VI 1-min) that matching remains an adequate description of the data. Fantino (1969) found that choice (relative response rates) for a particular pair of terminal link schedules became more extreme than would be expected by simple matching, when the size of the initial link schedule was reduced. Presumably other variables will be discovered which will restrict the generality of the matching relation in concurrent chains schedules. Already other models have been developed to account for the effects of initial link length on relative rates of responding (e.g. Fantino, 1969; Wardlaw and Davison, 1974).

IV.3 The Present Problem

The purpose of the present work was to investigate some context and paradigm dependent effects of TO under conditions in which increases in absolute reinforcement density was controlled. To accomplish this objective both rate of reinforcement (context) and rate of TO (paradigm) were manipulated in concurrent chains schedules. This method was employed, firstly, because it provided a very elegant means for controlling for the increased absolute

density of reinforcement that is produced by any behaviours that serve to reduce the frequency of TO. Secondly, as Schuster and Rachlin (1968) and others have shown, choice paradigms involving relative rates of responding are more sensitive to the effects of independent variables than is absolute rate.

In the present studies the logic of the concurrent tests was as follows: using concurrent chains schedules pigeons were, under various conditions, presented with a choice between two schedules of reinforcement. In one of these schedules the timer programming reinforcements was intermittently stopped for a fixed period of time (EXT). In the other schedule, a TO in the form of a blackout was delivered intermittently, simultaneously with suspension of the reinforcement timer. In both schedules, the absolute density of reinforcement was the same, the only difference being that blackouts were delivered in the TO schedule. The control schedule, which was simultaneously available to the bird during the choice phases, consisted of systematically adjusting the density and distribution of reinforcements in time, to account for the changes produced by the introduction of TO in the other chain. With this method of programming TOs, choices for the non-TO schedule could not be due to the increased density of reinforcement produced

by the avoidance of TOs.

IV.4 Experimental Rationale

Earlier it was argued that it would be logically consistent for TO to have effects which are context dependent. Some of the empirical evidence has prompted a few researchers to suggest that the overall rate of reinforcement, into which TO is introduced, is the most important contextual factor controlling the effects of TO (Herrnstein, 1955; Dardano, 1974). Specifically, data from PR schedules (Dardano, 1974) and VI schedules (Herrnstein, 1955) indicate that the effects of TO vary inversely with changes in overall rate of reinforcement. Under conditions of high reinforcement density TO appears to be aversive; under conditions of low reinforcement density TO appears not to be aversive or, in some cases, has appetitive properties.

Thus, in the present experiments absolute rate of reinforcement was varied over a limited range. If Dardano (1974) and Herrnstein (1955) are correct, then under conditions of high overall reinforcement density, schedule components containing TO would not be preferred to schedules of equal absolute reinforcement density; whereas, under conditions of low overall density schedules containing TO would be preferred.

It was also argued earlier that the effects of T0 should be paradigm dependent. In other words the rule dictating the correlation between T0 and responding should, to some extent, determine the effects of T0. This possibility was examined in the present experiments through manipulation of the rate of presentation of T0. The rate of occurrence of other events whether they are aversive or appetitive, is an important controlling variable of their effects with maximal effects occurring at the highest rates (Azrin and Holz, 1966; Schuster and Rachlin, 1968; Catania and Reynolds, 1968; Deluty, 1976). Thus, this variable was studied to see whether under the present conditions, similar effects occur with T0.

V. EXPERIMENT 1

The purpose of this experiment was to investigate the effects of response dependent timeout from positive reinforcement: a) in concurrent chains schedules of reinforcement, b) over a limited range of concurrent reinforcement rates and c) under conditions in which choice for the alternative component to the schedule containing TO did not lead to increased rate of reinforcement. To meet these requirements TOs were presented in one terminal link of the concurrent chains schedule, equivalent periods of extinction (EXT) in the other, and performance under these conditions compared to baselines in which neither event occurred. Several replications were conducted over a range of overall reinforcement densities.

For this experiment there were a number of possible outcomes in terms of initial link preferences and terminal link response rates, each with an associated hypothesis. First, the TO-component could be aversive relative to the EXT-terminal link with the degree of aversiveness being either constant or variable as a function of reinforcement density. If this were the case then the EXT-terminal link would be preferred over the TO-component in all experimental conditions. Also, response rates in the EXT-terminal link

would be expected to be higher under all conditions.

The second possibility is the EXT-component could become aversive relative to the TO-component due to the increase in nonreinforced responding that occurred as a result of the presentation of the unsignalled extinction periods (Amsel, 1958; Terrace, 1971).. Under these circumstances preference for the TO-component would represent avoidance of the EXT-terminal link i.e. the TO-component would be expected to have a reinforcing function similar to that observed in fixed and progressive ratio schedules. Presumably preferences for the TO-component would vary in an orderly fashion with overall reinforcement density because the aversiveness of the EXT-component (and hence the reinforcing properties of the TO-component) would depend on the amount of reduction in reinforcement density occasioned by the extinction periods. Specifically, preferences for the TO-component would be expected to increase with increasing reinforcement density.

The third possible outcome of this experiment combines some aspects of the previous two. Building upon the findings of Herrnstein (1955) and Dardano (1973; 1974) as well as others, this hypothesis predicts an inverse relationship between initial-link preferences and overall density of reinforcement. When terminal link reinforcement densities

are high, presentation of TO should be aversive. Thus, relative response rates would favour the EXT-component. However, when reinforcement densities are low the terminal link schedules should become aversive and presentation of TO should be reinforcing since it would temporarily remove stimuli correlated with that schedule. Thus, this hypothesis predicts a shift in preference for the EXT-component to the TO-component as overall density decreases from relatively high to low values.

Fourth, TO could be neutral with respect to the control procedures used (i.e. EXT in the alternate terminal link) and thus no clear cut preferences for either schedule would be evident in the initial links of the chains. Also, response rates in the terminal link schedules would be expected to be the same in both chains.

Fifth, preference for the TO-component could occur, not because the EXT-terminal link becomes aversive, but because of its failure to provide information about the unavailability of reinforcement. In this regard, the TO-terminal link would be more informative about conditions of reinforcement owing to the high correlation between TO and non-reinforcement. Organisms have been observed to prefer situations whose onsets reduce uncertainty about consequent reinforcement conditions even though such situations

ultimately lead to the same reinforcement conditions (Green and Rachlin, 1977). Furthermore this "information" hypothesis would predict that choice during the initial links would vary directly with the amount of uncertainty reduction occasioned by the occurrence of TO.

Finally, as suggested earlier, the TO-terminal link could be preferred because of the higher relative density of reinforcement occurring in that terminal-link discriminative stimulus. Recall that during TO, the key light and reinforcement timer were turned off for a fixed time period; but during extinction, in the alternate terminal link, only the reinforcement timer was turned off. Also, the absolute rate of reinforcement (reinforcements in real time) was the same in either schedule. Other things being equal, in a given session the stimulus correlated with the TO-terminal link would be on for a shorter total time than the stimulus correlated with the EXT-terminal link. The key light in the TO-terminal link in a given session would be on for the total time spent in that terminal link minus the sum of the durations of the total number of TOs that were presented. On the other hand, the key light in the EXT-terminal link would be on for the total time spent in that terminal link including the extinction periods that were presented. Moreover, since the absolute rates of reinforcement were

equal in both terminal links and reinforcement never occurred during TO, the relative rate of reinforcement in the TO-terminal link stimulus would have to be higher than in the EXT-terminal link stimulus. Thus, the birds might be expected to prefer the TO-terminal link simply because it was correlated with a higher relative rate of reinforcement. Another way of expressing this hypothesis is to say that the stimulus in the TO-terminal link would be a more potent conditioned reinforcer because of the correlation with a higher rate or density of reinforcement than the stimulus in the EXT-terminal link (e.g. Herrnstein, 1964). Either way, initial link preferences for the TO-terminal link as well as higher response rates in that terminal link would be expected.

V.1 Method

Subjects: Four experimentally naive White Carneau pigeons were maintained at 80% of their free-feeding weights. They were not studied on days that their weights exceeded or fell below $80\% \pm 15$ gms.

Apparatus: Four Lehigh Valley Operant Key Pecking Chambers were used. Each chamber was enclosed in a plywood box insulated with acoustical ceiling tile. Masking noise and ventilation was provided by two 100-CFM Dayton blowers located on the left side wall and back wall, respectively,

of each chamber and holding box. The translucent (perspex) response keys were located on the right wall. The centre key was only used during preliminary training. The stimuli used on the side keys (red, green and yellow) were projected on the reverse side of the translucent key by an In-Line Digital Unit. A 5.08 cm. aperture located directly below the centre key provided access to the grain hopper during periods of reinforcement. General illumination was provided by a houselight located above the centre response key. All experimental contingencies and response measures were programmed and recorded by a PDP-8I digital computer located in a separate room.

Procedure:

Preliminary training. The four birds were first adapted to the experimental chambers and trained to eat out of the hopper. They were then handshaped to peck the centre key which was illuminated by a blue light. A single peck to the centre key darkened it and produced 3-sec access to the hopper containing mixed grain. The houselight remained on during reinforcement throughout this and all subsequent phases of the experiment.

In the following session both side keys were illuminated yellow and the centre key turned off. A single alternation schedule was in effect such that alternating

responses were reinforced on a continuous reinforcement (CRF) schedule. That is, a single peck to either side key was reinforced only if the previous peck had occurred to the alternate key. This condition was in effect for one session of 60 reinforcements.

The next session consisted of presenting the two terminal-link stimuli on the side keys according to their own separate initial link schedules with the keys dark during the initial links. The initial links consisted of concurrent random time (RT) 15-sec schedules (Conc (RT 15-sec. RT 15-sec)). The left terminal link stimulus was red and the right green. Each stimulus was illuminated for a duration of three minutes and correlated with a random interval (RI) 30-sec schedule of reinforcement.⁸ After the three minutes had elapsed, control returned to the initial link schedules and a new cycle began. These conditions prevailed for a total of seven (7) sessions of 60 reinforcements each.

Two-Key Concurrent Chains Schedule 1. After the nine preliminary training sessions all birds were placed on the first concurrent chains schedule. During the concurrent initial

⁸Under all conditions constant probability random interval schedules were used to program reinforcers in both links. In all schedules the minimum inter-reinforcement interval was 5 sec. The probability that a response would be reinforced was .08 every 5 sec in the initial links and varied from .33 to .04 in the terminal links.

links, the key lights were illuminated yellow and each was correlated with a RI 60-sec schedule. Each of the initial link schedules operated independently, such that the timing of the intervals in one initial link occurred even if the bird responded to the other initial link. /

A changeover ratio of one response (COR 1) was in effect such that the first response following a changeover to an alternate key was never reinforced. Entry into the terminal links was response contingent and occurred on the average every 30 sec. A programmed entry into a terminal-link schedule resulted in a change in key colour from yellow to red on the left key and from yellow to green on the right key. During either terminal link schedule the initial link timers were stopped and the alternate key was darkened. Responses to the darkened keys were ineffective. The terminal link schedules were in effect for a duration of 3 min at which point control returned to the initial link stimuli. Both terminal link stimuli were correlated with identical RI 30-sec schedules of primary reinforcement. A reinforced key peck darkened the key and presented the bird 3-sec access to the hopper of mixed grain.

Independence of Concurrent Initial links. Three of the four birds developed consistent position preferences under the Conc [(Chain RI 60-sec. RI 30-sec) (Chain RI 60-sec. RI 30-sec)]

baseline schedule. It was quite likely that an extraneous source of variability had entered the situation such that initial link responses were not exclusively under the control of the independent terminal link schedules of conditioned reinforcement. For No. 1, No. 3 and No. 4 the following steps were taken to establish independence in the initial link responses: 1) The timer programming terminal link entries for the preferred key was stopped. If responding on the preferred key did not extinguish to zero, suggesting that some of the responses to the preferred key were being maintained by reinforcements on the alternate key, then the preferred initial link stimulus was darkened and extinction sessions continued. 2) Once responding on the preferred initial link key extinguished to zero, contingencies were reversed so that responding on the alternate key was extinguished to zero. The logic underlying these procedures was that if responding to the initial link keys was exclusively under the control of the terminal link conditioned reinforcers, then one should be able to separately and independently extinguish responses to either alternative by simply eliminating reinforcement in that initial link. When extinction to zero was complete on the non-preferred key, the original Conc [(Chain RI 60-sec RI 30-sec) (Chain RI 60-sec RI 30-sec)] schedule was reinstated with one

additional feature. To maintain independence between the initial link schedules, the first two responses following a changeover were never reinforced (COR 2).

Baseline Conditions. Figure 2 presents a diagram of the concurrent chains schedule used in Experiment 1. The inner loop of the figure refers to the baseline conditions. As can be seen from the left side of Figure 2 both keys were illuminated yellow during the first initial link. Responding on the left key occasionally (RI 60-sec) produced the left terminal-link stimulus shown at the top of the inner loop. While in the left terminal link, the left key light was changed to red and the right key darkened. During baseline, this terminal link stimulus was successively correlated with a RI 30-sec, RI 60-sec or RI 120-sec schedule of reinforcement. The respective schedule operated for three minutes whereupon control returned to the initial link schedules and a new cycle began. Inspection of the bottom of the inner loop reveals that similar conditions were upheld in the right terminal link except that the key colour changed from yellow to green and the left key darkened.

TO Conditions. Experimental phases were interpolated between successive baseline determinations. The outer loop in Figure 2 diagrams the TO conditions. Again, as is presented on the left hand side of Figure 2 both keys were illuminated yellow

Figure 2. Concurrent Chains Schedule 1. A diagram of the concurrent chains procedure used in Experiment 1. Complete cycles are shown from one choice period to the next for baseline (inner loop) and experimental (outer loop) conditions.

Figure 2

during the initial link. Responding on the left key occasionally (RI 60-sec) produced the left terminal link stimulus shown at the top of the outer loop in Figure 2. While in the left terminal link, the left key light was changed to red and the right key darkened. During experimental conditions this terminal link stimulus was also successively correlated with either a RI 30-sec, RI 60-sec or RI 120-sec schedule of reinforcement. The terminal link was in effect for 3 min, 2 min of which was taken up by the respective schedule of reinforcement and 1 min by either a TO or EXT period (see Figure 2, at top). After the 3-min terminal link, control returned to the initial link schedules as diagrammed at the right of Figure 2 and a new cycle began. Examination of Figure 2 at the bottom of the outer loop shows that conditions were the same in the right terminal link except that the key colour changed from yellow to green and the left key darkened.

In the EXT-terminal link response dependent periods of non-reinforcement were presented on a RI 120-sec schedule with a limited range of intervals. A 1-min EXT was scheduled to occur during each EXT-terminal link entry but could not occur during the first or last 30 sec of that terminal link. Since the periods of non-reinforcement were 1 min in duration, this requirement was met by scheduling an EXT to occur at

either 30, 40, 50, 60, 70, 80 or 90 sec into the terminal link. These intervals between the onset of the terminal link and the onset of EXT were randomly sampled without replacement so that when each interval had been selected, once from the total sampled (i.e. after 8 successive terminal link entries on the EXT-key) the cycle repeated itself. Programmed in this way there was at least 30 sec at the beginning and end of each terminal link in which EXT did not occur. During EXT the reinforcement scheduling apparatus was turned off. In the event that reinforcement and EXTs were scheduled to occur simultaneously, reinforcement was given precedence over EXT.

In the TO-terminal link, conditions were exactly the same as in the EXT-link except that the apparatus was "blacked out" when a TO was scheduled along with termination of the scheduling apparatus for reinforcement. Thus, reinforcement density, in real time, was carefully controlled in the TO and EXT-terminal links.

Experimental Design. A single subject design was used such that each subject was run successively under each experimental and baseline condition. Table 1 presents the sequence of terminal-link conditions for each bird. The first six conditions consisted of baseline and experimental sessions at RI 30, RI 60 and RI 120-sec terminal-link reinforcement

Table 1

Sequence and duration of conditions in the terminal links in Experiment 1

Trial Cond.	No. 1		No. 2		No. 3		No. 4		
	Left Key	Right Key	No. of Sessions	Left Key	Right Key	No. of Sessions	Left Key	Right Key	No. of Sessions
1	RI 30-sec	RI 30-sec	15	RI 30-sec	RI 30-sec	41	RI 30-sec	RI 30-sec	67
2	RI 30-sec (EXT)	RI 30-sec (TO)	58	RI 30-sec (TO)	RI 30-sec (EXT)	30	RI 30-sec (TO)	RI 30-sec (EXT)	47
3	RI 60-sec	RI 60-sec	58	RI 60-sec	RI 60-sec	64	RI 60-sec	RI 60-sec	29
4	RI 60-sec (TO)	RI 60-sec (EXT)	15	RI 60-sec (EXT)	RI 60-sec (TO)	40	RI 60-sec (EXT)	RI 60-sec (TO)	15
5	RI 120-sec	RI 120-sec	16	RI 120-sec	RI 120-sec	51	RI 120-sec	RI 120-sec	16
6	RI 120-sec (EXT)	RI 120-sec (TO)	17	RI 120-sec (TO)	RI 120-sec (EXT)	37	RI 120-sec (TO)	RI 120-sec (EXT)	13
7	RI 30-sec	RI 30-sec	22	RI 30-sec	RI 30-sec	30	RI 30-sec	RI 30-sec	22
8	RI 30-sec (TO)	RI 30-sec (EXT)	23	RI 30-sec (EXT)	RI 30-sec (TO)	37	RI 30-sec (EXT)	RI 30-sec (TO)	13
9	RI 60-sec	RI 60-sec	50	RI 120-sec	RI 120-sec	20	RI 60-sec	RI 120-sec	16
10	EXT	RI 60-sec	13	EXT	RI 120-sec	19	RI 60-sec	RI 120-sec	22

rates, respectively. During experimental conditions TOs were scheduled to occur in one terminal link and equivalent periods of EXT were similarly scheduled to occur in the alternate terminal link. The position of TOs in the terminal-link schedules was counterbalanced between birds over the three terminal-link reinforcement rate conditions (see Table 1, Conditions 2, 4 and 6). A second determination at RI 30-sec was taken in all birds following completion of Condition 6 (see Table 1, Conditions 7 and 8).

Conditions 9 and 10 determined the effects of simply extinguishing one of the initial link responses. The purpose of this procedure was to study a variable (initial link extinction) with known experimental effects, under conditions in which the experimental variables (TO) exerted, at best, weak behavioural control. If the initial link extinction procedure produced substantial changes in preference, as one might expect, then it would be difficult to argue that the concurrent chains technique had earlier become insensitive to the effects of TO at RI 60-sec and RI 120-sec. No. 1 and No. 3 were studied under RI 60-sec terminal link schedules while No. 2 and No. 4 were studied under RI 120-sec terminal link schedules. Condition 9 was baseline with Condition 10 providing the extinction manipulation.

Sessions were conducted six days a week and were

terminated following either 60 reinforcements or 90 min whichever came first. Each condition was terminated when the distribution of responding on the initial link keys met a day-to-day stability criterion applied to the last nine sessions: the nine sessions were divided into three groups of three sessions each and the median of the three choice proportions in each group was determined; to satisfy the stability criterion these three group medians (M1, M2 and M3) could not span a range greater than 10% (.10).

Quantitative Measures. The pertinent quantitative measures are diagrammed in Figure 3 which shows the sequence of events during two typical cycles of an experimental condition. The first pair of lines show the concurrent initial links of the chains. The four lines labelled 2A show the terminal link conditions for the TO key. The four lines labelled 2B show the terminal link conditions for the EXT key. The line at the bottom labelled 3 shows food reinforcements. Responses are shown as discrete vertical deflections on the appropriate lines. The small arrows mark those responses which actually result in some change. Thus, (see pair of lines in 1): it is a response to the TO-key that produces the terminal link during the first cycle and a response to the EXT key that does so in the second cycle. During the first cycle responses to the red (TO) key produce TO and food

Figure 3. A schematic representation of the sequence of events during two typical cycles of an experimental condition (see text for definition of terms).

Figure 3

(see Figure 3, lines 1 and 3 in 2A and line 1 in 3, respectively). During the second cycle responses to the green (EXT) key produce EXT and food (see Figure 3, lines 2 and 3 in 2B and line 1 in 3 respectively). The three basic variables are: number of responses, duration of conditions and number of food presentations, symbolized by the letters P, T, and R, respectively. Lower-case letters refer to the initial link of a chain, upper-case letters to the terminal link and the subscripts T and E to the TO and EXT key, respectively. Thus: (see also Figure 3)

- P_T = number of responses to the TO key during the initial link.
- P_E = number of responses to the EXT key during the initial link.
- P_T = number of responses to the TO key during the terminal link.
- P_R = number of responses to EXT key during the terminal link omitting those that occur during periods of extinction.
- P_E = number of responses to the EXT key during extinction in the terminal link.
- t = duration of initial links.
- T_T = duration of TO terminal link, omitting the duration of food presentations.
- T_S = duration of TO terminal link omitting the duration of food presentations and the duration of TO presentations.

T_E = duration of EXT terminal link omitting the duration of food presentations.

T_R = duration of EXT terminal link omitting the duration of food presentations and the duration of EXT presentations.

R_T = number of food presentations produced by responses to the TO key.

R_E = number of food presentations produced by responses to the EXT key.

V.2 Results and Discussion

All of the data presented are means of the last five sessions under each condition for each bird.

Initial Link Absolute Rates. Figure 4 presents the mean response rates during the initial links on the TO and EXT-keys. The triangles represent response rates in the TO-initial link and the squares represent the EXT-initial link. Where two determinations were taken (RI 30-sec) the mean of the two is presented along with the range of the two values. Response rates are presented over the three scheduled reinforcement densities for each of the birds. The lower panels display the baseline conditions; the upper panels the experimental conditions. The daily response rates were calculated by dividing the total number of responses on the respective initial link key (p_T or p_E , see Figure 3) by the total time spent in the initial links (t) during that session. Thus the response rate in the TO initial link can be symbolized by $\frac{p_T}{t}$ and in the EXT initial link as $\frac{p_E}{t}$.⁹

Under baseline conditions the initial link response rates were relatively unaffected by increasing overall reinforcement density. Also, response rates on the TO and EXT-keys were quite comparable over the three reinforcement

⁹ All of the means and their respective standard errors are presented in the left two columns of Table 1 in Appendix A.

Figure 4. Responses/min in the TO-(triangles) and EXT-(squares) initial links as a function of reinforcement density in the terminal links. Lower panels present baseline conditions, upper panels present experimental conditions. Vertical bars represent the range of values for the TO-(solid) and EXT-(dashed) initial links where two determinations were taken.

Figure 4

densities in three of the four birds (No. 1, No. 2 and No. 4). Such was not the case for No. 3. The attempt to establish independence between the two initial-link keys for this bird, through differential extinction, was unsuccessful in counteracting No. 3's rather strong right key bias. This preference is perhaps not readily apparent in the lower panel of Figure 4 because of the alternation of the position of TO and EXT over the reinforcement density conditions. Consider the TO component for the moment. For No. 3, the TO component was the left key at 120 reinforcements/hr (RI 30-sec), the right key at 60 reinforcements/hr (RI 60-sec) and the left key at 30 reinforcements/hr (RI 120-sec). But No. 3 exhibited a strong and consistent right key preference throughout the course of the study. This explains the apparent alternation of response rates in the TO component (which was on the right key under RI 60-sec only) over reinforcement densities during baseline conditions.

The upper panels in Figure 4 present the absolute response rates in the initial links under the experimental conditions of TO and EXT over the three overall reinforcement densities studied. For three of the four birds (No. 1, No. 2 and No. 4) response rates in the TO-initial link increased with increasing reinforcement density. Response rates in the EXT-initial link either did not change (No. 4) or declined

with increasing reinforcement density. For P3 little change occurred as a result of the introduction of TO and EXT suggesting that the variables controlling the position bias were more potent than the independent variables.

The lower panels of Figure 5 present differences in initial-link response rates between experimental and baseline conditions as a function of reinforcement density. Filled triangles represent the difference score (obtained by subtracting mean response rate during baseline from mean response rate during TO) for the TO-initial link. Filled squares represent the same difference score for the EXT-initial link. These calculations were performed first, to determine the extent to which initial-link response rates during TO and EXT as revealed in the upper panels of Figure 4 represented a change from baseline. Secondly, difference scores allowed for examination of the direction of any observed changes from baseline as revealed in the vertical deflections from the zero axis (indicating no difference) in the lower panels of Figure 5. It is clear that the greatest effects of TO and EXT relative to baseline were at 120 reinforcements/hr. In birds No. 1, No. 2 and No. 4 response rate in the TO-initial link at 120 reinforcements/hr increased over baseline in both determinations where as for No. 3 an increase was observed only on the second determination.

Figure 5. Lower panels present difference scores in the TO-(triangles) and EXT-(squares) initial links as a function of reinforcement density. Upper panels present preference scores as a function of reinforcement density (see text for description of calculations). Vertical bars represent range of values when two determinations were taken.

Figure 5

2

Conversely, at this same reinforcement density response rate in the EXT-component decreases on both determinations with the exception of the second determination for No. 4. Thus, preference for the TO-component at 120 reinforcements/hr consisted of both an increase in response rate in the TO-initial link, as compared to baseline, and a decrease in the EXT-initial link. Minimal effects were observed at 30 and 60 reinforcements/hr with the possible exception of reductions in response rate in the EXT-initial link at 60 and 30 reinforcements/hr in birds No. 1 and No. 2 respectively. A slight reduction from baseline was also observed in the TO-component for bird No. 1 at 30 reinforcements/hr.

The upper panels of Figure 5 present preference scores obtained by taking the absolute difference of the scores plotted in the lower panels of Figure 5. The zero horizontal axis is the point of no difference between the TO and EXT scores. Thus, deflections above the zero axis represent a difference favoring the TO-component (i.e. the change from baseline in the TO-initial link being greater than that in the EXT-initial link); deflections below the zero axis indicate a difference favoring the EXT-initial link. Plotted in this fashion these scores can be considered to represent the degree of preference for either initial link as a function of reinforcement density. In all four birds the greatest prefer-

ences were for the TO-terminal link at 120 reinforcements/hr. However, except in the case of bird No. 1, preferences do not appear to increase monotonically with increasing reinforcement density. In both No. 2 and No. 4 no preference for either component is apparent at 60 reinforcements/hr and only slight preferences for TO were observed at 30 reinforcements/hr. For bird No. 3 the function is virtually flat and near zero possibly reflecting the effects of the position bias evident in this data.

Terminal Link Absolute Response Rates. Figure 6 presents mean response rate during the terminal links in all conditions examined. The filled triangles in the figure represent response rates in the TO-terminal link and the circles, the EXT-terminal link.¹⁰ The lower panels in the figure are the baseline conditions; the upper panels the experimental conditions. Response rates in the TO-terminal link were calculated by dividing the total number of responses in that link (P_T) by the total time spent in that link omitting the total duration of the sum of the obtained TOs (T_S). This time base was chosen because of the fact that the birds did not respond during TO so that the blackout

¹⁰All of the means and their respective standard errors are presented in Table i, Appendix A. The mean of the two determinations taken at 120 reinforcements/hr is presented in Figure 6 along with the range of the two values.

Figure 6. Responses/min in the TO- (triangles) and EXT- (squares) terminal links as a function of reinforcement density. Lower panels present baseline conditions, upper panels present experimental conditions. Vertical bars represent the range of values for the TO- (solid) and EXT- (dashed) terminal links where two determinations were taken.

Figure 6

was functionally the same as removing the key from the apparatus. Thus, calculation of response rates that included TOs in the time base would have been biased towards lower values. To make the response rate measure in the EXT-terminal link comparable to the measure in the TO-link, response rates in the former were calculated by dividing the total number of responses in that link, omitting those that occurred during periods of extinction (P_R), by the total time spent in the EXT-link omitting the total duration of the sum of the extinction periods (T_R).¹¹

In the lower panels of Figure 6 the baseline response rates increased with increasing overall reinforcement density with the exception of the EXT-terminal link for No. 2. This increase appeared to be uniform in both the TO and EXT-terminal links. In the experimental conditions, displayed in the upper panels of Figure 6, for three of the four birds, (No. 1, No. 2 and No. 3) response rates in both the

¹¹ Table 2 presents mean response rates in the EXT-terminal link calculated both omitting extinction periods ($\frac{P_R}{T_R}$) and including extinction periods ($\frac{P_R + P_E}{T_E}$).

➤ Comparisons of response rates calculated both ways for all birds at each of the terminal-link reinforcement rates reveals that they are very similar and do not indicate that the extinction periods were discriminated.

Table 2

Mean response rate in the EXT-terminal link for all birds over the three reinforcement densities. Response rates are calculated both omitting $\left(\frac{P_R}{T_R}\right)$ and including $\left(\frac{P_R + P_E}{T_E}\right)$ extinction periods.

Reinf./hr	Subject No.	Calculation 1	Calculation 2
		Omission of Extinction Periods $\left(\frac{P_R}{T_R}\right)$	Inclusion of Extinction Periods $\left(\frac{P_R + P_E}{T_E}\right)$
		Resp./min	Resp./min
120	1	98.2	103.3
120	2	65.5	64.9
120	3	56.3	58.0
120	4	50.4	55.0
60	1	91.2	83.1
60	2	64.4	63.2
60	3	47.3	54.4
60	4	54.3	52.4
30	1	74.9	67.7
30	2	63.6	61.1
30	3	47.8	42.9
30	4	49.4	43.4

TO and EXT-terminal links increased with increasing reinforcement density.¹² While terminal link response rates were not quite as orderly with respect to overall reinforcement density for No. 4, the rates in the TO-terminal link were higher than the EXT-terminal link at both 120 reinforcements/hr (RI 30-sec) and 30 reinforcements/hr (RI 120-sec).

Figure 7 presents the difference between response rates in the experimental and baseline conditions for the TO and EXT-terminal links. Where two determinations were taken (i.e. at 120 reinforcements/hr) the range of the values is presented along with the mean of the determinations. Upward deflections from the zero axis depict an increase over baseline; downward deflections a decrease from baseline. For birds No. 1 and No. 2 response rate in the TO-terminal link increased from baseline as an orderly function of reinforcement density. For No. 3 the only increase from baseline was at 120 reinforcements/hr, whereas for No. 4 increases over baseline were relatively constant as a function of reinforcement density. Similar consistency was not observed in the

¹²For bird No. 1 on the first determination, a decrease in response rate in the TO-terminal link occurred from 60 to 120 reinforcements/hr. However, as indicated by the range of the values for the two determinations, a substantial increase occurred on the second determination.

Figure 7. Difference scores in the TO-(triangles) and EXT-(squares) terminal links as a function of reinforcement density (see text for description of calculations). Vertical bars represent range of values where two determinations were taken.

TERMINAL LINK RESPONSES / MIN.
(DIFFERENCE SCORE E.-B)

Figure 7

EXT-terminal link. However, in birds No. 1, No. 2 and No. 4 the magnitude of the change from baseline in the TO-terminal link was greater than in the EXT-terminal link regardless of which direction responding changed in the latter.

Comparison of Figures 4 and 6 reveals that the terminal links were more sensitive than the initial links to changes in overall rate of reinforcement. Also, in the experimental conditions some covariation occurred between initial link response rates on the TO-key and terminal link absolute rates of responding in the TO-link. In particular, both increase with increasing overall reinforcement density. Parallels between the two response measures in the EXT-component are not as obvious.

Extinction Probe in Initial Links. The initial links were probed to determine sensitivity to variables with known behavioural effects such as extinction (see Table 1, p. 67, Conditions 9 and 10). The probes were important because only weak behavioural control was observed in the initial links at 60 reinforcements/hr (RI 60-sec) and 30 reinforcements/hr (RI 120-sec). The probe sessions consisted of simply turning off one of the initial link reinforcement timers and determining whether responding extinguished to that key. Table 3 presents the results from this manipulation.

Table 1

Extinction probe in initial links. Columns include: subject number, terminal link reinforcements/hr, experimental conditions in the initial links, responses/min in the extinguished initial link, responses/min in the non-extinguished initial link and relative responses/min in the non-extinguished initial link.

(1)	(2)	(3)	(4)	(5)	(6)	
Subject No.	T-Link Reinf./hr	Exp'tal Condition (I-Link)	Mean Resp./min Extinguished I-Link	Mean Resp./min Non. Ext. I-Link	Mean Relative Resp./min Non. Ext. I-Link	
		Left Key	Right Key			
1	60	RI 60-sec	RI 60-sec	39.4	45.1	.54
	60	EXT	RI 60-sec	0.74	79.5	.99
2	30	RI 60-sec	RI 60-sec	27.8	34.7	.55
	30	EXT	RI 60-sec	1.8	35.0	.95
3	60	RI 60-sec	RI 60-sec	24.1	15.9	.40
	60	RI 60-sec	EXT	3.7	24.9	.87
4	30	RI 60-sec	RI 60-sec	25.1	25.2	.50
	30	RI 60-sec	EXT	2.6	23.9	.91

Columns 4 and 5 in Table 3, present the absolute rates on the extinguished initial-link key, and the non-extinguished key, during baseline and probe conditions respectively. During baseline, except for No. 3, the absolute rates on either key were quite similar and for all 4 birds, quite comparable to the rates obtained on previous determinations (see Figure 4, p. 74). However, the extinction probe produced marked reductions in response rates on the respective keys to a near zero level. Bird No. 3 reached a higher asymptote on the extinguished key than the others suggesting that variables other than terminal link entry were still maintaining the high response rate on the preferred key. In all four birds, the extinction probe produced a strong preference for the non-extinguished initial link as is shown by the relative rates of responding in column 6 of Table 3. The powerful effects of this variable strongly suggest, with the exception of bird No. 3, that a high degree of sensitivity was maintained throughout the course of the study. Thus, reduced sensitivity was not responsible for the diminished effects of TO and EXT at 60 reinforcements/hr and 30 reinforcements/hr.

Relative Response Rates in TO-Initial Link. Figure 8 presents relative rate of responding in the TO-initial link $\left(\frac{P_T}{P_T + P_E} \right)$ as a function of: (a) relative rate of obtained reinforcement

Figure 8. Relative response rate in the TO-initial link as a function of total-time (left panels) and stimulus-time (right panels) relative rate of reinforcement in the terminal links. Open circles represent baseline determinations; filled circles are experimental determinations. Solid diagonal is the line of perfect matching; dashed diagonal is the calculated linear regression line through the data points.

Figure 8

in the TO terminal link calculated using the total-time base (T_T) and (b) relative rate of obtained reinforcement in the TO-terminal link calculated using the stimulus-time base (T_S). Thus, in the former case, relative rate of reinforcement is defined as $\frac{R_T/T_T}{R_T/T_T + R_E/T_E}$ (Figure 8 left panels)

and in the latter as $\frac{R_T/T_S}{R_T/T_S + R_E/T_E}$ (see Figure 8 right panels).

This distinction between measures of relative reinforcement rate was made to determine which measure was more preferable in terms of the proportion of variance accounted for in initial link relative response rates. Logically, the outcome of this comparison has implications for the hypotheses considered in the introduction. The ten data points in Figure 8 correspond to the eight baseline and experimental determinations obtained in Experiment 1 (see Conditions 1 to 8 in Table 1, p. 72) plus one baseline and experimental determination taken under the concurrent chains schedule of Experiment 2 (see Table 4, p. 105). Open circles represent baseline determinations; filled circles represent experimental determinations. Each point is the mean of the last five sessions under the respective conditions.¹³

The solid 45 degree diagonal line in each panel traces the

¹³The means for both relative reinforcement and relative response rates are presented in Table ii Appendix A.

path of perfect matching between relative frequency of responding in the TO-initial link and relative frequency of primary reinforcement (by each of the two definitions of this concept) during the TO-terminal link. The dashed line is the calculated linear regression line through the data points. The linear equations are on each plot as well as the correlation coefficients, and standard errors of estimate. For all Ss except No. 3, there is less scatter around the regression line with stimulus-time rate of reinforcement as the independent variable than with total-time rate of reinforcement.

Relative rate of responding as a function of relative rate of reinforcement, calculated using the total-time base, is presented in the left panels of Figure 8. The correlations between these variables are both low and unreliable ($p = \text{N.S.}$ for all coefficients). Also, there is little consistency between birds, in that, for two birds, the slopes are less than one (No. 1 and No. 4) and for the other, the slope is greater than one (No. 2). For No. 3 the "shot gun" scatter of points reflects the response bias discussed earlier (see Figure 4, p. 74).

In contrast, the relation between relative response rate in the initial links and relative rate of reinforcement, calculated using the stimulus-time base (right panels of Figure 8), is substantially more orderly. With the exception

of No. 3, the correlations are relatively high and statistically reliable ($p < .05$ for No. 1, No. 2 and No. 4 respectively). Also, the slopes of the regression lines while comparable between birds are consistently lower than 1.0 and the y-intercepts are greater than zero suggesting that perfect matching did not obtain. For No. 3 there is little change in the scatter of points with the change in relative reinforcement density which again reflects the insensitivity of this bird's initial link responses to the experimental variables.

Relative Response Rate in TO-Terminal Link. Figure 9 presents relative rate of responding in the TO terminal link $\left(\frac{P_T/T_S}{P_T/T_S + P_R/T_R} \right)$

as a function of relative rate of reinforcement in the TO-link using the total-time base (left panels) and the stimulus-time base (right panels). Open circles represent baseline determinations; filled circles experimental determinations.¹⁴ The solid line in each panel traces the path of perfect matching between relative response rate and relative rate of reinforcement (by each of the two definitions of this concept). The dashed line is the least squares fit to the array of points in each of the panels. Also presented in each panel is the

¹⁴The means and standard errors of the relative response and reinforcement rates are presented in Table ii Appendix A.

Figure 9. Relative response rate in the TO-terminal link as a function of total-time (left panels) and stimulus-time (right panels) relative rate of reinforcement in the terminal links. Open circles represent baseline determinations, filled circles are experimental determinations. Solid diagonal is the line of perfect matching; dashed diagonal is the calculated linear regression line through the data points.

RELATIVE RATE OF REINFORCEMENT

$$\left(\frac{\frac{R_T}{T_T}}{\frac{R_T}{T_T} + \frac{R_E}{T_E}} \right) \quad \left(\frac{\frac{R_T}{T_S}}{\frac{R_T}{T_S} + \frac{R_E}{T_E}} \right)$$

Figure 9

regression equation, correlation coefficient and the standard error of estimate. Again, there appears to be less scatter around the best fitting line when stimulus-time reinforcement rate is used as the independent variable than when total-time reinforcement rate is used.

The correlations between relative rate of responding in the terminal links and relative rate of reinforcement are again both low and unreliable ($p = \text{N.S.}$ for all four coefficients). The best fitting regression lines have positive slopes in two birds (No. 1 and No. 2) and negative slopes in two birds (No. 3 and No. 4) suggesting no consistent relationship between the two variables.

On the other hand, the relationship between relative rate of responding in the TO-terminal link and relative rate of reinforcement, calculated using the stimulus-time base, is clearly more consistent. Correlations between the two measures were statistically reliable in three of the four birds ($p < .05$ for No. 1, No. 2 and No. 3 and $p = \text{N.S.}$ for No. 4). The slopes of the best fitting lines were all positive and similar between birds. All four regression coefficients were considerably less than 1.0 and the y-interceptions greater than 1.0 indicating an undermatching relation between responding and reinforcement.

Comparison of initial-link relative rates of responding (Figure 8) to terminal-link relative rates (Figure 9) reveals that in both cases the data were more orderly when $\frac{R_T/T_S}{R_T/T_S + R_E/T_E}$ was used as the independent variable. Although in both cases straight line functions provided an adequate fit to the data points, the slopes of these functions were consistently higher when relative rate of responding in the initial links was the dependent variable.

Summary and Conclusions. Experiment 1 examined the effects of TO on choice and rate of responding over a range of reinforcement densities in a concurrent chains schedule. The major finding was that the terminal-link schedule containing TOs was preferred to the alternate, control schedule with the magnitude of the preference varying with overall rate of reinforcement. However, initial-link rates, when compared to baseline, revealed consistent increases in the TO-initial link only at 120 reinforcements/hr. Initial-link preferences were also directly proportional to the relative rate of reinforcement in the terminal links when the latter was calculated using stimulus-time as the temporal base. Such orderly relations between relative responding and relative reinforcement are not uncommon in concurrent schedules (Autor, 1969; Herrnstein, 1961; 1964; Fantino, 1969). However,

these studies, and most others, have reported a matching relation between relative response rate and relative reinforcement rate. In the present study, consistent undermatching functions were obtained. Obviously the indirect effect that TO-presentations had on relative density of reinforcement in the TO-terminal link is different than would be expected had relative reinforcement densities been manipulated directly. This discrepancy might be attributed to the effects of TOs themselves. We shall return to this point later.

A secondary finding in the present study was that rate of responding in the TO-terminal link increased with increasing overall reinforcement density and was higher than in baseline at practically all values of overall reinforcement density. Response rates in the EXT-component underwent less change with respect to baseline. The effects in the TO-terminal link are analogous to behavioural interactions in other experimental situations such as multiple schedules of reinforcement. A behavioural interaction has been defined as a change in behaviour during the presentation of one stimulus brought about by changing the schedule associated with a different stimulus (Reynolds, 1961a). This change in behaviour is termed contrast when the change in the rate of responding during the presentation of one

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stimulus is in a direction away from the rate of responding generated during presentation of the other stimulus.

Behavioural interactions in multiple schedules notwithstanding, the question arises as to whether the contrast effect in the present data occurred locally within the TO-terminal link component or between terminal link components. The presentation of TO in single schedules of reinforcement has been known to produce behavioural contrast in the form of an increase in response rate in the unchanged schedule component (cf. Reynolds, 1961a; Sadowsky, 1973). However, in the present study another possibility exists. Recall that the absolute rate of reinforcement in the EXT-terminal link decreased with the inception of the EXT-contingencies, whereas the rate of reinforcement (stimulus-time) in the TO-terminal link was unchanged with respect to baseline. Behavioural interactions between terminal-link components have been observed in studies in which rate of reinforcement has been manipulated directly (e.g. Hursh and Fantino, 1973). An interaction of this nature could have occurred to produce the increased response rate in the TO-terminal link. The fact that relative rate of responding in the TO-terminal link varied proportionally with relative rate of reinforcement supports the notion that behavioural contrast occurred between terminal link components. Further discussion

of these results will be carried out after consideration of the findings of Experiment 2.

VI. EXPERIMENT 2

The purpose of this experiment was to provide a systematic replication of Experiment 1. Several changes were made in basic methodology and in parameter values. These changes consisted primarily of attempts to strengthen the controlling variables of concurrent chains performance as well as some of those that control the aversive function of TO. First, the method of programming concurrent chains schedules was changed in an attempt to eliminate the problem of response bias. Specifically, the schedules were programmed using the more customary technique of returning control to the initial-links after each reinforcement. Also the initial-link schedules were shortened to RI 30-sec. Secondly, a design change consisted of determinations being taken when terminal-link schedules were either: RI 15-sec, RI 30-sec or RI 60-sec. No measurements were taken at RI 120-sec. The inclusion of RI 15-sec in this study was done to examine TO-effects on responding maintained at very high reinforcement densities since the effects observed at RI 60-sec and RI 120-sec were minimal in Experiment 1. Finally, the rate of TO and EXT-presentations in the terminal links was increased from approximately 30/hr (VI 2-min) to 240/hr (RI 15-sec). It was reasoned that the apparent failure to

observe punishing properties of TO in Experiment 1 may have been because of its low absolute rate of presentation. Rate of occurrence of an aversive event is an important controlling variable with maximal effects occurring at the highest rates (Azrin and Holz, 1966; Schuster and Rachlin, 1968; Deluty, 1976). Since TO is at best a weak aversive stimulus (Leitenberg, 1965) it may have to occur at unusually high frequencies before its aversive properties can be measured (Kaufman and Baron, 1968).

VI.1 Method

Subjects: Eight White Carneau pigeons served as subjects in Experiment 2. Four birds were from Experiment 1 and four were experimentally naive. These birds were also maintained at 80% of their free-feeding weights and were not studied on days that their weights exceeded or fell below $80\% \pm 15$ gms.

Apparatus: The apparatus was the same as that used in Experiment 1.

Procedure:

Preliminary training. The four naive birds went through precisely the same set of pretraining procedures as did the birds in Experiment 1. Except where noted, the experimental parameters were the same as in the first study. After hopper training, each bird was hand shaped to peck the centre

key) illuminated blue. The single alternation schedule followed, with the centre key darkened and the side keys illuminated yellow. The concurrent chains schedule was presented next, with the initial link keys dark and terminal link presentations programmed on separated RI 15-sec schedules. The left terminal link was a red key correlated with a RI 15-sec schedule; the right terminal link was a green key also correlated with a RI 15-sec schedule. The difference between this preliminary schedule and the one used in the previous experiment was that control returned to the initial links of the chains following every reinforcement. That is, the duration of either terminal link was not held constant but depended on the scheduling of reinforcements. Instead, the number of reinforcements per cycle was held constant at one. This procedure was carried out for a total of seven sessions of 60 reinforcements each.

Two Key Concurrent Chains Schedule 2. In this phase, the four naive birds were placed on the second concurrent chains schedule. During the initial links, the side keys were illuminated yellow and correlated with separate RI 30-sec schedules of conditioned reinforcement. In all conditions examined, a changeover ratio of two responses was in effect (COR 2) such that following a changeover neither the first nor the second response was ever reinforced. As in the

previous phase the left terminal link was a red key correlated with a RI 15-sec schedule of grain reinforcement; the right terminal link was a green key correlated with a RI 15-sec schedule. A reinforced key peck darkened the key and presented the bird three seconds access to the hopper of mixed grain. This condition remained in effect for a total of 15 sessions of either 60 reinforcements or 90 min, whichever came first.

Independence of Concurrent Initial Links. As in the first study, responses to both initial-link keys were separately extinguished in an attempt to establish independence between the two simultaneously available response alternatives. Once extinction was complete to one of the keys the contingencies were reversed such that non-reinforcement occurred to the alternate initial-link key. Upon completion of extinction to the second key the baseline Conc [(Chain RI 30-sec. RI 15-sec) (Chain RI 30-sec. RI 15-sec)] schedule was reinstated.

Baseline Conditions. As in the previous study, the terminal links of the concurrent chains schedule during baseline were correlated with equivalent schedules of food reinforcement. Figure 10 presents a diagram of the concurrent chains schedule used in this experiment. The inner loop refers to the baseline conditions. The initial link keys were always correlated with RI 30-sec schedules with the side keys illuminated yellow. The COR 2 remained in effect under all conditions. The terminal

Figure 10. Concurrent chains Schedule 2. A diagram of the concurrent chains procedure used in Experiment 2. Complete cycles are shown from one choice period to the next for baseline (inner loop) and experimental (outer loop) conditions.

Figure 10

link components were correlated with RI 15, RI 30 or RI 60-sec schedules of food reinforcement. The duration of either terminal link varied since it depended upon the programming of reinforcements in the terminal links.

TO Conditions. The outer loop of Figure 10 represents the conditions during the experimental phases of the study. In all experimental conditions, the initial link schedules remained exactly the same as in baseline. Also, the reinforcement schedules in the terminal links were either RI 15, RI 30 or RI 60-sec. In the TO-terminal link, TOs were presented on a RI 15-sec schedule. The duration of TO was 1 min. Since the length of a given terminal link depended on the occurrence of reinforcement and TOs were scheduled independent of reinforcements, either zero, one or more than one TO could occur in the terminal link of a given cycle. During TO, all lights in the chamber were turned off along with the reinforcement programming timers. In the event that a reinforcement and TO were scheduled to occur simultaneously, reinforcement was given precedence over TO. However, the scheduled TO was held over for the first response in the succeeding terminal link.

In the extinction terminal link, conditions were exactly the same as in the TO-link, except that no blackout of the apparatus occurred. Instead, the reinforcement

schedule was simply suspended for the one minute period (see Figure 10). Thus, in this study as in the previous one, absolute reinforcement density was carefully controlled in the TO and EXT terminal links.

Experimental Design. Birds No. 5 to 8 were run under each experimental and baseline condition in a single subjects design. Table 4 presents the sequence of conditions for each bird. With the exception of No. 8 at RI 60-sec and No. 7 at RI 15-sec, a baseline determination was taken both prior to and following an experimental condition at RI 15, 30 and 60-sec terminal link reinforcement rates, respectively (see Table 4). This second determination of baseline was taken in order to facilitate the transition from one reinforcement density to the next. Thus, the shift from one reinforcement density to another occurred between two baselines rather than from one experimental condition to a new baseline. For No. 7 an additional baseline and experimental determination was taken at the RI 15-sec terminal-link reinforcement rate (see Table 4, Conditions 9 and 10).

In addition, birds No. 1 to 4 were run in this experiment at RI 30-sec terminal link reinforcement rates only (see Table 4 bottom). For these birds conditions were approximately the same as in Experiment 1 except that Schedule 2 was used to program the concurrent chains procedure.

That is, TOs and EXT-periods were presented on RI 2-min schedules thereby approximating the rate of TO and EXT used in Experiment 1. This replication was carried out to determine whether the parameters of Experiment 1 produced different effects with the new concurrent chains procedure.

During experimental sessions, TOs were scheduled to occur in one terminal link and equivalent periods of EXT were similarly scheduled to occur in the alternate terminal link. Again, the order of position of TOs in the terminal link was counterbalanced between birds over the three reinforcement rate conditions (see Table 4, Conditions 2, 5 and 8 for No. 5, No. 6 and No. 8; Conditions 2, 4 and 7 for No. 7).

Sessions were conducted six days a week and were terminated following either 60 reinforcements or 90 min, whichever came first. Each condition was terminated when the distribution of responding on the concurrent initial-link keys met the day-to-day stability criterion used in Experiment 1 (p. 69).

VI.2 Results and Discussion

All of the data presented are means of the last five sessions under each condition for each bird. For baselines, where more than one determination was taken, the average of the two is presented along with the range of the values.

Response and reinforcement rates in the initial and the terminal links were calculated as described in Experiment 1 (cf. Figure 3, p.70).

Initial Link Absolute Response Rates. Figure 11 presents the mean response rates during the initial links for birds No. 5, 6, 7 and 8 on the TO and EXT keys. The triangles represent response rates in the TO-initial link $\left(\frac{P_T}{T}\right)$ and the circles, response rates in the EXT-initial link $\left(\frac{P_E}{T}\right)$.

Response rates are presented over the three scheduled terminal link reinforcement densities (RI 60-sec or 60 reinforcements/hr, RI 30-sec or 120 reinforcements/hr and RI 15-sec or 240 reinforcements/hr). The lower panels display the baseline conditions; the upper panels, the experimental conditions.¹⁵ As was observed in Experiment 1, the initial link response rates during baseline were relatively unaffected by increasing reinforcement density. Also, for two of the four birds (No. 5 and No. 6) there was no apparent preference for either alternative under baseline conditions. The remaining two birds (No. 7 and No. 8) developed pronounced position preferences; No. 7 to the left key and No. 8 to the right key.

¹⁵ All of the means and their respective standard errors are presented in the left two columns of Table i in Appendix B.

Figure 11. Responses/min in the TO- (triangles) and EXT- (squares) initial links as a function of reinforcement density in the terminal links. Lower panels present baseline conditions, upper panels present experimental conditions. Vertical bars represent the range of values for the TO- (solid) and EXT- (dashed) initial links where two determinations were taken.

Figure 11

Turning to the upper panels of Figure 11 it can be seen that under the TO-EXT conditions, two of the four birds (No. 5 and No. 6) responded faster in the TO-initial link than in the EXT-initial link at all three reinforcement densities. Except for the response rates of No. 5 in the EXT-initial link, initial link rates do not appear to vary systematically with reinforcement density, as they did in Experiment 1. However, the magnitude of the differences between response rates in the TO and EXT-links is substantially greater in this experiment at all reinforcement densities (see birds No. 5 and No. 6 in Figure 10 vs birds No. 1, 2 and 4 in Figure 4, p.74). For both No. 5 and No. 6 the largest differences occur at 120 and 60 reinforcements/hr.

While No. 7 and No. 8 retained their position biases during the experimental conditions, the effects of TO are detectable if responses are compared to baseline. These comparisons are most easily made by reference to the lower panels of Figure 12 which present difference scores between initial-link response rates under experimental conditions and response rates under baseline conditions. Upward deflections from the zero axis represent an increase in response rate from baseline; downward deflections a decrease from baseline. With the exceptions of No. 5 at 120 reinforcements/hr, No. 6 at 60 reinforcements/hr and No. 7 at

Figure 12. Lower panels present difference scores in the TO-(triangles) and EXT-(squares) initial links as a function of reinforcement density. Upper panels present preference scores as a function of reinforcement density (see text for description of calculations). Vertical bars represent range of values when two determinations were taken.

SCHEDULED REINFORCEMENTS
(PER HOUR)

Figure 12

60 reinforcements/hr, response rates in the TO-initial link (triangles) increased over baseline. However, as with absolute response rate, there appears to be no consistent pattern in changes from baseline between birds, as a function of reinforcement density.

Conversely, except for the first determination of No. 7 at 120 reinforcements/hr, response rates in the EXT-initial link decreased from baseline. Again, no consistent pattern of change from baseline is apparent although, if the data of the birds not exhibiting position preferences are considered alone, it is clear that reductions in response rate in the EXT-component were a U-shaped function of reinforcement density. It should be noted that preferences for the TO-component observed in this experiment are consistently due to both an increase in response rate in the TO-initial link under experimental conditions and a decrease in response rate in the EXT-initial link. These preferences are displayed in the upper panels of Figure 12 which, as in Experiment 1, (see Figure 5, p. 77) present preference scores obtained by taking the difference of the scores plotted in the lower panels of Figure 12. The zero horizontal axis is the point of equivalence between the TO and EXT-difference scores. Deflections above the zero axis represent a difference favoring the TO component (i.e. the change from baseline in

the TO-initial link being greater than that in the EXT-initial link); deflections below the zero axis indicate a difference favoring the EXT-initial link.

With the exception of No. 6 at 60 reinforcements/hr, it is clear that the TO-terminal link was preferred at all reinforcement densities studied. However, preferences did not appear to vary consistently as a function of reinforcement density. For No. 5 and No. 8 U-shaped functions were obtained with the greatest preference for the TO-terminal link occurring at 240 reinforcements/hr. Conversely, for No. 6 and No. 7 inverted U-shaped functions were obtained with the greatest preference at 120 reinforcements/hr. It is interesting to note that although position biases were evident in the data of No. 7 and No. 8, clear-cut effects of TO and EXT can be observed when response rates under the experimental conditions are compared to baseline.

Terminal Link Absolute Response Rates. Figure 13 presents the mean response rates during the terminal links as a function of scheduled reinforcement density. Response rates were calculated exactly as they were for the terminal links

Figure 13. Responses/min in the TO-(triangles) and EXT-(squares) terminal links as a function of reinforcement density. Lower panels present baseline conditions, upper panels present experimental conditions. Vertical bars represent the range of values for the TO-(solid) and EXT-(dashed) terminal links where two determinations were taken.

Figure 13

in Experiment 1 (cf. Figure 3, p. 69).¹⁶

With the exception of bird No. 6 the baseline response rates in either terminal link increased with increasing overall reinforcement density (see Figure 12, lower panels). Also, response rates in either terminal link did not differ substantially. These results essentially replicate those of Experiment 1 (see Figure 5, lower panels, p. 77).

Turning to the upper panels of Figure 12, it can be seen that response rates in both terminal links increase with increasing reinforcement density, except for bird No. 5 in the TO-terminal link at 240 reinforcements/hr and bird No. 7 in the EXT-terminal link at 120 reinforcements/hr. However, the rate of change in the TO component as a function of reinforcement density was greater than in the EXT-component. These results are similar to those obtained in Experiment 1 except that the interaction between reinforcement density and

¹⁶All of the means and their respective standard errors are presented in the right two columns of Table i, Appendix B. As in Experiment 1 response rates in the EXT-terminal link were calculated both omitting extinction periods $\left(\frac{P_R}{T_R}\right)$ and including EXT-periods $\left(\frac{P_R + P_E}{T_E}\right)$.

These results are presented in Table 5. Comparison of response rates calculated both ways for all birds at each of the terminal link-reinforcement rates reveals that except at 240 reinforcements/hr they are very similar and do not constitute evidence that the EXT-periods were discriminated. However, at 240 reinforcements/hr there is some indication that response rates were lower during the EXT-periods.

Table 5

Mean response rate in the EXT-terminal link for all birds at 240, 120 and 60 reinforcements/hr. Response rates are calculated both omitting $\left(\frac{P_R}{T_R}\right)$ and including $\left(\frac{P_R + P_E}{T_E}\right)$ extinction periods.

T-Link Reinf./hr	Subject No.	Calculation 1	Calculation 2
		Omission of Extinction Periods $\left(\frac{P_R}{T_R}\right)$	Inclusion of Extinction Periods $\left(\frac{P_R + P_E}{T_E}\right)$
		Resp./min	Resp./min
240	5	110.4	85.0
240	6	64.9	56.9
240	7	67.6	43.6
240	8	58.1	42.8
120	5	73.4	64.9
120	6	55.3	54.2
120	7	36.0	34.3
120	8	43.5	40.3
60	5	60.7	55.4
60	6	49.2	49.4
60	7	55.2	49.0
60	8	41.2	40.6

the occurrence of TO vs EXT is more pronounced in this study. The larger interaction is due mostly to the greater difference in response rate between the TO and EXT-terminal links at 120 and 240 reinforcements/hr.

The effects of TO and EXT in the terminal links are presented in Figure 14 as a function of changes from baseline. At each level of reinforcement density terminal link-response rate in the baseline condition was subtracted from that in the experimental condition. Thus, deviations below the zero horizontal axis represent reductions in response rate relative to baseline and deviations above the same axis indicate increases in responding over the baseline rate. Considering the TO component it is clear that the effects of TO were, to some extent, dependent on the reinforcement density into which it was introduced. At 240 reinforcements/hr substantial increases in response rate $\left(\frac{P_T}{T_S}\right)$ occurred in all birds. However, such consistency between subjects was not observed at either 120 or 60 reinforcements/hr. At the former, responding either increased in the TO-terminal link (No. 7 and No. 8) or was virtually unaffected (No. 5 and No. 6). Likewise, response rate at 60 reinforcements/hr was unaffected in two birds (No. 5 and No. 8) but underwent substantial decreases in the remaining two (No. 6 and No. 7).

Figure 14. Difference scores in the TO-(triangles) and EXT-(squares) terminal links as a function of reinforcement density (see text for description of calculations). Vertical bars represent range of values where two determinations were taken.

TERMINAL LINK RESPONSES / MIN.
(DIFFERENCE SCORE E-B)

SCHEDULED REINFORCEMENTS
(PER HOUR)

Figure 14

In contrast, in the EXT-component response rate $\left(\frac{P_R}{T_R}\right)$ decreased in the majority of instances with the greatest effects occurring at 120 reinforcements/hr in three of the four birds (No. 5 No. 7 and No. 8). With the exception of No. 8 only slight changes from baseline were observed at either 60 or 240 reinforcements/hr.

Relative Response Rate in the TO-Initial Link. Figure 15 presents relative rate of responding in the TO-initial link $\left(\frac{P_T}{P_T + P_E}\right)$ as a function of (a) total-time relative reinforcement rate and (b) stimulus-time relative reinforcement rate. Open circles represent baseline determinations; filled circles represent experimental determinations.¹⁷ The solid 45-degree diagonal line in each panel traces the path of perfect matching between relative frequency of responding in the TO-initial link and relative frequency of primary reinforcement (by each of the two definitions of this concept) during the TO-terminal link. The dashed line is the calculated linear regression line through the data points. The linear equations are on each plot as well as the correlation coefficients and the standard errors of estimate.

¹⁷ The means for both relative reinforcement and relative response rates are presented in Table ii Appendix B.

Figure 15. Relative response rate in the TO-initial link as a function of total-time (left panels) and stimulus-time (right panels) relative rate of reinforcement in the terminal links. Open circles represent baseline determinations; filled circles are experimental determinations. Solid diagonal is the line of perfect matching; dashed diagonal is the calculated linear regression line through the data points.

Figure 15

Considering relative rate of responding as a function of relative rate of reinforcement calculated using the total-time base, (left panels Figure 15) it is evident that in three of the four birds the correlations between these variables are low and unreliable. For birds No. 7 ($p = \text{N.S.}$) and No. 8 ($p = \text{N.S.}$) this might well be expected, owing to both the response biases exhibited by these birds, and the alternation of the position of TO over scheduled reinforcement densities (see Table 4, p.105). But in the remaining two birds there is little consistency. In bird No. 5 a significant negative correlation was obtained ($p < .05$); in bird No. 6 a low positive correlation was obtained ($p = \text{N.S.}$).

In contrast, the relation between relative rate of responding in the initial links and relative rate of reinforcement calculated using the stimulus-time base (right panels of Figure 15) is substantially more orderly. For birds No. 5 and No. 6 the correlations are relatively high and statistically reliable ($p < .05$ and $p < .01$ respectively); the slopes of the regression lines are positive and the y-intercepts greater than zero. As was observed in Experiment 1 the regression coefficients are considerably less than one supporting the observation that perfect matching did not obtain. For birds No. 7 and No. 8 the change in the scatter

of points in the right panels largely reflects the change in the definition of relative reinforcement. However, for bird No. 8 the correlation is slightly positive, albeit not statistically reliable ($p = N.S.$), and the slope of the best fitting line is on the order of those observed for No. 5 and No. 6.

Relative Response Rate in TO-Terminal Link. Figure 16 presents relative rate of responding in the TO-terminal link

$\left(\frac{P_T/T_S}{P_T/T_S + P_R/T_R} \right)$ as a function of relative rate of reinforcement in the TO-terminal link using (a) the total-time base

and (b) the stimulus-time base. Open circles represent baseline determinations; filled circles, experimental determinations.¹⁸ The solid line in each panel is the matching line between responding and reinforcement. The dashed line is the least squares fit to the array of points in each of the panels. Also presented in each panel is the correlation coefficient, the regression equation and the standard error of estimate.

For three of the four birds (No. 5, No. 7 and No. 8) there is less scatter around the regression lines when the independent variable is relative rate of reinforcement

¹⁸The means for relative response and reinforcement rates are presented in Table ii Appendix B.

Figure 16. Relative response rate in the TO-terminal link as a function of total-time (left panels) and stimulus-time (right panels) relative rate of reinforcement in the terminal links. Open circles represent baseline determinations; filled circles are experimental determinations. Solid diagonal is the line of perfect matching; dashed diagonal is the calculated linear regression line through the data points.

Figure 16

calculated using the stimulus-time base. Examination of the left column of panels in Figure 16 reveals that, with the exception of bird No. 6, the correlation between relative responding and total-time relative reinforcement rate is minimal and inconsistent between birds ($p = \text{N.S.}$ for all three coefficients). For bird No. 6, the correlation between these variables is significantly different from zero ($p < .05$). Three of the slopes of the best fitting lines are positive and one is negative. Of the three that are positive, one coefficient is > 1.0 (No. 6) and two are < 1.0 (No. 7 and No. 8).

In rather sharp contrast, the relationship between relative rate of responding in the TO-terminal link and relative rate of reinforcement, calculated using the stimulus-time base, is clearly more consistent in three of the four birds. The correlations between these variables for birds No. 5, 7 and 8 are statistically reliable ($p < .05$ for No. 5 and No. 7 and $p < .01$ for No. 8) and the respective regression coefficients are quite similar. Again, as was observed in Experiment 1, the slopes of the regression lines are considerably less than one and the intercepts greater than zero, further suggesting an undermatching relation between terminal link responding and reinforcement. For bird No. 6, the regression line is virtually flat indicating little or no

relationship between the variables. This result is, in part, due to the occurrence of a pronounced reduction in terminal-link response rate occasioned by TO-presentations at RI 60-sec (see Figure 14, p.117). In contrast, at both 120 and 240 reinforcements/hr response rate increased in the TO-terminal link.

Replication of Experiment 1 Parameters. Table 6 presents the initial-link and terminal-link response rates for birds No. 1 to No. 4 for the baseline and experimental replications under concurrent chains Schedule 2. Birds No. 1 and No. 2 were run at RI 30-sec terminal-link schedules while birds No. 3 and No. 4 were run at RI 60-sec terminal-link schedules.

Considering, first, the initial-link response rates, it can be seen that during baseline, except for No. 3, response rates were quite similar in the TO and EXT-initial links. No. 3 continued to emit the strong right key bias present throughout Experiment 1. For all four birds the baseline values obtained using Schedule 2 were quite comparable to the respective values obtained with Schedule 1 (see Figure 4, (p. 74) lower panels).

In the experimental conditions the effect of TO and EXT was to produce a higher response rate in the TO-initial link, than in the EXT-initial link, for three of the four birds. This shift in preference is reflected in the increase

Table 6

Initial link absolute and relative response rates and terminal link response rates for birds No. 1, 2, 3 and 4 for baseline and experimental determinations under Schedule 2. Columns include: subject number, terminal link reinforcements/hr, terminal link conditions, responses/min in the TO-initial link, responses/min in the EXT-initial link, relative response rate in the TO-initial link, responses/min in the TO-terminal link and responses/min in the EXT-terminal link.

Bird No.	T-Link Reinf./hr	T-Link Condition	$\frac{P_T}{t}$	$\frac{P_E}{t}$	$\frac{P_T}{P_T + P_E}$	$\frac{P_T}{T_S}$	$\frac{P_R}{T_R}$
1	120	Baseline	47.8	46.9	.50	156.3	173.8
	120	TO-EXT	39.1	26.1	.60	171.8	150.5
2	120	Baseline	31.1	38.9	.44	63.2	70.1
	120	TO-EXT	48.3	36.3	.57	75.7	57.2
3	60	Baseline	12.4	21.6	.36	58.3	64.2
	60	TO-EXT	11.6	28.1	.29	55.9	67.0
4	60	Baseline	32.2	27.4	.54	48.6	46.7
	60	TO-EXT	35.7	22.2	.61	53.0	44.8

in relative rate of responding $\left(\frac{P_T}{P_T+P_E}\right)$ in the TO-initial link

(see Table 6). Bird No. 3's initial-link response rates remained virtually unchanged with respect to baseline, as again, the response bias proved to be insensitive to the effects of the independent variable. Overall, the results from these TO-EXT determinations compare favorably to those obtained with Schedule 1 (see Figure 4 upper panels, p. 74).

Likewise, the results obtained under baseline conditions in the terminal links, replicated those of Experiment 1. Except for bird No. 1, who inexplicably underwent a substantial increase in terminal-link response rates during baseline, the absolute response rates in the TO-terminal link and EXT-terminal link were both similar to each other and similar to the respective rates obtained in Experiment 1 (see Table 6 vs Figure 5, p. 77).

Under experimental conditions, higher response rates were observed in the TO-terminal link than in the EXT-terminal link. This result directly replicates the previous study. In three of the four birds (No. 1, 2 and 4) response rate in the TO-terminal link increased over baseline. This was also observed at 120 reinforcements/hr in Experiment 1 (see Figure 5, p. 77). In contrast, the response rates for the same three birds in the EXT-terminal link were lower than in base-line. The response rate of Bird No. 3, in

either terminal link, changed slightly with respect to baseline with a mild decrease in the TO-terminal link and a comparable increase in the EXT-terminal link. These results contrast with those obtained in Experiment 1 where a decrease was observed in the EXT-terminal link and no change in the TO-terminal link.

Summary and Conclusions: Experiment 2 examined the effects of a relatively high density schedule of TOs on choice and rate of responding over a range of reinforcement densities in a concurrent chains schedule. The major finding was that relative to baseline, the schedule containing TOs was clearly preferred to an alternate schedule adjusted for reinforcement density by the addition of an equivalent number of EXT-periods. Preferences were quite substantial in some instances but were not systematically related to terminal-link absolute reinforcement density. In particular, in three of the four birds the greatest preferences were not observed at the highest reinforcement density (240 reinforcements/hr - see Figure 12, p.110). This result is in contrast with Experiment 1 in which the largest preferences were observed at the highest reinforcement density. A possible explanation stems from the fact that at 240 reinforcements/hr the EXT-component appeared to be discriminated to some extent (see Table 5, p.115). That is, response rate in the

EXT-terminal link including periods of extinction $\left(\frac{P_R + P_E}{T_E}\right)$

was lower than when responding during EXT was omitted from the calculation. The discriminability of EXT at 240 reinforcements/hr allows for the possibility that EXT had some of the functional properties of TO. This effect may have modulated preference for the TO component at 240 reinforcements/hr.

Although preferences did not vary systematically with respect to absolute reinforcement density, they were orderly with respect to relative reinforcement density in the terminal links if the latter was calculated excluding the duration of the TOs. That is, relative rate of responding in the initial links was proportional to stimulus-time relative rate of reinforcement. Although proportionality was observed between relative responding and reinforcement, the slopes of the linear functions describing this relation were substantially less than one. If relative density of reinforcement were the only controlling variable exerting any influence, perfect matching functions may have been expected (Autor 1969; Herrnstein 1961; 1964). The present data suggest, therefore, that the occurrence of TOs reduced the magnitude of preference shift expected from the matching law. Clearly, in evaluating the properties of TO, consideration also must be given to its effects over and above the

context in which it is presented. That is, the effects of TO extend beyond the changes in reinforcement density which it produces. The implications of this assertion will be considered in the general discussion of the dissertation.

A secondary finding in this study was that relative rate of responding in the TO-terminal link was also proportional to the relative rate of reinforcement, calculated using the stimulus-time base. Again, the functions describing the relation between these variables indicated pronounced undermatching. Thus, it seems that the effects of TO on absolute response rates in the terminal links are to some extent, dependent on the context of relative reinforcement in which TO is presented. However, the proportionality between reinforcement and responding in the terminal links apparently begins to break down at the lower absolute reinforcement densities because, while relative reinforcement density $\left(\frac{R_T/T_S}{R_T/T_S + R_E/T_E} \right)$ in the TO-terminal link remained high at 60 reinforcements/hr, response rates tended to be lower than both the baseline levels of responding and responding during the EXT-component. Thus, the effects of TO on responding in the terminal-link schedules must be considered as a function of the absolute reinforcement density in the schedule, as well as the relative reinforcement density.

The problem of response bias that occurred in Experiment 1 reappeared despite the methodological changes introduced in Experiment 2. Briefly, these changes were: 1) shortening the initial links to RI 30-sec, 2) programming reinforcements such that control returned to the initial links after each occurred and 3) extinguishing responding in either initial link to zero prior to any extended training on the various concurrent chains schedules. Response biases in concurrent schedules are most likely due to a lack of independence between the response alternatives. Although the concurrent operants are topographically incompatible, it is still possible for changeover dependencies to develop between the two responses. These dependencies are commonly referred to as concurrent superstitions (Catania, 1966). The importance of maintaining independence between concurrent operants in simple concurrent schedules has been recognized for some time (Herrnstein, 1961). The changeover delay (COD) is perhaps the most widely accepted technique for achieving this end (Catania, 1966). However, in concurrent chains procedures, maintaining independence of the concurrent initial link responses has often not been assumed to be as critical as in the case of simple concurrent schedules. Perhaps the assumption is that responding is maintained by conditioned reinforcers (the terminal-link stimuli) which are weaker than the primary reinforcers and

therefore not as likely to maintain stereotyped response sequences on the two keys.

The present data, from both experiments, suggest that this assumption is in need of serious evaluation. In three of the eight birds examined, strong position biases developed despite such protective measures as a changeover ratio (COR2) and separate extinction of both initial link responses. Fortunately, in the second study at least, the initial-link performance of the biased birds still remained sensitive to the independent variables under study. Response biases such as these have also been reported in other studies employing the concurrent chains procedure, but they have either been ignored (Fantino, 1969) or controlled statistically (Davison and Temple, 1973).

The susceptibility of the concurrent chains procedure to the development of concurrent superstitions implies a need for some careful parametric research with variables affecting changeover responses. An obvious starting point would be to manipulate the duration of the changeover delay in the initial links and determine its effects on the concurrent performances (cf. Shull and Pliskoff, 1967). Such parametric data would be particularly valuable in studies which employ the concurrent chains procedure as a baseline to explore the effects of other variables. In such cases the occurrence of concurrent super-

stitutions, at best, prevent precise specification of the functional relations between concurrent responding and its controlling variables and, at worst, totally mask the expression of these relationships.

VII GENERAL DISCUSSION

The purpose of the two experiments presented in this dissertation was to determine whether the effects of TO from positive reinforcement were either context or paradigm dependent under conditions in which increases in rate of positive reinforcement resulting from avoidance of TO were controlled. Earlier studies of the effects of TO have been criticized for allowing absolute density of reinforcement to increase as a function of response produced reductions in the rate of TO (Leitenberg, 1965). In the present research a concurrent chains procedure allowed for an unconfounded determination of the effects of TO over a limited range of reinforcement densities. Control for increases in positive reinforcement was achieved by presenting TO in one terminal link of the concurrent chains schedule, while equivalent durations of extinction were employed in the other and comparisons of performance under these conditions were made relative to baselines in which neither event occurred. The reinforcement context was manipulated in both studies by varying the rate of reinforcement in the terminal link schedules. The paradigm scheduling TOs was manipulated such that in the first experiment the rate of TO presentations was low; in the second it was much higher.

The results indicated that in both studies, the TO-terminal link was preferred. In Experiment 1 the magnitude of this preference appeared to depend on the rate of reinforcement in the terminal links, with most of the effects occurring at the highest reinforcement density. In Experiment 2 the nature of the relationship was not as consistent. Also, in both experiments the percentage of responses emitted in the TO-initial link was directly proportional to the relative rate of reinforcement in the TO-terminal link if this were calculated omitting the duration of the TO periods. That is, stimulus-time relative rate of reinforcement, as an independent variable, accounted for more of the variance in relative response rates than did relative rate of reinforcement calculated using a total-time base. Similar orderly relations between relative rate of responding and relative rate of reinforcement were observed in the terminal links.

The results of both experiments when compared, suggest that Experiment 2 was a successful systematic replication (Sidman, 1960) of Experiment 1. The similarity between the two sets of data was particularly impressive in view of the methodological differences between the studies. In Experiment 2 the apparatus programming the concurrent chains schedule was changed so that it had

shorter initial links and each reinforcement terminated a cycle and reinstated the initial links of the next cycle. In Experiment 1 a cycle ended after 3 min in the terminal links. Also, TOs and EXTs were presented at a rate of four per min as compared to .5 per min in Experiment 1. Despite these methodological changes, similar effects in the two studies were observed in both the initial and terminal links.

While the similarities in the results of the two studies were substantial, some differences were observed. In Experiment 2 the shifts in preference for the TO component were greater in magnitude. Also, at the lower terminal link reinforcement density (e.g. RI 60-sec) the effects of TO were to reduce response rates in that terminal link, whereas in Experiment 1 TO either increased or did not affect terminal link responding at RI 60-sec. The possibility exists that these differences may be attributable, in part, to methodological differences in concurrent programming between the two studies. However, it is more likely that the differences observed were due to the changes made in the independent variable, namely the higher rate of TO and EXT in Experiment 2. Support for this contention may be drawn from the finding that the use of Experiment 1 parameters with the method of programming concurrent chains in

Experiment 2 did not produce results that were discrepant from those originally obtained in Experiment 1. Thus, differences in the effects of the independent variables in the two studies did not appear to be related to the differences in which the concurrent chains procedure was programmed.

VII.1 Alternative Hypotheses to Account for the Effects of TO.

In the introduction to Experiment 1 several alternative hypotheses were presented whose predictions did not include the possibility that relative response rate in the initial links would be proportional to stimulus-time relative rate of reinforcement. However, the finding that choice was proportional to relative reinforcement is not sufficient to preclude these hypotheses unequivocally. Accordingly, each hypothesis will be discussed separately in light of changes in absolute response rates as well as relative response rates in the two experiments.

1. TO Neutral With Respect to EXT in the Terminal Links.

This hypothesis stated that the TO and EXT were equivalent with regard to their effects on responding. Since the two events occurred with equal frequency and duration in opposite terminal links there should have been no clear cut preference for either schedule. This account is undoubtedly inadequate because clear cut preferences, varying as a function of reinforcement density, were observed

for the TO-terminal link.

2. TO Aversive Relative to EXT. This hypothesis predicted that TO would function as an effective punishing stimulus and thus the terminal link containing TOs would be aversive relative to the EXT-terminal link. If this were the case, then the EXT-terminal link should have been preferred over the TO-component in all experimental conditions. Also, response rates in the TO-terminal link should have been lower than in either baseline or the EXT-component.

This hypothesis is clearly inadequate. The EXT-component was never preferred over the TO-component and only in Experiment 2 at RI 60-sec was there a reduction in response rate observed in the TO-terminal link as compared to either baseline or the EXT-terminal link. It may be that the effects of TO as a punisher are only detectable in schedules of reinforcement that exert weak control over responding. However, in the present study, there was no direct evidence of an aversive function of TO in the highly sensitive choice phase of the concurrent chains schedule.

The present results appear on the surface to contradict those of a study by Carlson (1972). Carlson presented TO in one terminal link of a concurrent chains schedule and simultaneously adjusted the rate of reinforcement in the non-TO-terminal link so that it equalled the rate in the TO-

terminal link. Preferences were observed to favour the non-TO-component. In accordance with the present hypothesis choice for the non-TO component could be construed as being due to the aversive function of TO.

Although Carlson's (1972) findings and the present findings are not in agreement, a number of differences between the two studies should be pointed out. Carlson (1972) used monkeys in a lever pressing task in which TO consisted of a 15-sec period of lever retraction in that terminal link. Also Carlson adjusted the rate of reinforcement in the non-TO-terminal link by lowering the mean inter-reinforcement interval of the VI-schedule in that terminal link. The present study used pigeons in a key pecking situation in which TO consisted of a 1-min blackout of the apparatus. Additionally, reinforcement density in the non-TO-component was controlled by scheduling 1-min periods of EXT at the same rate as TO. Thus, in the present work the rate and distribution of reinforcements in real time was carefully controlled in both terminal links.

While the above differences in subjects and procedure may have been partially responsible for the discrepant findings, one other difference is considered more important. In Carlson's (1972) first experiment, TO was scheduled to occur simultaneously with entry into that terminal link.

This allows for the possibility that preferences for the non-TO-component were controlled by the delay of conditioned reinforcement (i.e. the onset of the TO-terminal link stimulus) occasioned by TO rather than the aversive function of TO.¹⁹

This hypothesis received some support from the results of Carlson's (1972) second experiment. When the onset of TO was delayed such that the conditioned reinforcing function of the TO-terminal link was unimpeded, preferences for the non-TO component declined and in some instances were actually in favour of the TO-terminal link. Thus, under conditions similar to the present experiments in which TO-onset was delayed, Carlson's results concerning the aversive function of TO are at best equivocal. Complete resolution of the differences between the two sets of data will have to await further research that controls for a number of factors which have varied between Carlson's (1972) study and the present work.

It is presently contended that if shifts in prefer-

¹⁹Relative delay of reinforcement has been shown in other studies to control preferences such that shorter delays are preferred (Chung and Herrnstein, 1967; Hursh and Fantino, 1973). In the present experiments TO either never occurred (Experiment 1) or only occasionally occurred (Experiment 2) simultaneously with entry into that terminal link so that delay of conditioned reinforcement could not have been an important factor.

ence from baseline are used as the evaluative criterion, the effects of TO were not aversive. However, this does not rule out the possibility that TO served as an aversive function in some other evaluative context. We shall return to this point later.

3. TO Aversive and Appetitive. A fourth possibility builds upon the findings of Herrnstein (1955), Dardano (1974) and others, that the effects of TO were inversely related to the density of reinforcement in the schedule in which it occurred. Dardano (1974) found that in a progressive ratio schedule TO functioned as either a punishing or a reinforcing event. The different TO-functions were related to the rate of food reinforcement. Under the conditions of the present experiment this hypothesis predicted that when terminal link reinforcement densities were high, TO should have been aversive and the EXT-component preferred. As the terminal link reinforcement rates became lower TO should have transformed from an aversive to a reinforcing stimulus so that a shift in preference from the EXT-component to the TO-component might have been expected.

If shifts from the baseline relative response rates are taken as an index of the effects of TO, the results obtained in both experiments are obviously incompatible with this hypothesis. Even with extremely high rates of TO-

presentation (Experiment 2) the TO-component rather than EXT was preferred under the higher reinforcement densities. However, in fairness to this hypothesis it could be argued that the effects of TO should be assessed using the matching law (Herrnstein, 1970) as the theoretical standard. If this were the case, the argument could be made that TO was aversive at the higher reinforcement densities since preferences were not as extreme as expected from matching. Nevertheless, even with the matching law as the evaluative standard, the variation in preference over the terminal link reinforcement densities was not consistent with that predicted from this hypothesis. In Experiment 2, preference for the TO-component was at least as extreme, if not more extreme, at 240 reinforcements/hr than it was at 60 reinforcements/hr.

A further defence of this position might be that the range of reinforcement densities was too limited to detect the reinforcing effects of TO. The possibility would remain, then, that at densities of reinforcement lower than those employed in these experiments, preference for the TO-component may have been more extreme than expected from the matching law. Certainly such bias has been observed in other contexts (Baum, 1974a). Perhaps further research with a number of determinations using a wider range

of reinforcement densities will provide evidence bearing on this issue.

4. TO as an Informative Event. Preference for the TO-component could have occurred because of the failure of EXT to provide information about the unavailability of reinforcement. This hypothesis is based on the notion that TO has the functional properties of a discriminative stimulus. It has been shown in a number of experimental contexts that organisms prefer situations whose onset reduces uncertainty about consequent reinforcement conditions, to situations in which uncertainty remains high, even though both situations ultimately lead to the same reinforcement conditions (Bower, McLean and Meacham, 1966; McMillan, 1974; Catania, 1975; Green and Rachlin, 1977).

The average uncertainty as to which of two mutually exclusive events (e.g. reinforcement and TO) will occur on a given trial can be specified (Green and Rachlin 1977) according to the equation:

$$H = p \log_2 \frac{1}{p} + (1-p) \log_2 \frac{1}{(1-p)} \quad (1)$$

where H refers to the amount of uncertainty expressed in bits and p and (1-p) are the probabilities of occurrence of the two events. When the two events are equally probable, then the uncertainty as to which event will occur is maximal and therefore the information provided by the occurrence

of that event is maximal at 1.0 bits. To the degree that the two events are not equiprobable, uncertainty necessarily decreases (along with H). Green and Rachlin (1977) using concurrent chains schedules varied the probability of reinforcement (p) in the terminal links. In one terminal link, discriminative stimuli signalled the outcomes (reinforcement or blackout) and in the other those events were uncorrelated with the same outcomes. Preferences were observed for the informative terminal link and were an inverted U function of the probability of reinforcement in the terminal links. The obtained preference functions were asymmetrical with regard to reinforcement probability but, consistent with Equation 1, peaked at values near .50 ($H = 1.0$). Also, preferences increased as a linear function of H .

The information hypothesis has important implications for the present work. In Experiments 1 and 2 conditions in the TO-terminal link could be construed as informative and in the EXT-terminal link as uninformative. Due to the stimulus properties of TO and its correlation with nonreinforcement, the occurrence of TO should have provided information to the subjects concerning the unavailability of reinforcement. Such information would not be provided in the EXT-terminal link because the periods of extinction

were unsignalled. Thus, preferences for the TO-component could have been a function of the information provided by the occurrence of TO rather than its effects on reinforcement rate.

Unlike in studies primarily concerned with the reinforcing function of information (i.e. which examine changes in responding as a function of changes in probability of reinforcement or H) the probability of TO in either of the present experiments remained constant in all conditions. This is because in both studies the rate of TO was controlled such that the proportion of total-terminal link time spent in TO was constant over reinforcement densities. In Experiment 1 the probability of TO was constant at .33; in Experiment 2 it ranged from .73 to .80. Thus, in neither experiment did uncertainty reach appreciably high levels, so at best, small but consistent preferences for the TO-terminal link would have been expected. Also, these preferences would not have been expected to vary with changes in reinforcement density.

Consideration of the preference functions displayed in Figures 5 (p. 77) and 12 (p.110) suggest that if information in the TO-terminal link was exerting any influence, it certainly was not the sole determinant of choice. In neither experiment were preferences invariant with respect to reinforcement

density. Despite minimal fluctuation in the probability of TO, preferences were consistently higher at 120 reinforcements/hr in Experiment 1 (see Figure 5, p. 77) and were either a U-shaped function or an inverted U-shaped function of reinforcement density in Experiment 2 (see Figure 12, p. 110). Also, in some instances preferences were of substantial magnitude in Experiment 2.

Thus, contrary to expectations from the information hypothesis, preferences for the TO-terminal link were not constant as a function of reinforcement density suggesting that complete explanation of the variability in preferences lies elsewhere. This is not to say that uncertainty reduction did not exert any influence on choices in the present experiments. Rather, it should be clear that other factors must be taken into account.

5. Frustration in the EXT-Component. An alternative possibility is that the TO-component was preferred not because it was more informative, but because the EXT-component became aversive. Earlier, a theoretical position was discussed which proposed that non-reinforced responding in the presence of a stimulus is sufficient for the development of frustration. To the extent that frustration is aversive (Amsel, 1962) that stimulus could be endowed with aversive properties (Terrace, 1971). If this hypothesis were applied to the present

experiments, we might have expected the EXT-component to have become aversive because of the increase in non-reinforced responding (and hence frustration) in that terminal link. Thus, preferences would be expected to shift from baseline in favour of the TO-terminal link.²⁰

Furthermore, the frustration hypothesis would predict that preferences for the TO-component should increase monotonically with increasing reinforcement density. The reasoning is as follows: during baseline, under conditions of high reinforcement density, the distribution of inter-reinforcement intervals is such that there would be a high preponderance of short intervals. The transition to experimental conditions, in which periods of EXT are presented in that terminal link, would constitute optimal conditions for the development of frustration since a relatively high percentage of longer inter-reinforcement intervals would now occur. That is, in comparison to baseline, a large amount of non-reinforced responding would result. This would produce frustration and hence shifts in the initial links in favour of the TO-component would be expected.

²⁰ Preferences for the TO-component could, in addition, be construed as being controlled by the same variables that produce escape responding in other reinforcement schedules (e.g. Brown and Flory, 1972; Dardano, 1973; 1974) where subjects seem to respond to produce periods of TO.

By contrast, as reinforcement density decreases during baseline, longer intervals between reinforcements would be expected to occur and Ss would, in effect, already be responding in the face of frustration. Consequently, when EXT is introduced (at the same rate and duration as at higher reinforcement densities) less frustration would be expected to develop because the subject has already experienced longer periods of non-reinforced responding.

To some extent the data of this dissertation are compatible with this hypothesis. Preferences were observed for the TO-component in both studies and in Experiment 1 these preferences were greatest at the highest reinforcement density - 120 reinforcements/hr (see Figure 5 upper panels, p. 77). However, the prediction of a monotonic relation between preference and reinforcement density was clearly not supported in either Experiment 1 or Experiment 2 (see Figures 5, p.77 and 12, p.110). This is particularly true in the preference data of Experiment 2 where substantial departures from monotonicity were observed.

The reader should be reminded that in Experiment 2 at 240 reinforcements/hr there was some evidence to indicate that the EXT-periods were discriminated in the experimental condition (see Table 5, p.115). However, the possibility that EXT may have been discriminated in that terminal link

probably does not have important implications for the frustration hypothesis. According to Amsel, (1962) and others, frustration builds up as a result of an increase in non-reinforced responding. Clearly, in the present work this condition has been met regardless of whether the EXT-periods were discriminable or not. Differential response rates during EXT and RI 15-sec in Experiment 2 in all likelihood were due to the greater contrast, at this reinforcement density, between the relatively long inter-reinforcement intervals that would accompany the introduction of EXT and the high preponderance of short intervals during baseline. Thus, conditions which have been suggested as producing frustration (EXT) may also result in discrimination. Whether the latter occurs appears to depend on the density of reinforcement in the baseline schedule.

Thus, the hypothesis which seeks to explain preference for the TO-component in terms of frustration developing in the EXT-component has been found lacking. The failure to find a monotonic relation between preference and terminal link reinforcement density is considered sufficient to cast doubt upon this hypothesis.

To summarize, in this section several alternative hypotheses have been considered in light of changes in preferences from baselines. The finding that relative

response rate in the initial links was proportional to relative rate of reinforcement in the terminal links is in itself, troublesome for all of these hypotheses. However, each was found lacking on other grounds. If changes in choice from indifference $\left(\frac{P_T}{P_T+P_E}\right) = .50$ during baseline are

taken as indicating the effects of TO, then the results directly contradict hypotheses which predict either a neutral or aversive function of TO at any of the conditions examined. However, two hypotheses predicted preference for TO which on the surface was consistent with the present findings. One of these hypotheses endowed the TO-terminal link with reinforcing properties due to the information it provided concerning the unavailability of reinforcement. The other proposed a reinforcing function of TO engendered by the development of frustration in the EXT-component. The former was found to be inadequate largely because preferences were not invariant with respect to reinforcement density, whereas the probability of TO, and hence the uncertainty reduction produced by its occurrence, was constant as a function of reinforcement density. The latter was found to be inadequate because preferences did not increase monotonically with increasing reinforcement density as predicted.

The remainder of the discussion will be focused on

the finding that choices were controlled to a significant extent by the stimulus-time relative rate of reinforcement.

VII.2 Preference and the Matching Law.

The final hypothesis presented in the introduction to Experiment 1 stated that the TO-terminal link would be preferred because of a higher relative density of reinforcement occurring in that terminal link. Thus, an observation of proportionality between relative response rates and relative rates of reinforcement would be in support of this hypothesis. Furthermore, in other studies using concurrent chains schedules, where relative density of reinforcement has varied, proportionality on the order of matching has been observed (Autor 1969; Herrnstein 1964). The relation specified by the matching law was summarized earlier by the equation $\frac{P_a}{P_a + P_b} = \frac{r_a}{r_a + r_b}$ in which P_a and P_b represent the number of responses in the initial links on keys a and b respectively and r_a and r_b the rates of reinforcement in the terminal links for keys a and b. Thus, if relative reinforcement density were the controlling variable of preferences, a matching relation would have been expected in the present studies.

Inasmuch as proportionality was observed between

relative response rates in the initial links and stimulus-time relative reinforcement rate, the slopes of the obtained least squares functions were consistently less than one. That is, preferences for the TO-initial link did not reach levels required by the matching law (Herrnstein, 1970). An obvious interpretation of the present data is that the failure to obtain matching in either experiment was due to the effects of TO. In particular, if TO had not occasionally interrupted reinforcement in one of the terminal links, relative response rates in the initial links would have been consistent with matching. However, deviations from matching have occurred in other situations. (Baum, 1974a; Fantino, 1969; Squires and Fantino, 1971) and should be considered in relation to the present results before serious consideration is given to the hypothesis that TO was responsible for the failure to obtain matching in the present work.

VII.3 Deviations From the Matching Law

Baum (1974a) defined two types of deviation from the matching law, bias and undermatching. Only the latter will be dealt with here because of its relevance to the present data. The term "undermatching" refers to any preference less extreme than the matching relation would predict (Fantino, Squires, Delbrück and Peterson, 1972). Quantitatively, undermatching occurs when the slope of the line

fitting relative response and reinforcement rates is less than one.

Baum (1974a) suggested that undermatching is related to the effects of contingencies controlling changeover responses. In regular concurrent schedules with no changeover delay (COD) or too short a COD, preferences tend to fall short of matching by remaining too near indifference (Herrnstein, 1961; Shull and Pliskoff, 1967). As the COD increases, differentiation increases and preference soon matches relative reinforcement (Fantino et al, 1972; Shull and Pliskoff, 1967).

As was discussed earlier, little is known about the effects of changeover contingencies in concurrent chains schedules because they are rarely used. In spite of this, some studies (e.g. Autor, 1969; Herrnstein, 1964) have reported confirmation of the matching relation in concurrent chains schedules in that relative responses in the initial links matched relative reinforcements in the terminal links. This is not to say that concurrent superstitions do not develop in concurrent chains procedures, thereby obviating the need for parametric studies of the effects of CODs. On the contrary, the present data, in which three of eight birds developed strong response biases to either of the two initial link stimuli, suggests that such a parametric

investigation is indeed warranted. However, the fact that matching has been reported in studies not employing CODs and did not occur in the present experiments in which changeover ratios were used, suggests that the undermatching obtained here was not due to inadequate use of changeover contingencies.

Another suggestion by Baum (1974a) was that the propensity to undermatch may be affected by deprivation. Baum himself (1972) found that in situations where deprivation is low because S is allowed to satiate, performance on concurrent schedules conforms to the matching relation with no COD or a shorter COD than usual. In terms of the present data, this account also falls short because the deprivation level used in the present study (80% of free feeding weight) was similar to that employed in studies where matching was obtained. In particular, Autor (1969) also used 80% of the bird's free feeding weight for his definition of deprivation and Herrnstein (1964) used 85% of the bird's free feeding weight.

In short, conditions which are known to produce undermatching in concurrent schedules do not seem readily applicable in interpreting the present data.

VII.4 Alternatives to the Matching Law in Concurrent Chains Schedules.

The foregoing discussion has been predicated on the assumption that the matching law is the appropriate theoretical standard against which the effects of TO are to be assessed. The recent development of alternative models to account for choice in concurrent chains schedules (e.g. Fantino, 1969; Squires and Fantino, 1971) leave open the possibility that it is not. For instance, Fantino (1969) argued that the ability of the matching law to account for most of the data in concurrent chains schedules may have been in part due to the widespread use of VI 1-min schedules in the initial links. Alternatively, he proposed that a major controlling variable of choice proportions in concurrent chains schedules was the length of the initial links or the expected time to reach the terminal links. Accordingly, Fantino (1969) presented a model which stipulated that the critical variable determining choice is the amount of reduction in expected time to primary reinforcement signified by entry into one terminal link, relative to the reduction in expected time signified by entry into the other terminal link. Quantitatively Fantino's formulation stated:

$$\begin{aligned}
 &= \frac{T-t_L}{(T-t_L)+(T-t_R)} \quad \text{when } t_L < T \text{ and } t_R < T \\
 \frac{R_L}{R_L+R_R} &= 1 \quad \text{when } t_L < T \text{ and } t_R > T \\
 &= 0 \quad \text{when } t_L > T \text{ and } t_R < T
 \end{aligned}$$

where T = average expected time to reinforcement from the onset of the initial links and t_L and t_R are the expected times to reinforcement for the left and right terminal links respectively. In subsequent experiments Fantino (1969) found that his model better accounted for choice data in concurrent chains procedures than the matching law over a range of equal and unequal initial link lengths. In all schedules the terminal links were unequal in order that in some conditions overall rate of reinforcement could be controlled.

In another study Squires and Fantino (1971) found that with equal terminal link schedules, variations in the length of either initial link produced orderly effects on choice. This necessitated an alteration of the original model such that a variable was added which accounted for the overall rate of primary reinforcement in each chain separately.²¹ This new model adequately described variations in choice proportions as a function of unequal initial link

²¹It should be noted that with equivalent terminal link schedules both the matching law (Herrnstein, 1974) and Fantino's (1969) model predict indifference with regard to choice.

lengths where terminal link schedules were identical.

The finding that initial link length affects choice in concurrent chains schedules is particularly germane to the present dissertation because a reduction in initial link length was one of the changes in methodology made prior to Experiment 2. The above models (Fantino, 1969; Squires and Fantino, 1971) predict that choice proportions should be more extreme at shorter initial link lengths than would be expected from the matching formulation. Thus, the more extreme preferences obtained in Experiment 2, as compared to Experiment 1, could have been due to the shorter initial links (RI 30-sec) used in Experiment 2 as well as the higher rate of TO. However, this possibility in relation to the findings of Experiment 2 does little to the description of the present data in terms of undermatching. If Fantino's model or Squires and Fantino's (1971) model had been used as the theoretical standard against which the effects of TO were to be evaluated, the conclusions would remain unaffected in the sense that undermatching or underprediction would still have been the important finding. Perhaps a greater degree of underprediction would be expected from the use of such models but it is not clear as to how such an outcome would affect interpretations given to these results. Also, it should be pointed out that although the matching law may

have certain shortcomings at shorter initial link lengths, in the present experiments proportionality was still observed between relative response and reinforcement rates under these very conditions.

VII.5 Conclusions.

The main conclusion to be advanced in this final section is that preferences in the present experiments were a joint function of both indirect and direct effects of TO. The indirect effect of TO is related to the context in which it is presented. In the present studies, where avoidance of the TO component was not followed by an increase in overall reinforcement density, the indirect effect of TO was to increase the relative rate of reinforcement in that terminal-link stimulus. That stimulus-time relative rate of reinforcement controlled preference to some degree is inferred from the finding that a significant percentage of the variance in the choice data was accounted for by this independent variable.

The direct effect of TO is in part related to the paradigm that arranges the correlation between TO and responding. In the present work TO was response contingent and of constant duration but varied in frequency between studies. The direct effect of TO in the two experiments was to prevent preferences from reaching the magnitude

expected from the matching relation (Herrnstein, 1970). This inference arises from the results of the least squared analyses of relative response and reinforcement rates which reliably produced best fitting lines with slopes less than one. In other words it is presently contended that in spite of preference shifts in favour of the TO-component, TO functioned as a punishing stimulus since preferences were suppressed or did not reach the extremes expected from the matching law. Further evidence that TO functioned as a punisher can be gleaned from the finding that a greater magnitude of undermatching was observed in Experiment 2 where the rate of TO was several times that in Experiment 1. Frequency of punishment has been shown to exert powerful control over responding in other situations. Generally, the rule is the greater the proportion of punished responses, the greater the response suppression (Azrin and Holz, 1966). This finding has been established in schedules of reinforcement in which the punisher is either electric shock (Azrin, Holz and Hake, 1963; Deluty, 1976) or TO (Zimmerman and Ferster, 1963). The present results, then, are in agreement.

The conclusion that TO has aversive properties relies on the assumption that the matching law is an acceptable standard against which the direct effects of

TO are to be evaluated. This assumption is defensible if consideration is given to the robustness and pervasiveness of the matching relation in concurrent schedules. To cite but a few examples, matching has been obtained a) when the COD has been varied from 2 to 20 sec (Shull and Pliskoff, 1967); b) when each of the responses is punished by electric shock in addition to being reinforced by VI schedules (Holz, 1968); c) when reinforcers differ, not in their rate of occurrence, but in the grams of food per reinforcement (Neuringer 1967b); d) when the proportion of time spent with each of the two stimuli is used as the dependent variable (Catania, 1963b) e) when the responses consist of standing on one side of a chamber or the other (Baum and Rachlin, 1969); and f) when three VI schedules of reinforcement are concurrently available (Pliskoff and Brown, 1976). Furthermore, and perhaps most important, matching of relative response rates to relative reinforcement rates has been observed in concurrent chains schedules (Autor, 1969; Herrnstein, 1964). In short, there is little reason to doubt that under the conditions employed in the present experiments, matching would have obtained had TO not been presented in one of the terminal links.

The conclusion that TO from positive reinforcement functioned as a punishing event by no means breaks new

ground. Leitenberg (1965) concluded that TO can function as an aversive stimulus under some conditions but the controlling variables of its effects were poorly understood. More recently, a number of studies have found TO to be aversive in several different paradigms. For instance, Kaufman and Baron (1968) using modified ratio schedules, found that TO punishment suppressed responding even though such suppression resulted in a loss of positive reinforcement. Carlson (1970), using a chained schedule, found that TO between links of the chain suppressed responding in the first link to a greater extent than a comparable delay of reinforcement. Branch et al., (1977) found that response contingent TO in the higher density component of a multiple schedule suppressed responding to a greater extent than did response independent TO which was scheduled at the same rate.

The present findings while consistent with previous studies provide an extension of the effects of TO to pigeons' responding on concurrent chains schedules. Use of the highly sensitive relative response rate measure in the initial links allowed for an assessment of an indirect effect of TO - the correlation between preference for the TO-terminal link and relative reinforcement density during the stimulus in that terminal link. This indirect effect of TO has been observed

in multiple schedules where one of the components consists of blackout (Reynolds, 1961a; Sadowsky, 1973). The effect was defined earlier as behavioural contrast (Reynolds, 1961a) and consisted of an increase in response rate in the unchanged (non-TO) component.

The observation that TO produces an increase in relative density of reinforcement and an increase in response rate has important implications for interpretations given to results where TOs are self-imposed. Earlier in the introduction (see II.6, p. 29) a number of paradigms were presented in which responses were acquired and maintained when the stimulus consequence was TO. For instance, it was observed that in fixed-ratio (Zimmerman and Ferster, 1964), progressive ratio (Dardano, 1973; 1974) and fixed-interval schedules subjects responded to escape into TO.

In view of the effects of TO isolated in the present experiments and others (Reynolds, 1961a; Sadowsky, 1973), it is plausible that increases in relative reinforcement density may affect TO-producing responses in single schedules of reinforcement. That is, responses which produce TO from a reinforcement schedule by virtue of removing the discriminative stimulus correlated with that schedule, are themselves correlated with an increase in relative reinforcement density when the schedule conditions are reinstated. Thus TO-producing

responses could in part be determined by increases in relative reinforcement density following their occurrence. A simple test of this hypothesis could be carried out by comparing local response rates following TO in FR-schedules to local response rates in the same FR-schedules under baseline conditions. Higher response rates following TO would perhaps reflect the effects of increased relative reinforcement density in the FR-schedule. The possibility would exist, then, that preferences in the present study and TO-producing responses in single schedules of reinforcement are controlled by the same variable - change in relative reinforcement density.

Finally, if, in the present research, the indirect effects of TO are attributable to changes in relative reinforcement density, to what can we attribute the direct effects of TO? A couple of alternatives can be considered. First, blackout as a stimulus may have unconditioned aversive properties. Although little is known about both the behavioural and physiological consequences of blackout, it seems reasonable to suggest that this aversiveness stems from the unconditioned suppression of behaviour that it elicits rather than there being something inherently aversive about the dark for the pigeon. Secondly, signalled withdrawal of reinforcement could be the important factor. Which of these variables controls the aversive function of TO is still open to empirical analysis.

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APPENDIX A

Table 1

Absolute response and reinforcement rates in the initial links and terminal links of Experiment 1. Columns include: subject number, terminal-link reinforcement schedule, terminal link-condition, responses/min in the TO-initial link, responses/min in the EXT-initial link, responses/min in the TO-terminal link, responses/min in the EXT-terminal link, total-time reinforcements/min in the TO-terminal link, stimulus-time reinforcements/min in the TO-terminal link, total-time reinforcements/min in the EXT-terminal link and reinforcements/min in the EXT-terminal link during non-EXT periods.

Bird No.	T-Link RI(sec)	T-Link Cond.	RESPONSE RATE/MIN					REINFORCEMENT RATE/MIN				
			T-LINK		T-LINK ¹			TO		EXT		
			$\frac{P_T}{t}$	$\frac{Se}{t}$	$\frac{P_e}{t}$	$\frac{Se}{t}$	$\frac{P_T}{T_g}$	$\frac{C_e}{T_g}$	$\frac{P_R}{T_R}$	$\frac{Se}{T_R}$	$\frac{R_T}{T_g}$	$\frac{R_e}{T_R}$
1	120	B ¹	40.6(1.2)	32.4(1.7)			93.8(6.0)		91.8(4.6)		2.13(.07)	2.23(.17)
	120	TO ¹	45.9(1.1)	21.2(2.4)			91.5(2.7)		80.2(3.4)		1.27(.09)	1.35(.02)
	120	B ²	33.7(.95)	36.1(.83)			98.7(3.4)		93.6(.67)		2.17(.16)	2.00(.09)
	120	TO ²	38.1(.83)	28.5(1.4)			147.5(2.1)		116.2(2.4)		1.26(.05)	1.18(.14)
	120	B ³	47.8(3.1)	46.9(1.6)			156.3(5.3)		173.4(5.6)		1.99(.14)	2.02(.09)
	120	TO ³	39.1(1.8)	26.1(.63)			171.8(3.4)		150.5(5.7)		1.49(.11)	1.30(.20)
	60	B ⁴	38.2(3.2)	45.6(2.9)			86.5(4.1)		86.6(2.3)		1.00(.11)	1.01(.06)
	60	TO ⁴	36.7(2.6)	36.5(1.7)			106.5(2.7)		91.2(2.1)		.50(.03)	.58(.05)
	30	B ⁵	34.9(2.9)	29.5(2.0)			75.8(2.7)		76.9(1.5)		.50(.02)	.50(.04)
	30	TO ⁵	30.5(2.4)	31.7(1.8)			88.6(2.5)		74.9(4.6)		.39(.04)	.39(.06)
2	120	B ¹	31.5(1.1)	26.9(2.1)			65.1(3.6)		66.0(1.6)		1.88(.12)	2.09(.16)
	120	TO ¹	45.4(1.6)	20.6(1.5)			87.3(1.8)		64.9(1.4)		1.23(.08)	1.70(.10)
	120	B ²	33.7(2.1)	42.6(3.2)			62.6(2.5)		51.7(.56)		2.09(.22)	1.88(.11)
	120	TO ²	48.6(1.0)	31.1(2.1)			85.8(1.4)		66.6(1.3)		1.18(.05)	1.13(.05)
	120	B ³	31.1(2.0)	38.9(1.1)			63.2(1.4)		70.1(1.8)		1.83(.16)	2.16(.16)
	120	TO ³	48.3(1.3)	36.3(2.0)			75.7(2.7)		57.8(1.7)		1.06(.10)	1.12(.09)
	60	B ⁴	42.6(.78)	37.8(1.6)			59.1(1.9)		60.7(1.6)		1.01(.07)	1.11(.09)
	60	TO ⁴	39.2(2.0)	37.2(2.9)			74.8(2.2)		64.4(1.4)		.63(.05)	.66(.01)
	30	B ⁵	39.1(3.0)	40.7(2.6)			57.8(1.1)		59.1(.95)		.62(.05)	.53(.06)
	30	TO ⁵	40.1(1.0)	34.8(1.2)			65.6(1.7)		63.6(1.8)		.30(.04)	.29(.05)

¹Denotes first determination

²Denotes second determination

TABLE 1 (continued)

Bird No.	T-Link RI (sec)	T-Link Cond.	$\frac{P_T}{t}$ Se	$\frac{P_e}{t}$ Se	$\frac{P_T}{t_g}$ Se	$\frac{P_R}{t_R}$ Se	$\frac{R_T}{T_T}$ Se	$\frac{R_T}{T_g}$ Se	$\frac{R_E}{T_E}$ Se	$\frac{R_E}{T_R}$ Se
3	120	B ¹	20.1(1.3)	32.2(1.1)	59.5(4.8)	67.1(1.6)	1.92(.11)	1.92(.11)	1.83(.19)	1.83(.19)
	120	TO ¹	15.3(1.7)	28.2(1.9)	70.1(1.3)	57.2(1.4)	1.30(.14)	1.94(.21)	1.04(.08)	1.63(.11)
	120	B ²	30.7(1.3)	20.6(2.3)	58.4(1.4)	56.9(1.91)	1.98(.09)	1.98(.09)	2.24(.09)	2.24(.09)
	120	TO ²	32.1(1.26)	16.3(1.5)	69.9(1.99)	55.3(1.6)	1.17(.05)	1.92(.21)	1.29(.07)	2.15(.08)
60		B ¹	22.4(1.6)	11.0(.53)	54.4(1.4)	59.2(1.1)	1.07(.07)	1.07(.07)	.97(.05)	.97(.05)
60		TO ¹	20.5(.50)	6.9(1.2)	54.9(2.3)	47.3(1.9)	.59(.11)	.88(.10)	.48(.05)	.72(.07)
60		B ²	12.4(1.2)	21.6(.91)	58.3(2.7)	64.2(1.9)	.88(.10)	.88(.10)	1.04(.06)	1.04(.06)
60		TO ²	11.6(.85)	28.1(2.7)	55.9(1.2)	67.0(2.7)	.67(.06)	.95(.09)	.67(.06)	1.19(.19)
30		B	6.6(.65)	22.3(.93)	48.9(1.9)	51.7(.04)	.59(.05)	.59(.05)	.55(.04)	.55(.04)
30		TO	6.6(1.7)	25.5(1.8)	46.8(1.3)	47.8(1.1)	.27(.04)	.41(.06)	.28(.03)	.43(.04)
4	120	B ¹	21.8(2.8)	23.9(2.7)	54.5(1.5)	53.8(1.5)	2.00(.08)	2.00(.08)	2.21(.24)	2.21(.24)
	120	TO ¹	28.9(1.8)	20.9(2.0)	57.8(1.23)	45.3(1.47)	1.06(.12)	1.59(.18)	1.11(.12)	1.94(.05)
	120	B ²	25.0(.58)	19.4(1.4)	55.1(1.31)	56.4(.67)	2.20(.16)	2.20(.16)	1.96(.17)	1.96(.17)
	120	TO ²	34.0(1.9)	20.9(.62)	63.3(1.4)	55.4(1.3)	1.11(.11)	1.74(.17)	1.28(.17)	1.03(.14)
60		B ¹	26.9(1.3)	18.9(.59)	46.1(1.70)	53.4(1.5)	.98(.09)	.98(.09)	.98(.09)	.98(.09)
60		TO ¹	26.2(.82)	18.9(1.4)	57.2(2.2)	54.3(1.3)	.59(.04)	.88(.07)	.71(.10)	1.05(.15)
60		B ²	32.2(1.1)	27.4(.67)	48.6(2.4)	46.7(1.6)	1.11(.10)	1.11(.10)	.94(.06)	.94(.06)
60		TO ²	35.7(.94)	22.2(.67)	53.0(1.2)	44.8(2.6)	.67(.07)	1.21(.21)	.72(.07)	1.04(.07)
30		B	18.6(2.0)	23.8(1.2)	54.3(1.8)	48.0(1.8)	.59(.07)	.59(.07)	.54(.06)	.54(.06)
30		TO	18.2(2.5)	22.4(2.3)	59.1(1.9)	49.4(1.9)	.23(.02)	.34(.03)	.34(.03)	.51(.07)

Table 11

Relative reinforcement and response rates in Experiment 1. Columns include: subject number, terminal-link schedule, terminal-link condition, total-time relative reinforcement rate in the TO-terminal link, stimulus-time relative reinforcement rate in the TO-terminal link, relative response rate in the TO-initial link and relative reinforcement rate in the TO-terminal link.

Subject	Terminal Link RI (sec)	Experimental Condition	Relative Reinf Rate		Relative Response Rate	
			T-Link	I-Link	T-Link	I-Link
			$\frac{R_T}{T_T + R_T}$	$\frac{R_T}{T_T + R_T}$	$\frac{P_T}{T_T + P_T}$	$\frac{P_T}{T_T + P_T}$
P1	120	B ¹	.53	.53	.55	.53
	120	TO ¹	.48	.59	.69	.53
	120	B ²	.52	.52	.51	.49
	120	TO ¹	.52	.62	.59	.56
	120	B [*]	.50	.50	.50	.47
	120	TO [*]	.54	.66	.60	.53
	60	B	.50	.50	.54	.50
	60	TO	.47	.56	.50	.53
	30	B	.50	.50	.54	.49
	30	TO	.49	.55	.49	.54
P2	120	B ²	.48	.48	.46	.50
	120	TO ¹	.52	.62	.69	.58
	120	B ²	.48	.48	.44	.55
	120	TO ¹	.51	.61	.61	.56
	120	B [*]	.46	.46	.56	.53
	120	TO [*]	.52	.67	.57	.57
	60	B	.52	.52	.53	.50
	60	TO	.48	.58	.53	.54
	30	B	.46	.46	.51	.51
	30	TO	.51	.60	.54	.51

¹Denotes first determination

²Denotes second determination

^{*}Denotes determination under Schedule 2

Table II (continued)

Subject	Terminal Link RI (sec)	Experimental Condition	Relative Reinf Rate		Relative Response Rate	
			T-Link		I-Link	
			$\frac{R_T}{T_T + R_T + E_T}$	$\frac{R_T}{T_T + R_T + E_T}$	$\frac{P_T}{P_T + E_T}$	$\frac{P_T}{T_T + E_T + R_T}$
P3	120	B ¹	.52	.52	.38	.53
	120	TO ¹	.55	.64	.36	.55
	120	B ²	.53	.53	.49	.51
	120	TO ²	.48	.59	.34	.56
	60	B ¹	.53	.53	.67	.52
	60	TO ¹	.52	.64	.75	.54
	60	B ²	.46	.46	.64	.52
	60	TO ²	.49	.55	.71	.55
	30	B	.53	.53	.26	.51
	30	TO	.50	.58	.25	.51
	120	B ¹	.52	.52	.49	.50
	120	TO ¹	.50	.60	.58	.56
	120	B ²	.53	.53	.56	.50
	120	TO ²	.48	.58	.62	.54
P4	60	B ¹	.50	.50	.59	.53
	60	TO ¹	.55	.54	.58	.51
	60	B ²	.46	.46	.54	.51
	60	TO ²	.49	.59	.61	.54
	30	B	.40	.48	.45	.53
	30	TO	.40	.50	.45	.54
	120	B ¹	.52	.52	.49	.50
	120	TO ¹	.50	.60	.58	.56
	120	B ²	.53	.53	.56	.50
	120	TO ²	.48	.58	.62	.54
	60	B ¹	.50	.50	.59	.53
	60	TO ¹	.55	.54	.58	.51
	60	B ²	.46	.46	.54	.51
	60	TO ²	.49	.59	.61	.54

APPENDIX B

Table 1

Absolute response and reinforcement rates in the initial links and terminal links of Experiment 2. Columns include: subject number, terminal-link reinforcement schedule, terminal link-condition, responses/min in the TO-initial link, responses/min in the EXT-initial link, stimulus-time reinforcements/min in the TO-terminal link, total-time reinforcements/min in the TO-terminal link, stimulus-time reinforcements/min in the TO-terminal link, total-time reinforcements/min in the EXT-terminal link and reinforcements/min in the EXT-terminal link during non-EXT periods.

Bird No.	T-Link RI(sec)	T-Link Cond.	RESPONSE RATE/MIN						REINFORCEMENT RATE/MIN					
			T-LINK			T-LINK			TO			EXT		
			$\frac{P_T}{t}$	Se	$\frac{P_C}{t}$	$\frac{P_T}{t}$	Se	$\frac{P_R}{T_R}$	$\frac{P_T}{T_S}$	Se	$\frac{P_T}{T_S}$	$\frac{P_R}{T_R}$	Se	$\frac{P_R}{T_R}$
5	240	B ¹	39.9(2.7)	58.9(3.8)		98.5(3.7)	114.7(2.0)		4.08(.25)	4.08(.25)		4.29(.44)	4.29(.44)	
	240	TO	71.0(1.3)	55.1(3.0)		143.5(4.4)	110.4(4.7)		.75(.07)	3.54(.17)		.90(.06)	4.05(.10)	
	240	B ²	49.8(1.9)	45.0(1.5)		106.6(3.5)	125.2(4.9)		4.08(.09)	4.08(.09)		4.08(.50)	4.08(.50)	
	120	B ¹	55.9(2.6)	49.1(1.6)		109.7(2.1)	101.4(1.3)		2.14(.29)	2.14(.29)		2.06(.14)	2.06(.14)	
	120	TO	51.8(3.9)	34.9(3.1)		146.9(2.8)	73.4(2.2)		.38(.03)	1.82(.15)		.44(.05)	2.16(.17)	
	120	B ²	39.5(1.4)	44.9(2.7)		103.0(3.1)	94.9(0.8)		2.15(.21)	2.15(.21)		2.01(.08)	2.01(.08)	
	60	B ¹	48.1(2.0)	37.3(2.7)		76.7(1.5)	73.9(4.4)		1.04(.06)	1.04(.06)		1.08(.07)	1.08(.07)	
	60	TO	54.4(2.5)	25.4(1.5)		63.2(2.6)	60.7(1.5)		.21(.04)	1.03(.20)		.25(.03)	1.36(.31)	
	60	B ²	48.7(2.9)	43.9(1.3)		69.8(0.6)	84.7(3.6)		.93(.10)	.93(.10)		.96(.05)	.96(.05)	
	240	B ¹	50.0(.87)	57.3(1.4)		60.5(2.3)	60.9(2.1)		3.65(.09)	3.65(.09)		3.84(.34)	3.84(.34)	
	240	TO	64.8(1.8)	53.0(1.4)		79.1(2.1)	64.9(2.0)		.02(.07)	4.03(.33)		.70(.09)	3.52(.12)	
	240	B ²	50.1(1.0)	52.5(0.7)		73.3(3.1)	69.3(1.7)		1.62(.22)	3.62(.22)		3.97(.23)	3.97(.23)	
6	120	B ¹	49.5(1.6)	54.6(1.4)		60.3(2.8)	68.5(2.8)		2.17(.17)	2.17(.17)		2.15(.23)	2.15(.23)	
	120	TO	72.3(2.4)	34.8(1.6)		61.4(3.6)	55.3(1.1)		.43(.03)	2.08(.13)		.37(.05)	1.70(.18)	
	120	B ²	45.8(1.5)	42.9(2.9)		69.2(2.0)	69.2(2.6)		2.06(.20)	2.06(.20)		1.89(.10)	1.89(.10)	
	60	B ¹	51.4(3.0)	42.6(3.4)		63.0(1.0)	62.2(1.2)		1.02(.07)	1.02(.07)		1.06(.05)	1.06(.05)	
	60	TO	61.3(4.2)	27.7(3.6)		27.6(1.5)	49.2(1.6)		.19(.03)	.91(.10)		.20(.01)	.98(.00)	
	60	B ²	57.3(1.9)	48.0(2.8)		65.6(0.7)	66.9(1.3)		.97(.00)	.97(.00)		.96(.12)	.96(.12)	
	240	B ¹	50.0(.87)	57.3(1.4)		60.5(2.3)	60.9(2.1)		3.65(.09)	3.65(.09)		3.84(.34)	3.84(.34)	
	240	TO	64.8(1.8)	53.0(1.4)		79.1(2.1)	64.9(2.0)		.02(.07)	4.03(.33)		.70(.09)	3.52(.12)	
	240	B ²	50.1(1.0)	52.5(0.7)		73.3(3.1)	69.3(1.7)		1.62(.22)	3.62(.22)		3.97(.23)	3.97(.23)	
	120	B ¹	49.5(1.6)	54.6(1.4)		60.3(2.8)	68.5(2.8)		2.17(.17)	2.17(.17)		2.15(.23)	2.15(.23)	
	120	TO	72.3(2.4)	34.8(1.6)		61.4(3.6)	55.3(1.1)		.43(.03)	2.08(.13)		.37(.05)	1.70(.18)	
	120	B ²	45.8(1.5)	42.9(2.9)		69.2(2.0)	69.2(2.6)		2.06(.20)	2.06(.20)		1.89(.10)	1.89(.10)	

¹ Denotes first determination

² Denotes second determination

TABLE 1 (continued)

Bird No.	T-Link RI(sec)	T-Link Cond.	$\frac{P_T}{t}$	Se	$\frac{P_e}{t}$	Se	$\frac{P_T}{t}$	Se	$\frac{P_R}{T_R}$	Se	$\frac{R_T}{T_T}$	Se	$\frac{R_T}{T_S}$	Se	$\frac{R_E}{T_E}$	Se	$\frac{R_E}{T_R}$	Se
7	240	B ¹	14.6(1.8)	42.8(3.2)	74.1(1.6)	73.1(3.7)	3.86(.35)	3.86(.35)	3.86(.35)	3.86(.35)	3.86(.35)	3.86(.35)	3.86(.35)	3.86(.35)	3.50(.20)	3.50(.20)	3.50(.20)	3.50(.20)
	240	TO ¹	28.2(1.0)	46.4(2.2)	97.5(2.6)	67.6(3.7)	.81(.05)	.81(.05)	.81(.05)	.81(.05)	.81(.05)	.81(.05)	.81(.05)	.81(.05)	.88(.06)	.88(.06)	.88(.06)	.88(.06)
	240	B ²	21.7(0.2)	48.5(0.9)	79.9(2.0)	70.8(2.4)	4.08(.19)	4.08(.19)	4.08(.19)	4.08(.19)	4.08(.19)	4.08(.19)	4.08(.19)	4.08(.19)	3.74(.30)	3.74(.30)	3.74(.30)	3.74(.30)
	240	TO ²	33.1(0.8)	37.1(0.9)	114.2(1.4)	69.4(4.0)	.92(.12)	.92(.12)	.92(.12)	.92(.12)	.92(.12)	.92(.12)	.92(.12)	.92(.12)	.83(.08)	.83(.08)	.83(.08)	.83(.08)
	120	B ¹	40.6(2.9)	17.0(1.0)	62.9(1.5)	63.6(4.9)	2.03(.19)	2.03(.19)	2.03(.19)	2.03(.19)	2.03(.19)	2.03(.19)	2.03(.19)	2.03(.19)	2.01(.19)	2.01(.19)	2.01(.19)	2.01(.19)
	120	TO	64.0(2.0)	1.4(0.5)	87.1(2.4)	36.0(4.7)	.42(.06)	.42(.06)	.42(.06)	.42(.06)	.42(.06)	.42(.06)	.42(.06)	.42(.06)	.44(.06)	.44(.06)	.44(.06)	.44(.06)
	120	B ²	46.3(2.2)	19.3(1.3)	56.4(1.9)	58.4(1.8)	1.99(.17)	1.99(.17)	1.99(.17)	1.99(.17)	1.99(.17)	1.99(.17)	1.99(.17)	1.99(.17)	2.05(.04)	2.05(.04)	2.05(.04)	2.05(.04)
	60	B ¹	20.4(2.0)	37.5(1.9)	55.0(3.1)	54.2(1.2)	1.15(.12)	1.15(.12)	1.15(.12)	1.15(.12)	1.15(.12)	1.15(.12)	1.15(.12)	1.15(.12)	.90(.09)	.90(.09)	.90(.09)	.90(.09)
	60	TO	12.9(2.5)	22.2(4.4)	35.8(0.9)	49.0(3.6)	.23(.02)	.23(.02)	.23(.02)	.23(.02)	.23(.02)	.23(.02)	.23(.02)	.23(.02)	.25(.02)	.25(.02)	.25(.02)	.25(.02)
	60	B ²	26.4(1.1)	42.0(1.0)	54.2(0.9)	54.0(3.5)	1.18(.14)	1.18(.14)	1.18(.14)	1.18(.14)	1.18(.14)	1.18(.14)	1.18(.14)	1.18(.14)	1.09(.10)	1.09(.10)	1.09(.10)	1.09(.10)
	240	B ¹	39.6(0.9)	32.4(1.6)	67.9(3.4)	69.7(1.4)	3.49(.16)	3.49(.16)	3.49(.16)	3.49(.16)	3.49(.16)	3.49(.16)	3.49(.16)	3.49(.16)	3.97(.13)	3.97(.13)	3.97(.13)	3.97(.13)
	240	TO	51.6(1.3)	19.6(0.6)	84.1(0.8)	58.1(0.9)	.76(.04)	.76(.04)	.76(.04)	.76(.04)	.76(.04)	.76(.04)	.76(.04)	.76(.04)	.76(.05)	.76(.05)	.76(.05)	.76(.05)
8	240	B ²	44.9(0.8)	25.3(0.7)	75.7(1.7)	78.3(1.5)	4.18(.21)	4.18(.21)	4.18(.21)	4.18(.21)	4.18(.21)	4.18(.21)	4.18(.21)	4.18(.21)	3.45(.11)	3.45(.11)	3.45(.11)	3.45(.11)
	120	B ¹	14.9(0.9)	50.3(2.7)	64.6(0.7)	70.9(2.1)	1.95(.17)	1.95(.17)	1.95(.17)	1.95(.17)	1.95(.17)	1.95(.17)	1.95(.17)	1.95(.17)	1.93(.10)	1.93(.10)	1.93(.10)	1.93(.10)
	120	TO	22.8(0.9)	48.1(1.1)	74.2(1.7)	43.5(3.0)	2.08(.10)	2.08(.10)	2.08(.10)	2.08(.10)	2.08(.10)	2.08(.10)	2.08(.10)	2.08(.10)	.43(.04)	.43(.04)	.43(.04)	.43(.04)
	120	B ²	23.7(1.6)	44.6(0.9)	70.8(2.2)	68.3(3.4)	1.97(.12)	1.97(.12)	1.97(.12)	1.97(.12)	1.97(.12)	1.97(.12)	1.97(.12)	1.97(.12)	2.02(.16)	2.02(.16)	2.02(.16)	2.02(.16)
	60	B ¹	47.8(1.8)	30.3(1.2)	59.8(2.8)	61.8(0.9)	.93(.04)	.93(.04)	.93(.04)	.93(.04)	.93(.04)	.93(.04)	.93(.04)	.93(.04)	1.18(.11)	1.18(.11)	1.18(.11)	1.18(.11)
	60	TO	56.5(1.1)	13.8(1.8)	55.1(3.8)	40.6(1.2)	1.06(.14)	1.06(.14)	1.06(.14)	1.06(.14)	1.06(.14)	1.06(.14)	1.06(.14)	1.06(.14)	.86(.04)	.86(.04)	.86(.04)	.86(.04)

Table 11

Relative reinforcement and response rates in Experiment 2. Columns include: subject number, terminal-link schedule, terminal-link condition, total-time relative reinforcement rate¹ in the TO-terminal link, stimulus-time relative reinforcement rate in the TO-terminal link, relative response rate in the TO-initial link and relative reinforcement rate in the TO-terminal link.

Subject	Terminal Link RI (sec)	Experimental Condition	Relative Reinforcement Rate		Relative Response Rate	
			T-Link	I-Link	T-Link	I-Link
			$\frac{R_T}{R_T + R_E + T_E}$	$\frac{R_T}{R_T + R_E + T_E}$	$\frac{P_T}{P_T + P_E + T_E}$	$\frac{P_T}{P_T + P_E + T_E}$
P5	240	B ¹	.49	.49	.41	.46
	240	TO	.47	.81	.56	.57
	240	B ²	.51	.51	.53	.54
	120	B ¹	.50	.50	.53	.48
	120	TO	.47	.81	.60	.67
	120	B ²	.51	.51	.47	.52
	60	B ¹	.49	.49	.57	.51
	60	TO	.45	.82	.69	.91
	60	B ²	.48	.48	.53	.55
P6	240	B ¹	.49	.49	.47	.50
	240	TO	.54	.85	.56	.55
	240	B ²	.48	.48	.48	.51
	120	B ¹	.50	.50	.47	.47
	120	TO	.54	.85	.74	.53
	120	B ²	.52	.52	.52	.50
	60	B ¹	.49	.49	.56	.51
	60	TO	.48	.81	.69	.36
	60	B ²	.53	.53	.55	.50

¹denotes first determination

²denotes second determination

Table 11 (cont'd)

Subject	Terminal Link RI (sec)	Experimental Condition	Relative Reinf Rate		Relative Response Rate	
			T-Link		I-Link	
			R_T/T_T	R_T/T_S	P_T	P_T/T_S
			$R_T/T_T + R_E/T_E$	$R_T/T_S + R_E/T_E$	P_T/P_E	$P_T/P_S + P_E/P_R$
P7	240	B ¹	.51	.51	.26	.50
	240	TO ²	.43	.81	.37	.59
	240	B ²	.53	.53	.31	.51
	240	TO ²	.52	.84	.45	.62
	120	B ¹	.50	.50	.70	.51
	120	TO	.50	.80	.90	.61
	120	B ²	.49	.49	.71	.49
	60	B ¹	.55	.55	.35	.50
	60	TO	.48	.80	.37	.42
	60	B ²	.52	.52	.38	.50
	240	B ¹	.47	.47	.55	.49
	240	TO	.50	.83	.72	.59
	240	B ²	.55	.55	.64	.49
	120	B ¹	.49	.49	.24	.48
P8	120	TO	.52	.83	.32	.63
	120	B ²	.49	.49	.35	.51
	60	B ¹	.44	.44	.61	.49
	60	TO	.47	.84	.80	.58
	240	B ¹	.47	.47	.55	.49
	240	TO	.50	.83	.72	.59
	240	B ²	.55	.55	.64	.49
	120	B ¹	.49	.49	.24	.48

END

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FIN