FREE-OPERANT AVOIDANCE OF TIME-OUT FROM RESPONSE-INDEPENDENT FOOD PRESENTATION BY PIGEONS PECKING A KEY

BY

GREGORY GALBICKA

A DISSERTATION PRESENTED TO THE GRADUATE COUNCIL
OF THE UNIVERSITY OF FLORIDA IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS
FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

1981

To all nineteenth-century scientists, living or dead

--magnetism notwithstanding--

ACKNOWLEDGEMENTS

The verbal behavior which follows is, in a very real sense, not my own. Rather, it is the culmination of interactions with a verbal community which, particularly during the past seven years, has progressively shaped that verbal behavior. I would hope that this influence is clear enough in the behavior itself, such that others will call it "their own." Should the contingencies responsible for this behavior have been less than exact, however, I would like to formalize some of them, and in that way express my gratitude.

First, the the members of the supervisory committee:

To Marc N. Branch, for his guidance and support during the past four years, which, while substantial, was never totally complete, lest my behavior become rule-governed and echoic.

To Edward F. Malagodi, for providing an integrative intraverbal repertoire found in no other single person, as well as sound advice.

To Henry S. Pennypacker, most responsible for the development of a minimal behavioral repertoire from which extensions were later formed, for not providing autoclitics until they were manded, thus strengthening my own.

To Robert J. Waldbillig, for providing additional "inside information." May we indeed by more closly aligned in the future.

And to John A. Cornell, whose central tendancy was always to understand this vast amount of verbiage.

Next, to my parents, Joseph A. and Dorothy M. Galbicka, and other members of my family, as well as to Janet Siwy, for supporting and nuturing my conviction in a natural science of behavior more strongly than they may imagine.

To the associated menbers of the Main Branch Lab, for technical as well as intellectual support.

To the New Wave Behaviorists, for providing a verbal community which did not severely punish novel verbal statements at odds with the prevailing contingencies, while heavily reinforcing occasional ones that were not.

To the other faculty and students (graduate and undergraduate) associated with the Experimental Analysis of Behavior at Fort Skinner, for accepting and, I am afraid, occasionally reinforcing certain behavioral eccentricities.

To Janie Partin, who independently acquired an intraverbal repertoire comparable to my own, for occasionally telling me what I should be saying.

And finally, to John T. McArthur and Ray A. Preston, without whom I would never have "ventured so far from home," intellectually or physically.

To all these the Tall Kid says "Thanks," hoping that my behavior in the future will be such that they will accept the recognition they deserve.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Abstract of Dissertation Presented to the Graduate Council of the
University of Florida in Partial Fulfillment of the Requirements
for the Degree of Doctor of Philosophy

FREE-OPERANT AVOIDANCE OF TIME-OUT FROM RESPONSE-INDEPENDENT FOOD PRESENTATION BY PIGEONS PECKING A KEY

By

Gregory Galbicka

August, 1981

Chairman: Marc N. Branch
Major Department: Psychology

The present experiments examined the behavior of food-deprived pigeons pecking a small translucent disc ("key"). Food was occasionally presented independently of responding, except during signalled "time-out" periods, during which food was never presented. Key pecking during "time-in" postponed the next time-out according to a free-operant avoidance paradigm. Successive time-outs followed one another at 5-sec intervals (i.e., the time-out--time-out interval=5 sec) unless a response occurred during time-in, in which case the next time-out occurred *x* sec after the last response, where *x* was the length of the response--time-out interval.

During Experiment I, stimuli correlated with time-in and time-out were projected on the key. Lengthening the response--time-out interval while maintaining a constant time-out--time-out interval progressively decreased response rates during time-in for all subjects.

During Experiment II, the importance of the delay contingency in maintaining the key pecking observed was examined by presenting time-outs response-independently at variable intervals matched to ones obtained under a preceeding free-operant avoidance condition. Response rates for all subjects decreased when the delay contingency was suspended in this manner.

The independent contributions of responding maintained by time-out-postponement and responding elicited by the time-in and time-out stimuli were examined with a two-key procedure during Experiment III. Responses to a continuously illuminated "delay" key during time-in postponed time-out, signalled by stimuli projected on a separate "signal" key. Response rates on the delay key during time-in for two subjects decreased as the response--time-out interval was lengthened. Responding on the signal key was unsystematically related to the response--time-out interval, and generally occurred at very low rates. The third subject responded on the delay and signal keys at comparable rates, and response rates on the delay key during time-in were unaffected by changes in the response--time-out interval.

Thus, free-operant time-out-postponement may control key pecking in the relative absence of elicited pecking, but elicited responding may contribute to the behavior observed.

GENERAL OVERVIEW

The analysis of operant behavior (i.e., behavior modified by its consequences) may be partitioned into four broad classes, depending on whether increases or decreases in some characteristic property of a consequent stimulus are programmed as response consequences, and the effect of such consequences on the subsequent frequency of said response. (Morse and Kelleher (1977) present a classification scheme similar to the one here but emphasize consequent stimulus presentation or termination, respectively, rather than increases or decreases in some aspect of the stimulus.) Increases in the frequency of a response *via* response-contingent increases in some characteristic (e.g., frequency, magnitude, duration, etc.) of a consequent stimulus are generally termed instances of "positive reinforcement." Increases in response frequency produced in this manner are distinguished from increases produced *via* response-contingent decreases in consequent ("aversive") stimulation, which are termed "negative reinforcement." The common use of the term "reinforcement" highlights the increases in response rate observed with both manipulations, regardless of whether responses increase ("positive") or decrease ("negative") some aspect of consequent stimulation. The analysis of these two types of control has developed simultaneously and for the most part independently.

However, a number of parallels exist in both the development of procedures and interpretations (see Hineline (1977) for a recent treatment of these similarities). The remaining two classes of analysis are those in which response frequency decreases following a history of response-contingent stimulation ("punishment"), and may be similarly classed as "positive" or "negative." (The present paper is concerned primarily with reinforcement operations and in particular negative reinforcement, and as such punishment will subsequently be discussed only occasionally.)

What follows is a review of the study of negative reinforcement, first with respect to the procedures that have been employed and second in terms of the controlling variables suggested as necessary for the acquisition and maintenance of behavior under this type of aversive control. The majority of the data to be reviewed involve the behavior of rats, and in particular rats depressing a small, generally rectangular piece of metal protruding perpendicularly from one wall of an experimental chamber (i.e., "bar" or "lever" pressing). This subject/response combination has so frequently been used in the analysis of negative reinforcement contingencies that exceptions need be, and have been, noted. The research conducted in the present studies represents one such exception and involves the modification of a frequently used procedure in the analysis of negative reinforcement. Under this modified procedure, food-deprived pigeons pecked a small translucent disc ("key"), and each peck postponed for a fixed period the occurrence of a signalled period of time-out from response-independent food presentation.

One final note is in order before proceeding. The response most often studied under negative reinforcement contingencies has not always been the lever press. Prior to the mid-1950's, a number of investigators (e.g., Mowrer & Lamoreaux, 1942) examined the effects of negative reinforcement contingencies on running in a "shuttle-box." This apparatus consists of a rectangular enclosure partitioned along the major axis into "sides" and some means of determining which side the subject occupies at different points in time. The response defined by such an apparatus is movement to the opposite side. Results from these experiments have, not impertinently, largely been excluded from the review. Running in a shuttle-box is affected by negative reinforcement contingencies in ways comparable to effects noted when bar pressing is the measured response. Since studies involving the latter are generally more contemporary, they have taken precedence over the former in the present review. Where important, however, either for historical reasons or in discussing response topography per se, results from experiments involving "shuttling" have been included.

CHAPTER I
NEGATIVE REINFORCEMENT. I: PROCEDURES

The procedures most often employed in the study of the maintenance of behavior by aversive stimuli may be broadly classified in terms of whether a response is experimentally programmed to delete, delay, or otherwise modify some characteristic property of the aversive stimulus. While the functional effects of these procedures may not be so clearly discernible, classification in terms of the experimentally programmed effects of responses provides a convenient, if arbitrary, means of distinction.

Deletion Procedures

Aversive events may be presented continuously or intermittently. When a response terminates a continuously present aversive event for some period of time, an escape paradigm is defined. The earliest studies involving such procedures were conducted by invesigators interested in respondent conditioning (e.g., Bechterev, 1913; Pavlov, 1927). Bechterev (1913), using electric shock delivered through a panel on which a dog's foot rested, reliably observed flexion following the onset of shock. Since in many cases flexion resulted in the termination of shock, it is difficult to discern whether the response was "elicited" by the presentation of the "unconditional stimulus" or was maintained as an effective escape response through response-contingent termination of shock.

Under the procedure described above, a single response resulted in termination of the aversive stimulus. Dinsmoor and his colleagues (e.g., Dinsmoor, 1968; Dinsmoor & Winograd, 1958) developed a procedure under which responses terminated shock according to a variable-interval (VI) schedule. Under this procedure, in the presence of continuous electric shock, the first response after some average interval of time produced a fixed period of shock-free time. They reported that rates of bar pressing in rats were directly related to the intensity of shock delivered (Dinsmoor & Winograd, 1958) and that responding maintained by escape from continuous shock was similar to responding maintained by a comparable VI schedule of deletion of frequent, irregularly-spaced brief shocks (Dinsmoor, 1968). (Whether this latter procedure should be termed "escape" is debatable, since shock was not continuously present. The distinction may be of little use, however, if the behavior maintained is similar. Rather, it may be more fruitful, as Hineline (1977) suggested, to consider both procedures as shock-deletion procedures which vary only with respect to the background density of aversive stimulation.)

Deletion procedures involving more intermittent shock include both free-operant procedures (where the opportunity to respond is continuously present) and discrete-trials procedures (where response opportunity is restricted). Sidman (1966) maintained bar pressing in rats under a procedure he termed "fixed-cycle avoidance" where a brief shock was scheduled to occur every t sec. A single response anytime during the inter-shock-interval cancelled the delivery of shock at the end of that cycle. DeVilliers (1972, 1974) modified this procedure such that shocks were scheduled to occur at variable rather than fixed intervals ("VI shock deletion"). Rats' bar pressing rates under this latter procedure were linearly related to the number of shocks deleted (deVilliers, 1974). When an independent VI shock deletion schedule was programmed simultaneously for each of two responses, relative response rates and relative rates of shock deletion were also linearly related (Logue and deVilliers, 1978). This latter relationship is similar to those obtained under analogous procedures involving positive reinforcement (See deVilliers (1977) for a recent review of this literature). Additionally, deVilliers (1974) observed both positive and negative behavioral contrast (cf. Reynolds, 1961; Schwartz & Gamzu, 1977) with rats lever pressing under a multiple schedule (in which two or more schedules, or "componenents," alternate in succession, each in the presence of a unique exteroceptive stimulus) with VI shock deletion schedules in the two components. He also noted that these contrast effects increased with decreases in component duration, an effect similar to that obtained under schedules of positive reinforcement (e.g., Shimp & Wheatley, 1971; Todorov, 1972).

Herrnstein and Hineline (1966) developed a procedure under which shocks could be delivered at random intervals according to one of two constant-probability distributions of inter-shock-intervals.

One distribution, the "post-shock" distribution, was effective if a response had not occurred since the last delivered shock. A single response deleted shocks scheduled by this distribution, and the shock delivery was subsequently controlled by the second ("post-response") distribution until a shock was delivered according to that distribution. Following this shock delivery, control reverted back to the post-shock distribution. Unlike the previously described shock-deletion procedures, not all shocks could be deleted by responding; responding deleted only those shocks scheduled according to the post-shock distribution. Responding was maintained under this procedure whenever the frequency of shock programmed by the post-response distribution was less than the frequency scheduled by the post-shock distribution, even with shock frequencies as close as six and nine per min, respectively, scheduled by the post-response and post-shock distributions.

A classification system originally developed by Schoenfeld and Cole (1972) to describe schedules of positive reinforcement can be extended to describe certain other free-operant negative reinforcement procedures. The system involves continuously repeating cycles $\underline{T}$ sec in duration. These cycles are further divided into subcycles denoted $\underline{t}^{D}$ and $\underline{t}^{\Delta}$. The first response during $\underline{t}^{D}$ deletes shock scheduled to occur at the end of $\underline{T}$. All other responses are ineffective. Hurwitz and Millenson (1961) programmed cycles of constant duration comprised of a $\underline{t}^{\Delta}$ and following $\underline{t}^{D}$ period, and manipulated the relative amount of time occupied by $\underline{t}^{D}$ in $\underline{T}$. With increases in the relative duration of t^D, response rates first increased then decreased in a manner similar to relations obtained by Hearst (1960) with comparable manipulations under an analogous schedule of response-contingent food presentation. Sidman (1962*a*) obtained results similar to Hurwitz and Millenson's when t^D occurred at the end of each cycle; however, when t^D was shifted towards the middle of T (such that t^Δ periods occurred both prior to and after t^D), responding ceased. Kadden, Schoenfeld and Snapper (1974) independently manipulated the probabilities of shock given a response during t^D and given no response, and found that bar pressing of rats was maintained whenever the former was less than the latter. They also noted that response rates were positively accelerated across T when t^Δ occupied a large portion of T, provided the probability of shock given a response in t^D was greater than 0.0 but less than that which suppressed responding.

Responding under the free-operant procedures described thus far deletes only the scheduled occurrence of brief, intermittent aversive stimulus presentations. Responding may also be maintained when it terminates a stimulus correlated with aversive stimulation, as well as deleting the aversive stimulus itself. Hake and Campbell (1972) produced positively accelerated patterns of lever pressing in squirrel monkeys resonding under a fixed-interval schedule of stimulus-shock complex termination. In the presence of a unique exteroceptive stimulus, brief shocks were delivered every 30 sec, and the first response after 3 min terminated for 3 min the stimulus correlated with shock delivery and interrupted the periodic delivery of shock.

Byrd (1977), also using squirrel monkeys, maintained patterns of lever pressing characterized by a pause followed by an abrupt transition to a high rate under a procedure similar to Hake and Cambell's except that a fixed number of responses (fixed-ratio) was required for termination, and Kelleher and Morse (1964) maintained schedule appropriate responding in squirrel monkeys when fixed-interval and fixed-ratio schedules of stimulus-shock complex termination alternated in the presence of distinctive stimuli.

Krasnegor, Brady and Findley (1971) examined various pairs of ratio requirements under a slightly different stimulus-shock complex termination procedure. Sessions consisted of repeating 90 sec cycles. The first 30 sec of each cycle was signalled by the illumination of a blue light (S_1), unless the subjects (rhesus monkeys) emitted a fixed number of lever presses. Completion of the ratio requirement terminated S_1 and produced a "blackout" for the remainder of the 90 sec cycle. If the ratio requirement was not met within the first 30 sec, the blue light was replaced by a green one (S_2) for 30 sec, again unless a fixed number of responses (not necessarily the same as that required in the presence of S_1) was emitted within 30 sec. Completion of the ratio requirement in S_2 likewise produced a blackout for the remainder of that cycle. If neither requirement was met, S_2 was followed immediately by illumination of a red light for 3 sec, during which 3 brief shocks were delivered at one-sec intervals, then by a 27-sec blackout. Subjects almost invariably completed one of the two ratio requirements and, hence, few shocks were delivered. When the ratio requirements in the presence of S_1 and S_2 were identical, responding was slightly "biased" towards S_2 (i.e., slightly more ratios were completed during S_2 than during S_1). When the requirement in one component was varied while maintaining the requirement in the other component constant at 30, the frequency with which ratios were completed during the varied component was inversely related to the ratio value but was directly related to this value in the constant component.

Studies of discrete-trials deletion procedures are less numerous than the above described free-operant ones. Hineline and Herrnstein (1970) used a discrete-trials procedure they termed "fixed-cycle deletion" to maintain bar pressing in rats. Twenty-sec trials ended with presentation of a brief shock unless a single response occurred during the trial, in which case the lever immediately retracted for the remainder of the trial and shock presentation at the end of that trial was deleted. Neffinger and Gibbon (1975) and Flye and Gibbon (1979) extended Gibbon, Berryman and Thompson's (1974) notion of "contingency spaces" to the analysis of aversive control by negative reinforcement with "partial avoidance" procedures. Like Hineline and Herrnstein's procedure, brief shocks were scheduled to occur at the end of each 20-sec trial unless a response occurred. As in fixed-cycle deletion procedures, responses were followed by retraction of the lever or produced some other exteroceptive stimulus change. However, unlike fixed-cycle deletion procedures, where the probability of shock given a response is always 0.00 and 1.00 given no response, partial avoidance procedures allow the probability of shock delivery given a response to be varied independently of the probability of shock given no response. Bar pressing in rats typically was maintained whenever the probability of shock given a response was less than that given no response. (A few subjects responded when the two probabilities were equal, however this responding was characteristically short-latency responses, and may have been either shock-elicited or -induced.)

Delay Procedures

Unlike the deletion procedures, delay (or postponement) procedures do not cancel discrete occurrences of aversive events, but rather postpone them for some period of time. (Again, the distinction is between the *experimentally programmed* effects of a response, not possible functional ones.) As with deletion procedures, delay procedures vary with respect to such parameters as continuous *vs*. intermittent aversive stimulation, fixed *vs*. variable delays, free-operant *vs*. discrete-trials procedures, etc.

Probably the most frequently used delay procedure is "free-operant avoidance" (Sidman, 1953). Typically, in the absence of responding, brief inescapable shocks occur at fixed intervals, specified by the "shock-shock" (SS) interval. Responses delay the next shock for some fixed period of time, termed the response-shock (RS) interval. Delays do not cumulate; that is, shock always occurs *x* sec (specified by the RS interval) after the most recent response. Sidman studied bar pressing of rats which resulted in shock-postponement under this procedure. However, a variety of species, responses and aversive events have been used with surprising generality of effects. Rats bar press under control of noise-postponement (Knutson & Bailey, 1974), postponement of time-out from response-independent food presentation (D'Andrea, 1971) or food presentations (Smith & Clark, 1972), and have "shuttled" (e.g., Harman & Hineline, in Hineline, 1977; Libby & Church, 1974) or run in a wheel (Weisman & Litner, 1969) when such responses delayed presentation of brief electric shocks. Dogs have acquired panel press (e.g., Rescorla, 1969) or shuttle (Rescorla, 1968) responses under shock-postponement procedures. Key pecking (e.g., Ferrari, Todorov & Graeff, 1973; Todorov, Ferrari & de Souza, 1974) or treadle pressing (e.g., Dinsmoor & Sears, 1973; Foree & LoLordo, 1970; Jowaisas, 1977; Rilling & Budnick, 1975; Smith & Keller, 1970) of pigeons have been comparably controlled under similar shock-postponement procedures, and key pecking which results in postponement of time-out from response-independent food presentation (Thomas, 1965_a_, 1965_b_) has also been examined. Numerous studies have reported free-operant avoidance in rhesus and squirrel monkeys (including Clark and Smith's (1977) of food-postponement), and humans have turned levers when such responses postponed time-out from response-independent money presentations (e.g., Baron & Galazio, 1976; Baron & Kaufman, 1966).

Reliable acquisition of free-operant avoidance depends on a relatively short SS interval with respect to the RS interval (Leaf, 1965; Sidman, 1962; but, cf. Clark & Hull, 1966) although the absolute values required for acquisition may vary depending on the response employed (see, for example, Harman & Hineline, in Hineline, 1977). Responding is also (possibly even more) reliably engendered when the basic procedure is modified to provide variable SS (Bolles & Popp, 1964), RS

(Sidman & Boren, 1957a) or SS and RS (Hineline, 1977) intervals. Patterns of responding engendered under free-operant avoidance procedures consist of fairly constant overall rates of responding, with transient increases in response rate ("bursts") immediately after delivery of the aversive stimulus (e.g., Boren, 1961; Ellen & Wilson, 1964). These increases may be due to responding elicited by aversive stimulus presentation (e.g., see Hutchinson, 1977) or maintained by adventitious escape contingencies. Boren (1961) provided suggestive evidence for the latter notion with a free-operant avoidance paradigm involving two levers, one effective only during RS and one only during SS intervals, respectively. With an SS interval=0 (a delay analog of escape), bursting occurred predominantly during RS intervals, but occurred more frequently on the SS-interval lever, the one associated with shock termination.

Although overall rates of responding are generally fairly constant under free-operant avoidance procedures, the distribution of times between successive responses, or interresponse-times (IRTs), has on occasion been reported to be non-random. Specifically, the conditional probability of an IRT (i.e., the probability of an IRT of length t sec given at least that amount of time has elapsed since the preceding response) has been reported to increase with increasingly long IRTs for rats shuttling (e.g., Libby & Church, 1974) or bar pressing (Sidman, 1966) and pigeons key pecking (Jowaisas, 1977) under free-operant shock-postponement procedures. This type of temporal control need not develop, however, prior to or concurrent with the development of stable performance in terms of overall response rate, and may appear in some subjects only after extended exposure under the procedure (see, for example, Sidman, 1966, particularly pp. 464. ff.).

Overall rates of responding maintained by free-operant avoidance procedures depend on the values of both the SS and RS intervals. Response rate generally increases rapidly to a maximum as the RS interval is increased to a value equal to or slightly less than the SS interval, then declines exponentially with longer RS-interval values (e.g., Clark & Hull, 1966; Klein & Rilling, 1972; Sidman 1953; Thomas, 1965a; Todorov, Ferrari & de Souza, 1974). Verhave (1959) obtained similar functions, with the exception of higher absolute response rates than those reported by Sidman (1953), when the number of responses required to initiate a new RS interval was raised from the traditional single response to eight responses. Additionally, response rates are directly related to both the intensity (Boren & Sidman, 1959; Klein & Rilling, 1972; Leander, 1973) and duration (Leander, 1973) of shock presented.

The standard free-operant avoidance procedure may be modified in a number of ways other than the ones cited above. One modification, termed "discriminated free-operant avoidance" (e.g., Sidman, 1955, 1957; Sidman & Boren, 1957b, 1957c), involves the interpolation of exteroceptive stimuli differentially correlated with the delivery of shock. As these procedures played an important role in the development of theoretical accounts of aversive control, detailed discussion will be reserved until later. Other variations of the basic procedure have been examined. Boren and Sidman (1957a) modified the standard free-operant avoidance paradigm to examine the effects of delivering only a percentage of shocks actually scheduled. Response rates were generally unaffected across a wide range of values until the probability dropped to approximately 0.05. These results are comparable to those obtained by Neffinger and Gibbon (1975) and Flye and Gibbon (1979) with their discrete-trials partial avoidance deletion procedure, where responding was maintained at substantial levels when as many as 95% of shocks scheduled to occur on trials with a response were cancelled.

Sidman (1962b) and Field and Boren (1963) modified the paradigm to produce an "adjusting avoidance" procedure. Under the standard free-operant avoidance procedure, shock is postponed to occur x sec after the last response, where x is the value of the RS interval. Under adjusting avoidance schedules, each response postpones shock for x sec, and the delay cumulates across successive responses to some maximum value. Thus, with an RS interval=15 sec, two responses spaced 8 sec apart would result in shock presentation being postponed until 23 sec after the first response under standard free-operant avoidance, but until 30 sec after the first response under an adjusting schedule. Responding maintained under adjusting avoidance schedules usually results in shock being greatly postponed, and the degree to which it is postponed is decreased with the addition of stimuli correlated with the time to shock presentation (Field &

Boren, 1963). Sidman (1966) pointed out another interesting difference between standard free-operant and adjusting avoidance procedures by noting that adjusting schedules do not provide differential consequences for spaced-responding. Under free-operant avoidance "efficient" responding (measured in terms of the number of responses per shock presentation) should be characterized by fairly widely-spaced responses since a response occurring soon after a response does not provide as much additional delay as one occurring relatively later. Indeed, as mentioned above, responding under free-operant avoidance procedures is typically characterized by an increase in the conditional probability of a response with increasing post-response time. Adjusting avoidance procedures do not provide differential delay of aversive stimulation following spaced responses, since each response adds a specified delay regardless of where it occurs in the RS interval. As such, one might not expect to see the increase in response probability with increasing post-response time. Sidman (1962b) reported exactly that; conditional probabilities of interresponse-times remained relatively constant or decreased at longer interresponse-times under such a procedure.

The last free-operant delay procedure to be discussed is that described by Sidman (1966) termed "fixed-interval avoidance" (more for the patterns of behavior produced, it seems, than for a specification of fixed periods of time between successive shock presentations). Sidman modified the deletion procedures which specify $\underline{t}^{\Delta}$ and $\underline{t}^{D}$ periods during which responding is ineffective or deletes shock scheduled to occur at the end of $\underline{t}^{D}$, respectively. Responses during

$\underline{t}^{D}$ under fixed-interval avoidance do not cancel the presentation of shock but rather prolongs the $\underline{t}^{D}$ period (and, thus, delay shock) for some fixed period of time. Patterns of responding engendered under this procedure were typically positively accelerated, more so than those reported by Kadden, Schoenfeld and Snapper (1974) under standard deletion procedures, possibly because each cycle under fixed-interval avoidance begins with shock presentation, which could act as a discriminative stimulus signalling the beginning of $\underline{t}^{\Delta}$, thus controlling a decreased rate of responding early in each cycle.

Hineline (1970) developed a discrete-trials procedure in which one shock was delivered during every 20 sec trial. Each trial began with insertion of a retractable lever into the chamber and, if no response occurred within 8 sec, a brief shock was delivered on the eighth sec. Two sec later the lever was retracted for 10 sec, and then reinserted to begin the next trial. If a response occurred prior to the delivery of shock, the lever immediately retracted, and shock delivery was delayed until 18 sec into the trial. Responding was reliably maintained under this procedure. Benodict (1975) modified this procedure to differentiate latencies to a response. With different groups of rats, the delay to shock was either directly or inversely related to response latency. Thus, for the "long-latency-long-delay" group, each sec in the latency to a response from trial onset added a sec to the delay to shock achieved by a response, while for the "short-latency-long-delay" group each additional sec in the response latency subtracted a sec from the delay. Response latencies for the first group were generally longer than those for the second.

Gardner and Lewis (1976, 1977) and Lewis, Gardner and Hutton (1976) developed a discrete-trials procedure to incorporate multiple delayed shock presentations. In the absence of responding, brief shocks were delivered (in the presence of a distinctive stimulus) at random intervals averaging 30 sec. A single response in the presence of this stimulus initiated a 3-min alternate condition correlated with a second stimulus, during which six shocks were delivered one sec apart, beginning either 10, 88 or 165 sec (under different experimental phases) after the response. (Further responses during the alternate condition had no scheduled consequences.) The percentage of time rats spent in the alternate condition was directly related to the delay to the first shock following a bar press which initiated the alternate condition, and substantial responding was maintained when a response delayed the presentation of as many as 12 similarly-spaced shocks for 105 sec. Similar results were also obtained with pigeons key pecking under a similar shock-delay procedure (Gardner & Lewis, 1977).

Stimulus Modification Procedures

The third and final class of aversive control paradigm includes those procedures which provide response-dependent modulation of some physical property of the aversive stimulus. While all deletion procedures may be considered to modify either the duration and/or the intensity of aversive stimulation, only those procedures which do not concomitantly decrease the frequency or otherwise change the temporal distribution of aversive events in time will be considered in this category.

Weiss and Laties (1959, 1963) modified the traditional escape paradigm by programming response-contingent intensity-reduction, rather than termination, of a continuously present shock which increased in intensity every _t_ sec without a response. This procedure has become known as "shock-titration" or "fractional escape." Response rates under such procedures are inversely related to the time between successive increments in shock intensity in the absence of responding, and decreases in the value of this parameter, as well as increasing the number of responses required for a decrement in shock intensity, results in an increase in the median intensity of shock delivered (Wiess & Laties, 1959). Powell and Peck (1969) reported that acquisition of lever pressing by rats was more reliable under a procedure where each lever press reduced for 20 sec the intensity of shocks delivered every five sec than with a standard free-operant avoidance procedure with an SS interval=5 sec and an RS interval=20 sec. Bersh and Alloy (1978) maintained lever pressing under IRT<_t_ schedules (which require that responses be spaced by less than _t_ sec to be effective) of shock-intensity reduction. Following an appropriate IRT, the intensity of shocks delivered at random intervals averaging 6 sec was reduced from 1.6- to 0.75-mA for a 15-sec period. Response rates in the presence of occasional low-intensity shock were inversely related for all subjects to the value of the required IRT. In a subsequent experiment (Bersh &

Alloy, 1980), shock intensity was held constant at 1.6-mA and IRT-contingent shock-duration reduction (from 1.0- to 0.3-sec) was programmed for one group of subjects while shock durations of matched duration were presented independent of responding to a second group. Responding was well maintained in the former while subjects in the latter group responded rarely if at all.

Lewis, Gardner and Lopatto (1980) developed a procedure, similar to the delay procedure of Gardner and Lewis (1976) previously described, to examine negative reinforcement via reduction in shock duration. Shocks were presented every 30 sec. Shock duration was 2.0 sec unless a response occurred, which resulted in a 3-min change in stimulus conditions ("alternate condition") during which shock duration was reduced. Bar pressing by rats was acquired when shock duration in the alternate condition was 0.1 sec. When shock duration was subsequently varied systematically across experimental phases, the percent of session-time rats spent in the alternate condition was inversely related to the duration of shock presented during it. Additionally, responding was maintained in experienced subjects and acquired in naive ones when the procedure was modified such that all but the first shock delivered during the alternate condition were shorter (0.1-sec) than the 2.0 sec shocks delivered in the absence of responding.

The final procedures to be considered under this heading do not produce direct response-contingent modulation of aversive stimuli, but rather produce stimuli correlated with imminent aversive stimulation. Responses under such procedures result in the termination of a stimulus condition during which brief shocks are presented at randomly-spaced intervals ("unsignalled condition"), and onset of a second stimulus condition ("signalled condition") which remains in effect for some fixed period of time. In the presence of the signalled stimulus condition, shocks are delivered as before, but are briefly (e.g., for 5 sec) preceded by the onset of an additional stimulus (e.g., a tone) which terminates with shock delivery. Thus, during the signalled shock component, shock is never delivered in the presence of the component-correlated stimulus alone (a "safety" signal), but rather only in the presence of the component-correlated stimulus and the pre-shock stimulus (a "warning" stimulus). Responding which results in the presentation of safety stimuli increases with increases in shock intensity (Harsh & Badia, 1975) and is maintained when signalled shocks are of greater intensity or longer duration (Badia, Culbertson & Harsh, 1973) or occur more frequently (Badia, Coker & Harsh, 1973) than unsignalled shocks.

Under these procedures, the probability of shock delivery in the presence of the safety stimuli (i.e., $Pr(S/S_s)$) is 0.00 and 1.00 in the presence of the warning stimulus (S_w). Badia, Harsh, Coker and Abbot (1976) examined bar pressing in rats under conditions intermediate to these. They manipulated the $Pr(S/S_w)$ by only occasionally presenting shock at the end of the warning stimulus (while maintaining the $Pr(S/S_s)=0.00$ and found that responding was little affected. As the $Pr(S/S_w)$ was decreased, subjects responded at rates similar to those obtained when every warning stimulus was followed by shock. In contrast, increasing the Pr(S/S_s), by occasionally delivering shock without the pre-shock stimulus, while holding the Pr(S/S_w) constant, produced systematic decreases in response rates.

CHAPTER II
NEGATIVE REINFORCEMENT. II: CONTROLLING VARIABLES

Continguous vs. Consequent Control

The systematic analysis of behavior controlled by aversive stimuli most likely began with the defensive conditioning studies of Pavlov (1927) and Bechterev (1913). Pavlov studied salivation elicited by injection of acidic solutions into the mouth, while Bechterev concentrated on leg flexion elicited by presentation of shock to the feet of dogs. Both found that responding could be elicited by presentation of a stimulus correlated with aversive stimulation, and suggested that this responding was acquired simply due to the correlation of conditioned and unconditioned stimuli. It did not take long, however, for others (e.g., Schlosberg, 1934; Zener, 1937) to suggest that the consequences of the acquired response may be of importance in the maintenance of responding. The first experimental test of this notion (Schlosberg, 1934) was, surprisingly, anything but convincing. Rats for which a tail flick prevented delivery of electric shock responded at levels as low as others that were shocked response-independently. Other investigators, however, later found clear differences in responding as a function of whether or not the response could terminate or delete an aversive event (e.g., Brogden, Lipman & Culler, 1938; Hunter, 1935). Brogden, Lipman and Culler (1938), for example, found that presentation of shock following a 2-sec tone engendered wheel running in guinea pigs confined to the wheel, regardless of whether shock was presented after every tone presentation or only those during which a response did not occur. This response was maintained, however, only in subjects exposed to response-contingent shock deletion. When running had no scheduled consequences, it diminished. Thus, it appeared that the consequences of at least some responses did importantly determine whether a response was maintained; response-contingent termination ("escape") or postponement ("avoidance") of aversive stimulation maintained responding more readily than did situations void of such consequences.

While these results answered a simple question, they raised many more. In particular, which of the many possible dimensions of a consequence is/are necessary and sufficient for the maintenance of behavior through negative reinforcement? Situations involving escape responses were easily handled by Thorndike's (1914) law of effect, since the termination of an aversive event was undoubtedly a "satisfying state of affairs" and should thus lead to an increase in the subsequent probability of that response. Avoidance responses, however, were somewhat enigmatic in that the consequence of a successful avoidance response was the non-occurrence of an event, or the occurrence of a non-event, both of which were difficult to reconcile with the predominant learning theories of the time (e.g., Guthrie, 1935; Hull, 1943; Skinner, 1953), all of which to some degree or other emphasized stimulus-response (or response-stimulus) contiguity in the modification of behavior. The avoidance response clearly lacks this property, and as such alternate behavioral mechanisms seemed imperative.

Two-Factor Theories

A procedural detail, remnant from the classical conditioning heritage of aversive control procedures, provided the first and most long-lived account of avoidance behavior. Since early studies not reviewed here had emphasized stimulus-stimulus correlations, it was common to present an exteroceptive stimulus prior to the onset of the aversive stimulus. For example, in the Brogden et al. (1938) study, a tone was presented 2 sec prior to the delivery of shock to guinea pigs confined in a running wheel. Rotation of the wheel greater than one inch terminated the tone and precluded shock delivery, if the response occurred prior to shock onset. (Responses during shock had no scheduled consequences.) Thus, each response during the tone did produce an immediate environmental consequence, termination of the tone, and also deleted the upcoming scheduled shock. This led to the development of a number of "two-factor theories" (e.g., Mowrer and Lamoreaux, 1942; Schoenfeld, 1950; Sidman, 1953). Although differing to some degree, all suggested that what appeared to be "avoidance" responses were actually the result of interactions between more "fundamental" (contiguous) processes. The earliest and most influential propogator of two-factor theory was O. H. Mowrer. Mowrer proposed that the "avoidance" response was initially learned through its termination of the aversive stimulus. Borrowing from Freud (1936), he further contended that stimuli paired with aversive stimulation came to elicit (presumably through a respondent-conditioning process) "anxiety" or "fear". Responses which terminate such stimuli are subsequently maintained by the immediate anxiety- or fear-reduction they provide. Thus, what appear to be avoidance responses are actually responses maintained by escape from acquired motivational states elicited by stimuli paired with aversive stimulation (i.e., "anxiety" or "fear"). Schoenfeld (1950) rejected the postulation of acquired motivation states in deference to a more descriptive analysis. He suggested that paired stimuli (again through respondent conditioning) acquired aversive characteristics, and it was escape from these "conditioned" aversive stimuli that was responsible for the maintenance of responses in the absence of primary aversive stimulation.

The free-operant avoidance paradigm developed by Sidman (1953) provided the first major attack on two-factor theories of the type above (even though he suggested one of his own). Since according to two-factor theories responding is maintained by the termination of exteroceptive stimuli correlated with aversive stimulus presentation, a procedure that does not provide such stimuli should not maintain responding. Obviously, such a procedure does maintain responding, and thus apparently refutes the importance of conditioned motivational states or aversive stimulus termination.

Sidman suggested instead that the responding observed was determined by the interaction of two "gradients of punishment". One, the "distribution-of-punishment" gradient, referred to the increased probability that "non-avoidance" responses would be followed by an aversive event as the RS interval was decreased. The distribution-of-punishment gradient was offered to account for increases in response rate observed with decreases in the length of the RS interval to values equal to or slightly less than the SS interval. That rates eventually reached a maximum suggested to Sidman the action of a "delay-of-punishment" gradient, which, at even shorter RS intervals, resulted in increasing suppression of the avoidance response itself. Although plausible, this interpretation never received prolonged attention, most probably due to the inability to measure directly changes in "non-avoidance" behavior.

Anger (1963) took a somewhat different view of free-operant avoidance and concluded that it signalled the death of two-factor theory prematurely. Since aversive stimuli, when they occur under free-operant avoidance procedures, almost always follow a response by a fixed amount of time, the passage of time without a response is differentially correlated with delivery of the aversive stimulus. In effect, "long time since the last response" becomes a conditioned aversive stimulus which can only be terminated by responding. Escape from such "conditioned aversive temporal stimuli" may thus serve as the basis for negative reinforcement responsible for the maintenance of responding under free-operant avoidance procedures.

Patterns of responding maintained by such procedures, characterized in rats by increases in the probability of a response with increasing post-response time (e.g., Libby & Church, 1974; Sidman, 1966), provide circumstantial support for such a notion.

As mentioned earlier, one of the major procedural modifications of the free-operant avoidance paradigm involves the interpolation of exteroceptive stimuli which signal impending aversive stimulation. These "discriminated free-operant avoidance" procedures have provided evidence which, if not directly counter to two-factor theories, necessitate assumptions which basically make the theory untestable. Sidman (1955) trained cats and rats to bar press under a free-operant avoidance procedure with RS and SS intervals equal to 20 sec. Once stable responding was engendered under this procedure, he added a light 5 sec prior to the presentation of each shock (a "pre-shock" or "warning" stimulus). Responses postponed shock as before (i.e., RS=SS=20 sec) and also postponed the light if they occurred prior to light onset (RL=SL=15 sec) or terminated the light in its presence. He found that the majority (60-75%) of responses occurred in the presence of the light, and the probability of a response increased slightly with increasing time since light onset. Similar effects have subsequently been reported with rhesus monkeys responding under a comparable procedure (Hyman, 1969). Ulrich, Holz and Azrin (1964) exposed rats to a similar procedure (i.e., RS=20 sec, RL=15 sec) with the exception that the SS interval equalled 5 sec and the SL interval 0 sec (i.e., the light was continuously present following shock until a response occurred). They found an even greater preponderance of responses occurred following the onset of the warning stimulus. It is not clear from a two-factor account why responding which delayed onset of the warning stimulus (a "conditioned aversive stimulus") was not maintained. Possibly the light was a "weaker" aversive stimulus, capable of maintaining responding by response-contingent termination but not delay of the warning stimulus. It is also somewhat surprising that responding was more probable later in the light period. Responses which immediately terminate the light presumably provide a greater amount of negative reinforcement and should, therefore, be more probable. Two-factor theories might point to heightened temporal stimulus control to account for the observed increase in response probability with increasing time since light onset.

Two additional experiments (Sidman, 1957; Sidman & Boren, 1957_b_) offer further difficulties for two-factor theories. In both studies, the value of the RS interval depended on the presence or absence of the pre-shock stimulus. For example, with a 5-sec pre-shock light, a response in the absence of the light postponed each shock for 20 sec (i.e., RS=20 sec), concomitantly postponing light onset for 15 sec (i.e., RL=15 sec). Should the subject pause longer than 15 sec, and hence the pre-shock stimulus be presented, these contingencies no longer held. Rather, the light remained on until a shock was delivered (i.e., RL=0 sec), and the RS interval, in the presence of the light, was reduced to the duration of the pre-shock stimulus (i.e., RS=5 sec). Sidman and Boren (1957b) found that with RS and RL intervals equal to 15 and 20 sec respectively in absence of a 5-sec pre-shock light, and 0 and 5 sec respectively in its presence, rats typically bar pressed only in the absence of the light. Once the light period was initiated, the subjects generally "waited out" the interval, received a shock, and then resumed responding. Sidman (1957) parametrically manipulated the RS interval while maintaining a constant RL interval, and subsequently examined a range of RL intervals in the presence of a constant RS interval. Responding under both these procedures can be summarized as occurring in the presence of the stimulus correlated with the less stringent response requirement (i.e., that which provided the greater delay to shock per response). These results are analogous to those obtained by Krasnegor, Brady and Findley (1971) under their sequential deletion procedure, and argue against a simple two-factor account, since responding varied systematically with changes in the delay achieved by a response to both the light and to shock, even though light presentation was consistently paired with shock under all conditions.

In a second experiment, Sidman and Boren (1975c) compared two procedures. After training rats to bar press under a free-operant avoidance procedure with RS=SS=20 sec, they programmed RL and RS intervals equal to 16 and 20 sec, respectively, in the absence of the light, but always presented shock 4 sec after light onset (i.e., responses during the light had no experimentally arranged consequences). Under this procedure, responding in the presence of the light decreased to very low levels. Response rates prior to light onset, after an initial transitory increase, returned to levels comparable to those obtained under initial free-operant avoidance training with no warning stimulus. In contrast, when responding in the presence of the light terminated it and postponed shock (similar to Sidman (1955)), responding occurred predominantly in the presence of the light. Both procedures, then, allowed for the establishment of the light as a conditioned aversive stimulus through respondent conditioning, since shock only occurred in the presence of the light, yet the former maintained a much higher rate of responding in the absence than in the presence of the warning stimulus.

Data obtained under procedures other than those just described also argue against a simple two-factor account of avoidance. For example, Bolles, Stokes and Younger (1966) compared two response topographies (running in a wheel and shuttling) under procedures which allowed for all possible combinations of response-contingent avoidance ("A"), shock termination ("T_s"), and/or warning stimulus termination ("T_w"). That is, with different groups of rats, responses resulted either in nothing or in one of the following set of possible consequences: A, T_s, T_w, AT_s, AT_w, T_sT_w, or AT_sT_w. Termination of the warning stimulus only (i.e., shock still occurred) did not maintain more shuttling than that obtained when shuttling had no effect, and both responses occurred more reliably when responding avoided shock, independent of stimulus termination.

Kamin, Briner and Black (1963) used a slightly different tactic to argue against the "anxiety-provoking" aspects of warning stimuli.

They trained subjects to respond under a signalled shock deletion schedule, and, later each day, exposed them to a schedule of response-contingent food presentation. Occasionally, they interpolated brief presentations of the pre-shock stimulus during the schedule of food presentation, and found that the degree to which behavior maintained by the presentation of food was suppressed by this stimulus was inversely related to the amount of responding maintained in the presence of that stimulus under the shock-deletion procedure. Since suppression of appetitive behavior by stimuli paired with the presentation of aversive events is typically viewed as a measure of the amount of "anxiety" produced by such stimuli, these data suggest that responding under the shock-deletion schedule was maintained better when the pre-shock stimuli evoked less, not greater amounts of "anxiety".

One-Factor Theories

Results such as the ones mentioned above have led to a general decreased acceptance of two-factor theories in favor of other interpretations (but, see Dinsmoor, 1977). Herrnstein (1969) offered a "one-factor" theory based on the notion of shock frequency reduction. He argued that "the reinforcement for avoidance behavior is a reduction in time of aversive stimulations . . ." (p.67). Herrnstein offers as evidence for this position data obtained under the previously described deletion procedure developed by Herrnstein and Hineline (1966). Under this procedure, shocks were scheduled according to two random distributions of inter-shock-intervals, and responding determined which distribution delivered the next shock. Herrnstein and Hineline found that responding was maintained when it decreased the frequency of shock delivery by as little as three shocks/min under that obtained in the absence of responding. It is important to note that responding does not achieve a specified fixed delay to shock under this procedure, although the average delay may be longer with response-contingent decreases in overall shock frequency, provided the subject does not make multiple responses between shock presentations. Since responding is maintained in the absence of any exteroceptive stimuli correlated with shock delivery, and in the absence of a programmed temporal contingency between responding and shock presentation, Herrnstein (1969) argued for the preeminence of shock frequency reduction (SFR) as the basis of negative reinforcement. That Logue and deVilliers (1974) found relative response rates to be systematically related to the relative SFR achieved by one of two responses and not to the relative number of shocks actually delivered provides additional support for this notion.

Hineline (1970), however, pointed out that all procedures employed to that time had confounded at least two of three possible controlling variables: 1) escape from conditioned aversive stimuli (exteroceptive, temporal or organismic), 2) SFR and 3) the (average) delay to the next aversive event. Thus, he argued that statements suggesting the controlling variable were most likely premature. He developed a discrete-trials procedure (Hineline, 1970) in an attempt to separate these variables. As previously discussed, the procedure consisted of 20-sec trials during which a single shock was delivered. In the absence of a response, a retractable lever was inserted into the chamber for 10 sec, a brief shock was delivered at the 8th sec, and then the lever was withdrawn for 10 sec. A response prior to 8 sec resulted in immediate retraction of the lever, and delayed shock presentation until the 18th sec of the trial. Thus, responding produced no overall SFR, since one shock was presented during every trial regardless of a response. The stimulus paired with shock delivery (i.e., "lever in" vs. "lever out") depended on whether a response occurred, since shocks were presented while the lever was inserted on trials without a response and while retracted if a response occurred prior to shock delivery. Thus, two-factor accounts might predict an oscillation in responding, initially escaping "lever in" by responding, then escaping "lever out" by not responding. Indeed, consistent responding would reliably produce rather than terminate the conditioned aversive stimulus, since shocks would always be presented when the lever was retracted, the immediate consequence of every lever press. Hineline found that responding was reliably and consistently maintained under this procedure. Consequently, he argued for the importance of delay to aversive stimulation as a controlling variable in the maintenance of responding by negative reinforcement, an argument which might be termed the "procrastination hypothesis": responding will be maintained when it achieves a delay to the next aversive event longer than that in the absence of a response, independent of any reduction in the overall frequency of aversive stimulation. The differentiation of response latencies as a function of the amount of delay they achieve (Benodict, 1976) further argues for delay as an important controlling variable.

Herrnstein (1969) took exception to this view, arguing that the results obtained could be viewed in terms of "shock-frequency reduction under the control of discriminative stimuli" (p. 69). That is, the presentation of the lever signals the opportunity to decrease the frequency of shock in the presence of the lever to zero. He cites the results of a second experiment by Hineline (1970) to support this interpretation. During this experiment, the paradigm just mentioned was modified such that responses still retracted the lever but resulted in shock delivery exactly 10 sec after the response. Thus, the trial length and frequency of shock delivery were inversely and directly related, respectively, to the latency to a response. Responding was not maintained under this procedure, which Herrnstein suggested resulted from equal frequencies of shock (one per 10 sec) in the presence or absence of the lever. Hineline, however, argued that delay was sufficient to maintain responding in the absence of any overall SFR (Experiment 1) but not in the presence of an increase in the overall frequency of shock (Experiment 2).

Lambert, Bersh, Hineline and Smith (1973) provided additional evidence against SFR as sufficient for the maintenance of responding by negative reinforcement. They used a procedure modeled after Hineline (1970), with 60-sec trials and lever presentation restricted to the first 10 sec. In the absence of a response, five shocks were delivered during each trial at one-sec intervals beginning at the 11th sec. A lever press cancelled the delivery of these shocks, but resulted in the immediate presentation of a single shock. Thus, responding produced a decrease in shock frequency but also resulted in a decrease in the delay to the first shock. Responding was not maintained under this procedure, which the authors suggested as an indictment of the one-factor theory based solely on SFR. Although suggestive, this procedure differs from all those previously discussed in that responding results in the immediate presentation of an aversive event, and as such may provide for alternative interpretations. Specifically, responding may not have been maintained due to inadequate negative reinforcement based on shock-delay but rather may have been actively suppressed by punishment. (Although some (e.g., Dinsmoor, 1954, 1977; Skinner, 1953) have argued that avoidance and punishment may not be independent processes, that contention has been challenged (e.g., Galbicka & Branch, 1981; Rachlin & Herrnstein, 1969) for reasons which, while germane to the present discussion, will be deferred to keep the scope of the review manageable.) Response-contingent aversive stimulation, of course, is nothing more than one limiting condition with regard to Sidman's (1953) notion of "delay-of-punishment" gradients (i.e., delay=0 sec). Thus, it is conceivable that all delay procedures can be analyzed in terms not of the negative reinforcement they provide via increases in the delay to aversive stimulation, but rather in terms of the decreased response suppression produced by delayed punishment. Such an analysis, as mentioned earlier, is handicapped by the inability to measure punished "non-avoidance" behavior, except when the delay equals zero (i.e., when aversive stimulation is response-contingent) as it was in the Lambert et al. study. Hence, although conceptually plausible, such a notion is very difficult (if not impossible) to verify experimentally. Alternative conceptualizations in terms of the relation between a specified response and aversive stimulation (e.g., response-contingent delay), while possibly incomplete, allow experimental treatment.

A systematic examination of the effects of delayed aversive stimulation in the absence of any SFR conducted by Gardner and Lewis (1974) provided more telling evidence for the importance of this factor in the maintenance of responding under negative reinforcement paradigms. Under their procedure, responding produced a 3-min change in stimulus conditions and interrupted the delivery of shock otherwise scheduled to occur at random intervals averaging 30 sec. Under the "alternate condition" initiated by a response, the same number of shocks which would, on the average, have been presented had a response not occurred (i.e., 6) were delivered. Thus, no <u>overall</u> SFR could occur. During the alternate condition shocks were delivered at one-sec intervals, beginning after a specified delay from the response which initiated the condition. That delay was, across experimental phases, either 10, 88 or 165 sec. The percent of time rats spent in the alternate condition (and, thus, the rate of responding in its absence) was directly related to the delay to the first shock achieved by a response. Additionally, substantial responding was maintained when as many as twelve shocks (representing a 100% shock-frequency <u>increase</u>) were delivered during the alternate condition and the delay to the first shock was 105 sec. This systematic effect of delay on response rate argues strongly for delay as an important determinant of the maintenance of responding by negative reinforcement, independent of (and in the face of an increase in) the frequency of shock delivered.

In a subsequent experiment, Lewis, Gardner and Hutton (1977) suggested that delay to the first aversive event may not be necessary in and of itself, provided that subsequent delays occur. They modified their previous procedure such that all but one (or two) of the shocks delivered during the alternate condition were delayed. The nondelayed shock(s) were delivered at exactly the same time they would have been delivered had a response not occurred. Responding was maintained in all subjects when one non-delayed shock was presented, and in two of six subjects (both of which had previously been exposed to the "one nondelayed shock" condition) when the first two shocks delivered were not delayed by a response. Similar results were obtained with comparable manipulations on pigeons' key pecking (Gardner & Lewis, 1977). The authors argued that these results implicate delays to the second and, to a less degree, third shock in a series of shocks as controlling behavior. Shull, Spear and Bryson (1981) recently reported that delays to the second (and to a lesser degree third) food presentations were systematically related to response rate under a procedure analogous to that just described but not involving delayed presentations of food. Although these data indicate that delays are capable of controlling responding, an account in terms of SFR, where the frequency of aversive stimulation is calculated using non-arithmetic averages, cannot be discounted at the present time. Shull et al. chose delay values carefully so as to preclude totally frequency differences, regardless of the averaging method used. Whether similar parameters of delayed aversive stimulation would systematically control responding remains to be determined.

Only changes in the distribution of aversive events in time have to this point been considered as possible controlling variables. It is clear from the data obtained under procedures which provide response-contingent reduction in physical characteristics of the aversive stimulus that such reductions can maintain responding in the absence of concomitant changes in the frequency of such events. Although some of these studies may be reconciled with the previous discussion by allocating shock frequencies to two separate classes dependent on some characteristic of the aversive stimulus (e.g., responding increases the delay to the next "intense" or "long" shock), procedures such as Weiss and Laties' (1959, 1963) shock-titration schedules, where the characteristic property of the aversive stimulus varies across a semi-continuous range, make such analyses difficult. Furthermore, demonstration of lawful interactions between physical properties of aversive events, for example the similar rates of responding maintained under free-operant avoidance procedures as a function of the product of the durations and intensities of shocks presented (Leander, 1973), suggest that accounts which emphasize factors other than changes in the temporal distribution of (classes of) aversive events may extend the precision possible in the prediction and control over behavior by negative reinforcement contingencies.

CHAPTER III
INTRODUCTION TO THE PRESENT EXPERIMENTS

Under free-operant avoidance paradigms (Sidman, 1953), responses postpone the occurrence of an aversive stimulus for $\underline{x}$ sec. Otherwise these events occur every $\underline{t}$ sec. These two temporal parameters are typically termed the response-shock (RS) and shock-shock (SS) intervals, respectively, underscoring a bias towards the use of electric shock as an aversive stimulus. Investigators interested in the control of behavior by response-contingent delay or deletion of aversive events (i.e., by negative reinforcement), apparently swayed by the logistical and behavioral superiority of electric shock (see Azrin & Holz, 1966), have selected it almost to the exclusion of other aversive events.

This bias generally may be of little concern, unless one is interested in studying negative reinforcement using pigeons as subjects. Pigeons have generally been considered prime subjects in the analysis of positive reinforcement contingencies (e.g., Ferster, 1953), and the analysis of operant behavior (i.e., behavior modified by its consequences) under such contingencies owes a great deal to them (e.g., Ferster & Skinner, 1957). In contrast, they have been used infrequently in the analysis of behavior controlled by negative reinforcement contingencies, and until very recently, their absence was highly conspicuous. One reason for this apparent omission may be purely logistical. Electric shock is most often delivered through the feet of subjects standing on an electrified floor. Pigeons, however, do not conduct electricity readily through their feet, unless special procedures, such as application of graphite (Ferster & Skinner, 1957) and extremely high electrical currents are used. Implanted electrodes (e.g., Azrin, 1959) may circumvent these problems at the expense of daily monitoring and cleaning, as well as the increased risk of infection. Thus, many invesitgators may simply be responding to these inconveniences and opting for more (at least structurally if not behaviorally) "cooperative" subjects, such as rats and monkeys. However, recent suggestions (e.g., Bolles, 1970, 1973) that the "laws" of negative reinforcement may lack "interpecies generality" (Sidman, 1960) have spurred a renewed interest in the demonstration of pigeon behavior acquired and maintained by negative reinforcement contingencies.

A second bias, interacting with the one previously mentioned, appears to have increased further the difficulty of providing demonstrations of negatively-reinforced behavior in pigeons. Specifically, it appears that the acquisition of key pecking, the most widely measured behavior of pigeons, may be retarded by the use of electric shock as an aversive stimulus. Shock elicits neck-contraction in pigeons (Smith, Gustavson & Gregor, 1972), a response incompatible with the targeted response, the key peck. Thus, competition between elicited and operant responses may impede the acquisition of the latter. Indeed, it appears that a number of other responses of pigeons, such as head lifting (Hoffman & Flescher, 1959), shuttling (e.g., Baum, 1973; MacPhail, 1968) and treadle pressing (e.g., Dinsmoor & Sears, 1973; Foree & LoLordo, 1970; Klein & Rilling, 1972, 1974; Rilling & Budnick, 1975; Smith & Keller, 1970) may be acquired more readily than key pecking under negative reinforcement contingencies. While studies demonstrating the control of responses other than key pecking by negative reinforcement indicate that the behavior of pigeons is not completely "immune" to negative reinforcement, they do so at the expense of direct comparison to the extant literature on key pecking under other sources of control.

Sidman (1960) noted that differences between species and reponse classes may more directly reflect important differences in the training procedures used than in the inherent characteristics of the classes. This appears to be at least partially the case with key pecking under the control of shock-reduction. A number of investigators have now demonstrated that key pecking can be shaped by response-contingent termination of trains of increasingly-intense brief shocks (e.g., Alves de Morares & Todorov, 1977; Ferrari & Todorov, 1980; Ferrari, Todorov & Graeff, 1973; Hineline & Rachlin, 1969a, 1969b; Rachlin & Hineline, 1967; Todorov, Ferrari & de Souza, 1974) or that control can be transferred from positive to negative reinforcement contingencies (e.g., Foree & LoLordo, 1974; Gardner & Lewis, 1977; Lewis, Lewin, Stoyack & Muehleisen, 1974; but cf. Schwartz & Coulter, 1971). However, the necessary and sufficient parameters responsible for the acquisition of key pecking have not been delineated fully, and the shaping procedures may be somewhat arduous, requiring a large investment of experimenter time or a degree of initial pretraining involving positive reinforcement. Given these difficulties, it is doubtful that many investigators will be willing to use pigeons as subjects when studying negative reinforcement.

The problems encountered when attempting to study negative reinforcement contingencies with pigeons do not stem primarily from either the use of the key peck as the measured response or electric shock as the aversive stimulus, but rather from the interactions inherent in their combined use. Hence, two possible experimental tactics are available. One involves measuring responses other than key pecking under negative reinforcement procedures based on electric shock-termination, -postponement, -intensity-reduction, etc. Such procedures, as discussed above, have, by and large been successful. Unfortunately, the results obtained may not be readily generalizable to the vast literature involving key pecking maintained by contingencies other than negative reinforcement, in that responses other than key pecking may not be as free as key pecking to vary across some measured dimension. For example, it is doubtful that a pigeon can press a treadle or lift its head as frequently for extended periods of time as it can peck a key. While this assumption may with further analysis prove incorrect, the fact remains that key pecking under sources of control other than negative reinforcement has been and continues to be more frequently analyzed than any other behavior of pigeons. Given the availability of this reference source, it would seem to be a disservice to relinquish it on the basis of methodological problems alone. The other available tactic, developing procedures involving key-peck-contingent reductions in some physical characteristic of an aversive stimulus other than electric shock, may be useful in this regard.

The prime candidate for an alternative aversive stimulus is "time-out," a signalled period during which positive reinforcement is never experimentally programmed. Time-out has been used successfully as an aversive stimulus with rats (D'Andrea, 1971; McMillan, 1967), monkeys (e.g., Ferster, 1958), pigeons (e.g., Ferster, 1958; Thomas, 1965a, 1965b) and humans (Baron & Galazio, 1976; Baron & Kaufman, 1966). The presentation of time-out does not require any special subject preparation or apparatus, and is thus logistically simpler to program than electric shock presentation.

The use of time-out with pigeons is additionally alluring, in that it may be used both to engender and maintain key pecking. Specifically, a number of investigators have reported that food-deprived pigeons will peck at a stimulus differentially correlated with the presentation of food (see Schwartz & Gamzu (1977) for a recent review of this literature). Since the presentation of time-out requires that it alternate with another stimulus situation during which reinforcement is available ("time-in"), one can "autoshape" (Brown & Jenkins, 1968) key pecking by locating the time-in stimulus behind the response key. Thus, key pecking may be reliably acquired with little or no preliminary training (other than training the subject to eat from the food magazine).

Although an aid in the acquisition of key pecking, the presence of stimulus-reinforcer contingencies requires that their contribution to key pecking subsequently maintained by negative reinforcement contingencies be assessed. (As an aside, the term "stimulus-reinforcer" should in the present context be translated "stimulus-food presentation," as it is most commonly used by others with schedules of response-independent or -dependent food presentation. It is not meant to describe differential relations between the presentation of particular stimuli and the occurrence of negative reinforcement.) Specifically, intermittent presentations of food or shock may elicit or otherwise "induce" behaviors (see, for example, Hutchinson (1977) and Staddon (1977) for recent reviews of these effects) which are or are not topographically similar to the operant response under investigation. To the extent that responses evoked by non-operant sources of control are topographically similar to the operant response, the separate contributions of operant and non-operant contingencies may "additively" interact in producing the overall frequency of the observed response. Conversely, if the operant and non-operant response classes are incompatible, the contingencies responsible for these response classes will produce a degree of "competition" between the two classes, since the occurrence of a member of one class will (momentarily) preclude the occurrence of a member of the other class. For example, key pecking directed towards stimuli differentially correlated with food delivery would be indistinguishable (on the basis of frequency, at least) from operant key pecks when these stimuli are projected on the operandum used to measure the latter. Thus, changes in the frequency of elicited key pecking resulting indirectly from manipulations of the operant contingency (i.e., resulting from changes in the frequency of, for example, time-out presentations and not from changes in the direct consequences of responding) might obscure functional relations between the operant contingency and the frequency of operant key pecking.

Interactions such as the ones described above between operant and non-operant response classes may be examined in a number of ways. One method involves response-independent presentation of stimulus events in precisely the same manner as under a previous condition during which the operant contingency was in force. Differences between responding maintained in the presence of the operant contingency and that maintained in its absence but with "yoked" distributions of stimulus presentations allow evaluation of the importance of the operant contingency in maintaining the behavior observed under the former (see, e.g., Coulson, Coulson & Gardner, 1970; Smith, 1973). They do not, however, allow for direct measurement of the independent contributions of operant and non-operant contingencies to behavior under such procedures. That is, responding maintained in the absence of a specific operant contingency (i.e., under the yoked procedure) may be primarily non-operant or may reflect the occurrence of spurious correlations between responses and stimulus events, leading to the "superstitious" (see Skinner, 1948) maintenance of operant behavior, or some combination thereof.

A more direct method of assessment involves "topographical tagging" (e.g., Catania, 1971, 1973; Keller, 1974) of different response classes, such that responses maintained by one set of contingencies are primarily directed towards one operandum, while responses under an alternate source of control occur on a separate operandum. With respect to the two sources of control over key pecking discussed above, such a "tagging" operation involves removing stimuli differentially correlated with the delivery of food from the key on which responses result in the presentation of reinforcement. Since any stimuli subsequently projected on this key are no longer differentially correlated with reinforcement, they should elicit no pecking, and responses on this key should primarily be under the control of operant contingencies. Elicited pecking should be directed towards the re-located reinforcement-correlated stimuli. By projecting these stimuli on a key other than that used to define operant responses, elicited responses may not only be separated from operant ones, but additionally may independently be measured.

The present set of studies examined key pecking maintained under free-operant avoidance of time-out from response-independent food presentation. Experiment I involved manipulation of the response--time-out (RS) interval (the amount of time each key peck postponed the next time-out) while maintaining a constant time-out--time-out interval (which specified the time between successive time-outs in the absence of a response). Experiment II examined the effect of removing the postponement contingency while presenting comparable frequencies and distributions of time-out response-independently. Finally, the independent contributions of the postponement and stimulus-reinforcer contingencies to the behavior observed were examined during Experiment III.

CHAPTER IV
EXPERIMENT I

Rates of responding under free-operant avoidance procedures generally increase as the delay achieved by a response increases to a value equal to or slightly less than the time between successive aversive events in the absence of responding, and then decrease exponentially as the response-contingent delay is lengthened further (e.g., Clark & Hull, 1966; Klein & Rilling, 1972; Sidman, 1953; Thomas, 1965a; Todorov, Ferrari & de Souza, 1974). Responding is generally maintained at a fairly constant rate with occasional transient increases ("bursts") following the presentation of an aversive event (Boren, 1961; Ellen & Wilson, 1964). Although the overall response rate is fairly constant, the times between successive responses, or interresponse-times (IRTs), often are distributed non-randomly. The conditional probability of an IRT=t sec (i.e., the probability of a response t sec after the preceding one given that t or more sec have elapsed) has been reported to increase as a function of IRT length with rats (e.g., Libby & Church, 1974; Sidman, 1966) and pigeons (Jowaisas, 1977). This type of temporal control need not always develop prior to or concurrent with the development of stable performance (in terms of overall rates of responding) under free-operant avoidance paradigms (Sidman, 1966, particularly pp. 464 ff).

The present experiment extends Thomas's (1965a) analysis of key pecking maintained under free-operant avoidance of time-out from response-independent food presentation. In Thomas's study, food was briefly presented response-independently at random intervals averaging 1 (or 3) min, except during 5 min time-outs that occurred every 10 sec in the absence of a key peck. Each key peck postponed the next time-out (under different experimental phases) for either 20, 30, 60, or 120 sec. The present study examined key pecking under a similar time-out-postponement procedure, but differed with respect to parameters of time-out duration and the length of response contingent time-out delay. Responses postponed the occurrence of the next 20-sec time-out from response-independent food presentation for some fixed period of time (either 5, 10, 20, or 40 sec). Otherwise, time-outs were presented every 5 sec. Except during time-out, food was briefly presented at random intervals averaging 30 sec. In addition to these parametric differences between the two studies, the present study provides a more extensive analysis than Thomas's by including response rates during both time-in and time-out, number of time-outs delivered and IRT distributions.

Method

Subjects

Three adult male, White Carneaux pigeons (Columba livia), previously used in an undergraduate laboratory course, were initially reduced to 80% of their free-feeding weights (475, 400 and 415 g for P-7820, P-9275 and P-6441, respectively). They were subsequently maintained on a 23 h deprivation regimen, with post-session feeding of mixed grain restricted so as to maintain the specified level of body weight. Each subject was individually housed in a colony room and had continuous access to water and health grit between experimental sessions.

Apparatus

Experimental sessions were conducted in a pigeon conditioning unit similar to that described by Ferster and Skinner (1957), measuring 30 cm wide by 31 cm long by 31 cm deep. An aluminum sheet served as the front wall of the chamber, all other walls were painted flat black. The front wall contained three standard response keys (R. Gerbrands, Co.) located 22 cm above the grid floor. Only the center key, located 15.5 cm from either side edge of the front wall, was operative. A static force of 0.15 N applied to the key briefly activated a "feedback" relay mounted behind the front wall and was recorded as a response. The key could be trans-illuminated with light from either of two 1.1-W, 28-V dc lamps located behind it and which were covered with either a white or red cap, respectively. A plexiglas extension mounted on the key protruded 0.15 cm beyond the front wall. (Such extensions have occasionally been reported to aid in the acquisition of key pecking under autoshaping procedures (e.g., Rachlin, 1969).) The other two keys did not extend beyond the front wall and remained dark throughout the course of the experiment. Directly beneath the center key was a 6 cm by 5 cm aperture through which mixed grain could be presented, dependent on the operation of a solenoid-driven grain feeder. A 1.1-W, 28-V dc lamp located directly above and behind this aperture was lit during grain presentations. General illumination during experimental sessions was provided by two 1.1-W, 28-V dc houselights located in either upper corner of the front wall and mounted behind reflectors which prevented direct downward illumination. The chamber was located in a room where white masking noise was continuously present. Noise from a ventilation fan mounted on the chamber ceiling also helped mask extraneous sounds. A PDP-8/f minicomputer, located in an adjacent room and operating under the SKED (Snapper, Stephens & Lee, 1974) or SuperSKED (Snapper & Inglis, 1978) software systems, programmed stimuli and recorded data. Also, cumulative response records of each session were generated by a Gerbrands (Model C-3) Cumulative Recorder located in the same room as the computer.

Procedure

Daily, one-hour sessions consisted of two possible stimulus situations with respect to keylight color; continuous transillumination with either white or red light. In the presence of the white light ("time-in"), grain was presented for 2 sec at random intervals averaging 30 sec (determined by a probability generator set equal to 0.03 and sampled every sec), whereas in the presence of a red keylight grain was never presented ("time-out"). Grain was also never presented within 3 sec of time-out termination but could occur immediately prior to a time-out or immediately after a response. Food presentation was not delayed after responses in an attempt to maintain the frequency of food presentation constant in the presence of large changes in response rate. Responses to the white key produced a "click" from the feedback relay and postponed the next time-out for the amount of time specified by the RT interval. In the absence of responding, time-outs followed one another at 5-sec intervals (i.e., TT interval=5 sec). Neither the TT or RT interval timed during food presentations. Termination of each 20-sec time-out was signalled by a brief (0.25 sec) darkening of the houselights in addition to reillumination of the key with white light. The RT interval length was manipulated across phases in successive order from 20 to 10 to 40 to 5 sec, while maintaining the TT interval equal to 5 sec. Each condition remained in effect until response rates in time-in and numbers of time-outs presented per session showed minimal variablility and no apparent trends for 20 consecutive daily sessions as determined by visual examination of graphic displays of these measures. The number of sessions each subject was exposed to the different RT interval values is presented in Table 1.

Since all subjects had histories involving magazine training and key pecking, little preliminary training was involved. One subject (P-7820) was exposed to a variety of preliminary "pilot" conditions, during which a number of variables (e.g., session

TABLE 1
LIST OF CONDITIONS AND SUMMARY MEASURES FOR EACH SUBJECT DURING EXPERIMENT I

SUBJECT	RI INTERVAL (sec)	SESSIONS (ORDER)	RESPONSE RATE (R/min)		TIME-OUTS
			Time-in	Time-out	
P-7820	5	72 (4)	43.62 (35.00-53.10)	0.71 (0.24-1.54)	41.7 (33-53)
	10	96 (2)	20.82 (16.50-25.32)	0.33 (0.10-0.78)	46.3 (35-65)
	20	171 (1)	12.18 (10.50-15.36)	0.24 (0.00-0.86)	25.0 (9-39)
	40	71 (3)	7.80 (6.42-11.16)	0.10 (0.24-1.54)	13.0 (5-32)
P-9275	5	42 (4)	21.72 (17.34-26.10)	0.27 (0.14-0.49)	105.2 (95-114)
	10	100 (2)	17.58 (15.06-19.86)	0.19 (0.00-0.44)	41.0 (30-72)
	20	74 (1)	8.94 (7.14-10.44)	0.14 (0.00-0.44)	31.5 (24-47)
	40	30 (3)	5.28 (4.20-6.36)	0.10 (0.00-0.25)	27.5 (17-35)
P-6441	5	69 (4)	39.16 (32.70-42.60)	2.53 (1.29-3.95)	25.0 (13-42)
	10	45 (2)	20.88 (15.80-26.94)	1.35 (0.17-2.71)	11.3 (5-15)
	20	[illegible] (1)	12.[illegible]0 (10.44-16.20)	1.73 ([illegible])	10.3 (7-33)
	40	43 (3)	9.60 (5.40-13.22)	0.63 ([illegible]-3.07)	5.6 (0-11)

---

aValues shown are the means of values observed during the last 10 sessions under each RI interval. Ranges of values observed during this period are shown in parentheses.

length, stimulus conditions, feeder cycle length, etc.) were unsystematically manipulated. The others were placed directly under the first experimental condition, with two slight exceptions. First, the feeder cycle was initially set at 4 sec. This value remained in effect until visual observation showed that each subject ate readily following the presentation of the magazine, at which point the cycle duration was reduced and subsequently maintained at 2 sec. Second, the probability of food presentation each sec was adjusted so that approximately one-half of the initial time-in periods contained a food presentation. This value was maintained until the first key peck, after which it was reduced to the value used subsequently throughout the experiment (i.e., 0.03).

Results

Both subjects initially placed directly under the experimental procedure pecked the response key within 15 min of the beginning of the first session. For all subjects, pecking occurred first during time-in, and always occurred more frequently during time-in than during time-out. Informal visual observations suggested that pecks during time-out generally occurred during the first few sec of a time-out, and often were initiated prior to time-out presentation.

Table 1 presents the means and ranges of summary measures obtained across the last 20 sessions of each condition for each subject. Response rates during time-in, graphically depicted in Fig. 1, were generally linearly decreasing functions of RT interval length when plotted on double-log arithmetic axes. (The correspondence between the mean and median response rates observed during the last 20 sessions under each RT interval suggested that daily session variability in this measure was generally normally distributed.) The exceptions to this generalization were the data from P-9275, whose response rate deviated from the linear function at the shortest RT interval. In contrast, response rates during time-out were not reliably different under the different conditions. Although the mean time-out response rate in some cases showed systematic decreases with increases in RT interval length, the ranges of values at all RT intervals show considerable overlap.

The relationship between RT interval and the number of time-outs delivered per session (see Fig. 2) was less consistent across subjects than that between RT interval and time-in response rate. Although there was a tendency for time-out presentations to decrease with longer RT intervals, these decreases were not systematically related to RT interval length. It is of interest to note the large differences in response rate under different RT intervals in the presence of similar frequencies of time-out presentation. For example, compare response and time-out rates for P-7820 under RT interval=5 and 10 sec and for P-6441 under RT interval=5 and 20 sec.

Figure 1. Response rates during time-in for each subject as a function of the RT interval. Points, horizontal lines and vertical bars represent means, medians and ranges of values observed, respectively, during the last 20 days exposure to each RT interval. Points have been slightly displaced to increase clarity. Note the logarithmic axes.

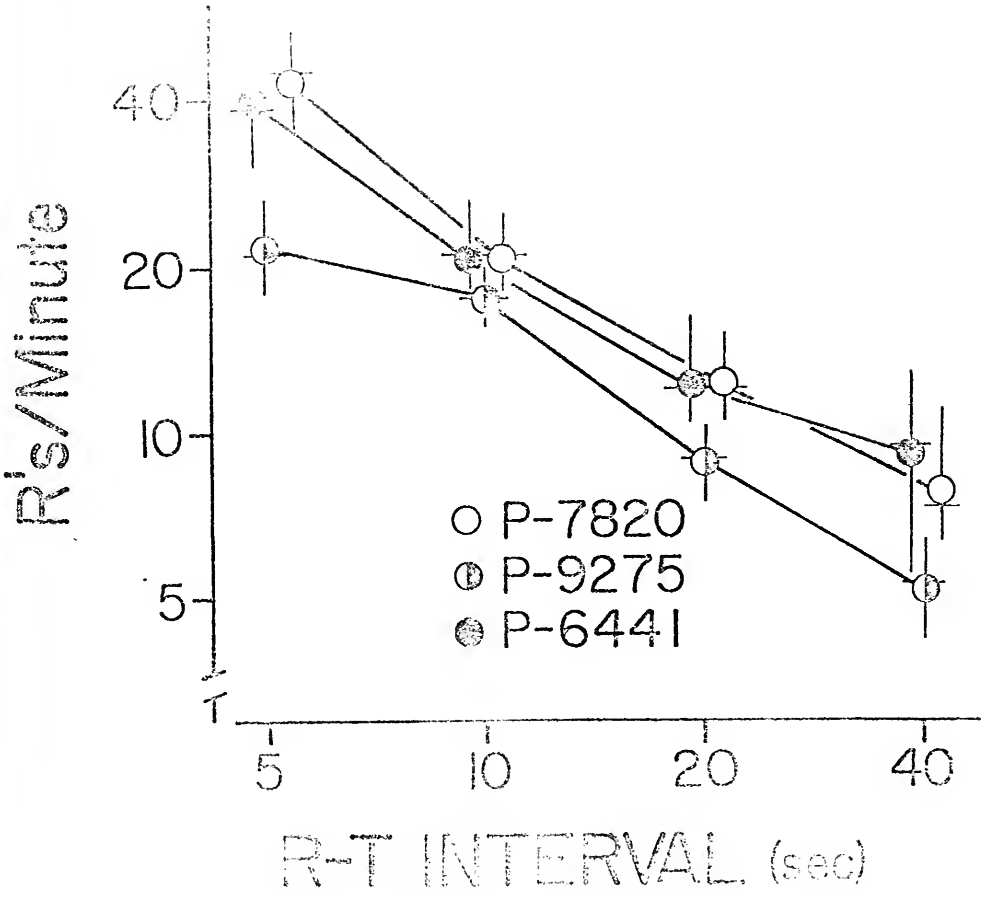
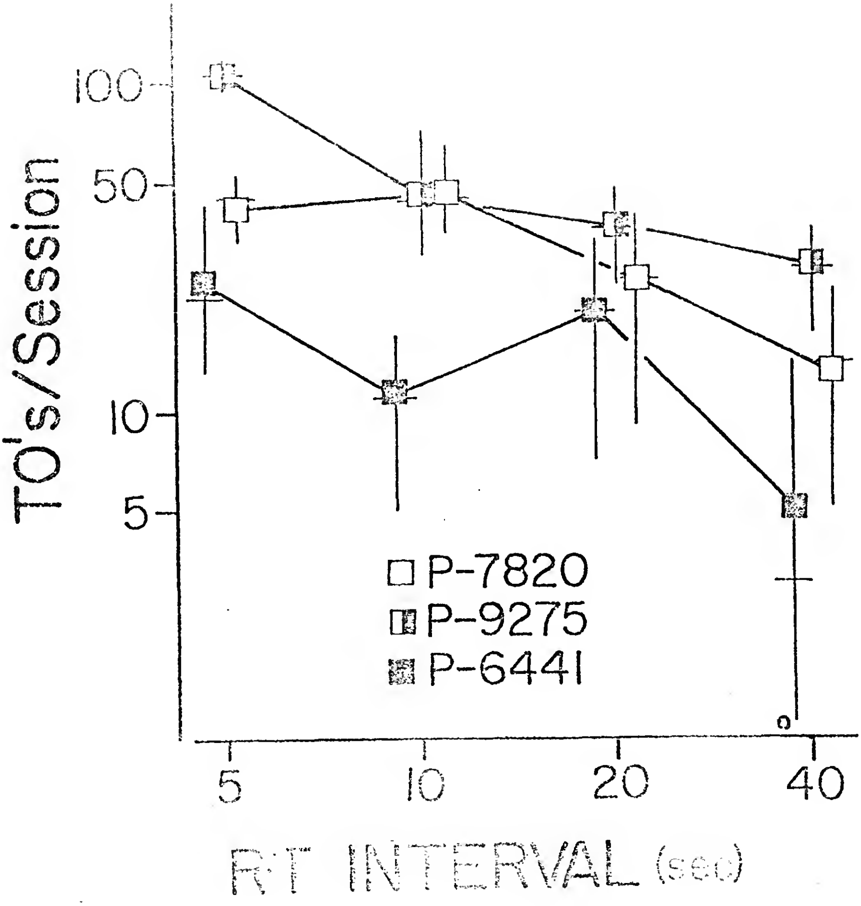

R's/Minute
40
20
10
5
5
10
20
40
R-T INTERVAL (sec)
○ P-7820
◐ P-9275
● P-6441

Figure 2. Numbers of time-outs delivered to each subject as a function of the RT interval. Figure characteristics are the same as those for Fig. 1.


100
50
10
5
TO's/Session
□ P-7820
◨ P-9275
▨ P-6441
0
5
10
20
40
RT INTERVAL (sec)

Cumulative response records obtained under the different RT interval values are presented for each subject in Fig. 3. Response rates were fairly constant within sessions, with occasional bursts following time-out (some examples of these have been denoted in the figure by arrows). Conspicuously absent from these records are any large "warm-up" effects (i.e., decreased response and increased aversive stimulus rates early in the session; see, e.g., Hineline, 1978a, 1978b; Sidman, 1966) characteristically shown by rats, but as yet unreported in pigeons, under comparable shock-postponement procedures. Although a careful analysis of such effects was not conducted, informal observation suggested that response rates were usually higher early in the session than late (e.g., see records for P-7820 at RT interval=5 and 10 sec, P-9275 at 5 and 20 sec, and P-6441 at 5 sec).

Patterns of responding within the RT interval are presented in Fig. 4. (Due to a program malfunction data are available for only some conditions.) Shown are the relative frequencies and conditional probabilities (i.e., IRTs/Op) of IRTs in each fifth of the RT interval averaged across the last 5 sessions under each condition. All subjects showed a high relative frequency of IRTs in the first class interval ("bin"), usually with monotonically decreasing frequencies thereafter. Three of the eight conditional probability distributions, however, show clear increases in the conditional probability of an IRT at values longer than the second bin. Subject P-7820 produced U-shaped distributions of

Figure 3. Representative cumulative records for each subject under the different RT intervals. In each record, time reads from left to right. The upper (response) pen stepped vertically with each response during time-in, reset to baseline after 550 responses, and was deflected during time-out (and the motor stopped). Defections of the lower (event) pen denote food presentations. Records were selected from sessions that most closely approximated both the median response rate and number of time-outs delivered at each RT interval.

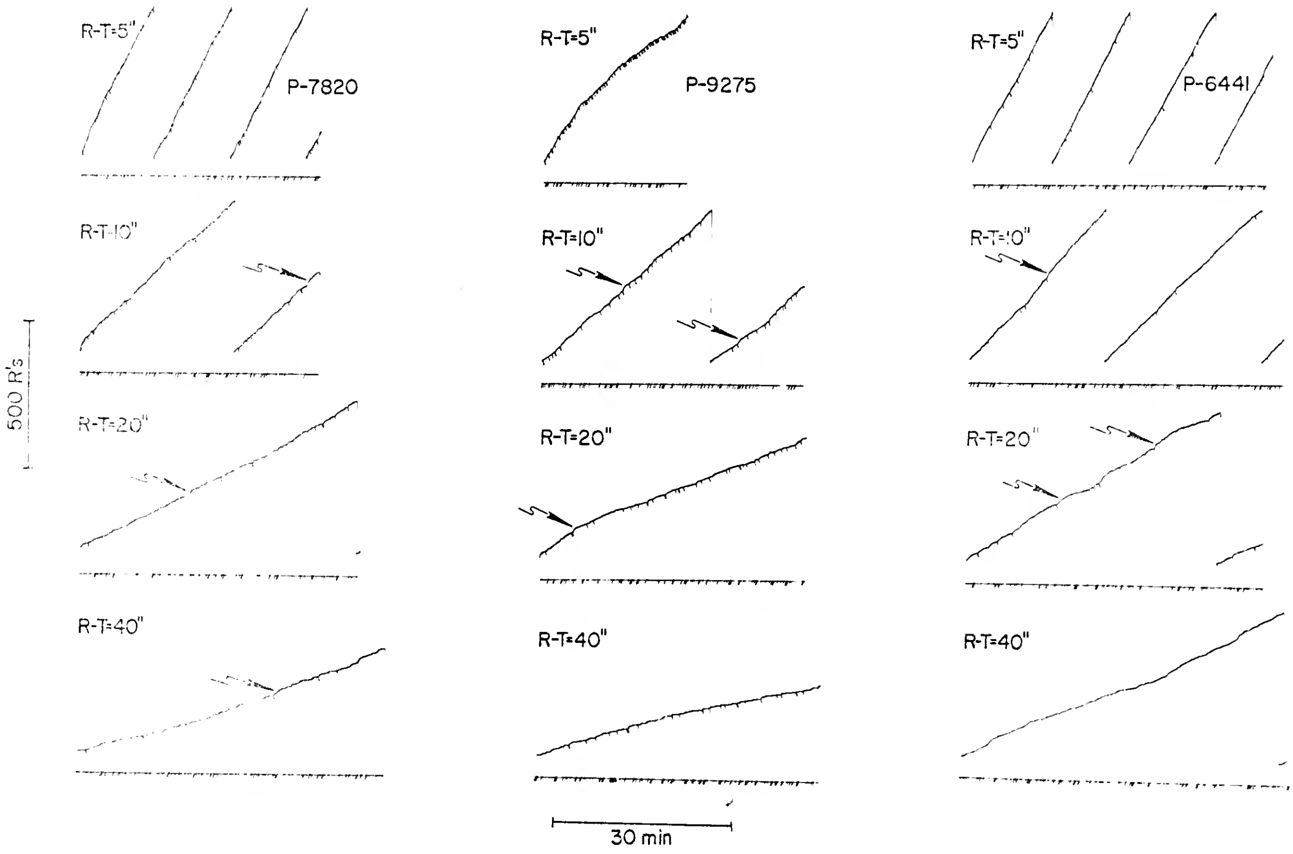
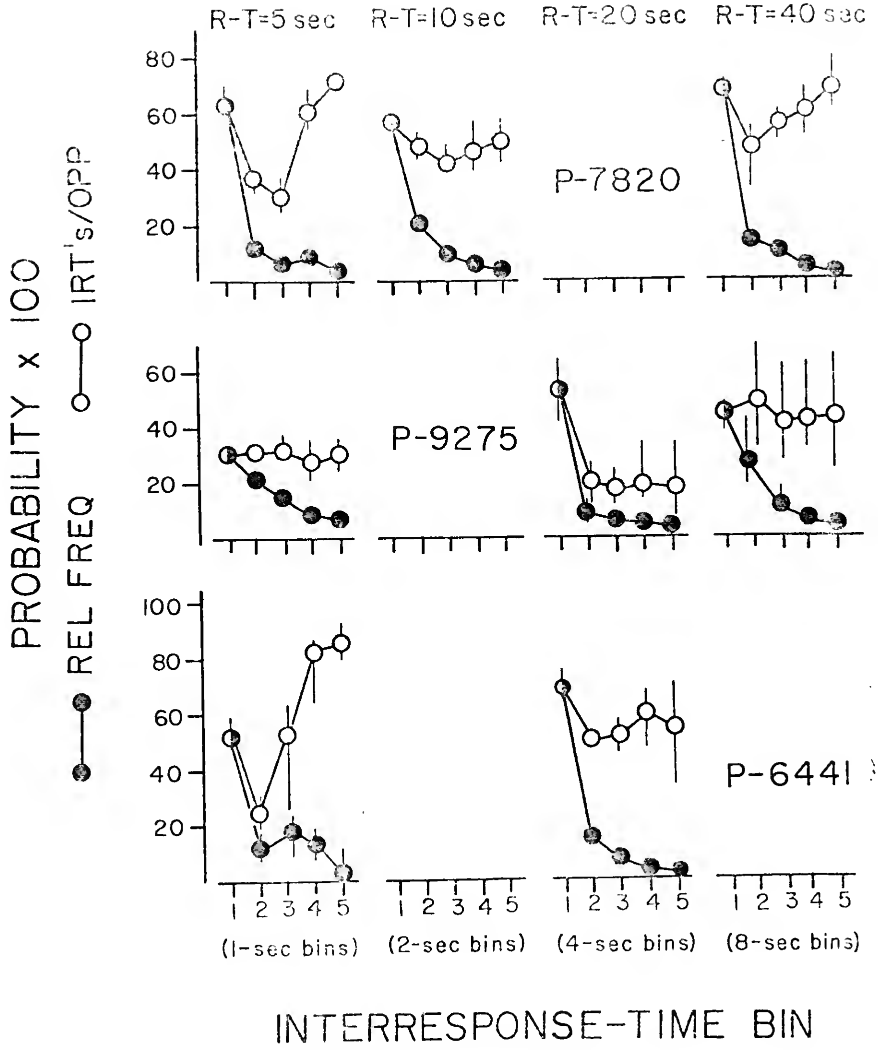

R-T=5"
P-7820
R-T=5"
P-9275
R-T=5"
P-6441
R-T=10"
R-T=10"
R-T=10"
500 R's
R-T=20"
R-T=20"
R-T=20"
R-T=40"
R-T=40"
R-T=40"
30 min

Figure 4. Relative frequency (filled circles) and conditional probability (open circles) distributions for IRTs in fifths of the RT interval. Points and vertical bars represent means and ranges, respectively, of values observed during the last 5 sessions at each RT interval. (Due to an apparatus malfunction, data are only available for some RT intervals.) Ranges of points without vertical bars are contained within the point.


R-T=5 sec
R-T=10 sec
R-T=20 sec
R-T=40 sec
P-7820
P-9275
P-6441
80
60
40
20
100
PROBABILITY x 100
REL FREQ
IRT's/OPP
1 2 3 4 5
(1-sec bins)
(2-sec bins)
(4-sec bins)
(8-sec bins)
INTERRESPONSE-TIME BIN

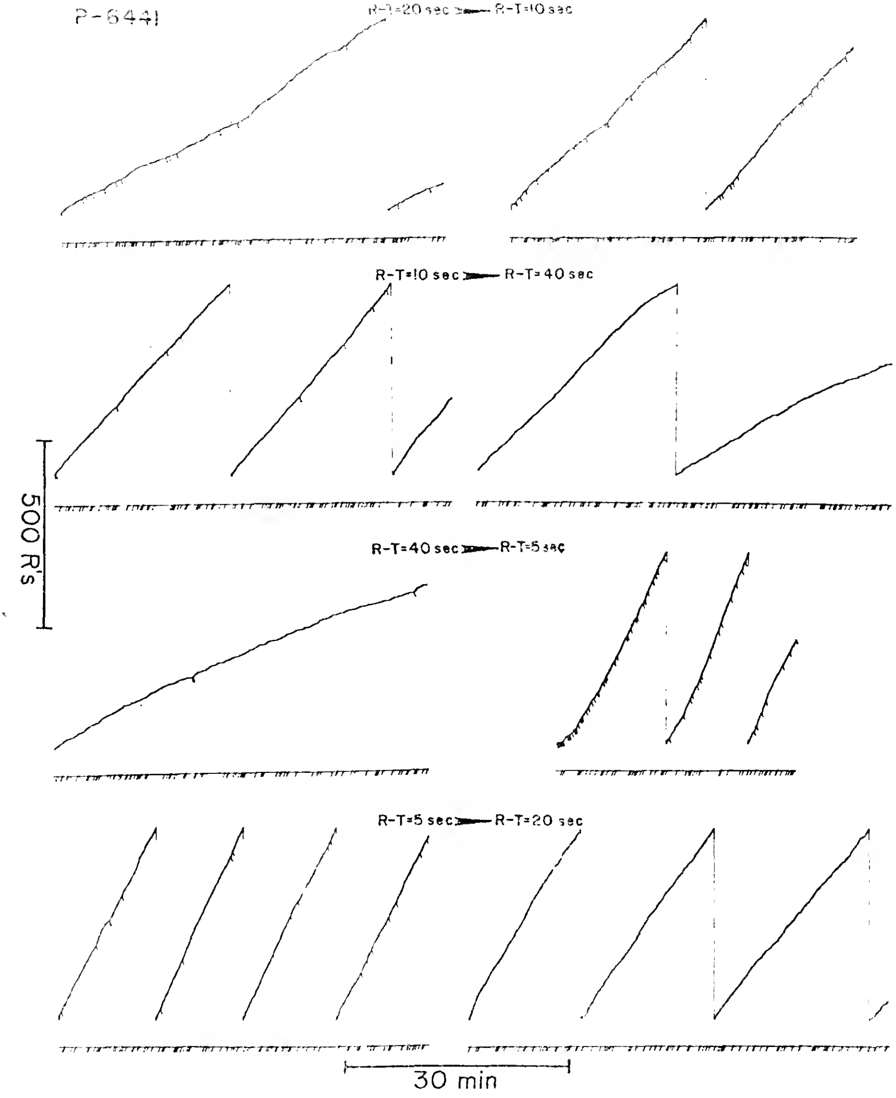
IRTs/Op at all RT intervals, although the differences in conditional probabilities between IRT classes were small at RT interval=10 sec. Interresponse-time distributions of P-9275 showed little temporal control over responding by RT interval at any RT interval length, whereas distributions for P-6441 showed temporal control over IRTs at RT interval=5 sec but not 20 sec.

The development of steady-state performance occasionally required a great deal of exposure to the different RT interval values, due more to short-term oscillations in response rate than to gradual transitions between experimental phases. Indeed, initial transitions were generally very rapid. Data depicting such transitions for P-6441, a representative subject, are presented in Fig. 5 in the form of cumulative response records. On the left are cumulative records obtained during the last day of exposure to one RT interval, and on the right those obtained under the first day of exposure to the subsequent RT interval. Comparison of records on the right with those immediately below it on the left (the first and last day of exposure to a specific RT interval, respectively) reveals that response rates approximating those obtained after extended exposure were generally obtained by the last third of the first session under the new RT interval value.

Discussion

Key pecking was reliably and quickly engendered in all subjects under the present procedure. It should be noted that the

Figure 5. Cumulative records depicting transistions in key pecking of P-6441 between different RT intervals. Records on the left show responding during the last session at a specific RT interval value, those on the right during the first session of the subsequent value. The first and last day of exposure to a particular RT interval is shown, respectively, in a record on the right and the one immediately beneath it on the left. Recording characteristics are the same as those for Fig. 3.


P-6441
R-T=20 sec ➤ R-T=10 sec
R-T=10 sec ➤ R-T=40 sec
500 R's
R-T=40 sec ➤ R-T=5 sec
R-T=5 sec ➤ R-T=20 sec
30 min

procedure used to establish key pecking in two of the subjects (P-9275 and P-6441) was merely a modification of the procedure used by Brown and Jenkins (1968) to "autoshape" key pecking. Under their procedure, one stimulus was reliably followed after 8 sec by the presentation of food, while food was never presented in the presence of a second stimulus. Under the present procedure, the time-in and time-out stimuli, respectively, defined a similar differential relation with respect to food delivery (see, e.g., Gamzu & Williams, 1971, 1973), with the exception that food presentation could occur anytime during the presence of the former stimulus, not just following it.

The linear relation obtained in the present study between time-in response rate and RT interval (when plotted on double-log axes) was comparable to ones reported by Thomas (1965a), who used a similar procedure, and by others using analagous shock-postponement procedures (e.g., Clark & Hull, 1966; Klein & Rilling, 1972; Sidman, 1953; Todorov, Ferrari & de Souza, 1974), suggesting that responding was maintained in similar ways. Whether response rates would have decreased at even shorter RT intervals, as it does in other species (e.g., Sidman, 1953) cannot be readily determined, since RT intervals shorter than the TT interval were not examined. However, P-9275's deviation from the linear function towards a lower response rate at RT interval= 5 sec may be indicative of that kind of process.

Although the functions obtained were similar, the absolute response rates observed in the present study were much greater than those obtained by Thomas (1965a). Response rates observed by Thomas ranged from approximately 0.4-3.6 R/min, but from approximately 5.0-40.0 R/min under the present procedure. Given the number of procedural differences between the two studies, it is impossible to interpret these differences. However, differences in time-out duration and/or rate of food presentation, while producing different absolute response rates, did not substantially change the form of the functions obtained here relating response rate during time-in to RT interval from that observed by Thomas. This suggests that the "behavioral process" represented by this function may be largely independent of variables other than the length of response-contingent delay of time-out.

One procedural feature seemed to enhance performance greatly during initial pilot studies. During pilot experiments, as in Thomas's study, the time-in and time-out stimuli were signalled originally only by colors of the keylight, with the houselight remaining continuously illuminated. Under this pilot procedure, presentation of the time-out stimulus was followed typically by the subject turning away from the stimulus and engaging in other behavior (e.g., pecking the floor, preening, etc.). As such, the subject would typically be facing away from the response key when time-out ended. Often, the subsequent time-in period would elapse and another time-out ensue. A brief darkening of the houselight at time-out termination was therefore employed in an attempt to provide a discriminative stimulus which would be effective regardless of the subject's orientation with respect to the response key. The addition of this stimulus resulted in rapid termination of other ongoing behavior when time-in began and immediate approach towards the response key, thus enhancing performance.

The patterns of responding maintained under the present procedure were also highly comparable to those reported for rats bar pressing under comparable shock-postponement procedures (e.g., Boren, 1961; Ellen & Wilson, 1964) with the exception of the apparent absence of a large warm-up effect (e.g., Hineline, 1978_a_, 1978_b_; Sidman, 1966). If further analysis substantiates the lack of warm-up, it may lend credence to Hineline's (1978_a_) suggestion that such effects reflect habituation of non-operant behaviors evoked by aversive stimulation. It is possible that elicited key pecking directed at the stimulus signalling food delivery interacted with negatively-reinforced key pecking in ways functionally similar to the interactions suggested by Hineline. However, rather than "competing" with operant behavior as Hineline suggests it does under free-operant shock-postponement procedures, elicited behavior under the present procedure may have combined additively with negatively-reinforced key pecking since the food-correlated stimulus was located on the response key. Hence, response rates early in the session might be expected to be increased, rather than decreased early in the session, due to this transient additive influence. There are presently no data describing within-session changes in elicited pecking to either support or refute this interpretation.

The inconsistent development of temporal control over responding by RT interval length (as evidenced by increasing conditional IRT probabilities with increases in IRT length) across subjects and RT intervals cannot at the present time be interpreted with confidence. Sidman (1966) suggested that such control may occasionally develop slowly, and that stable rates of responding may be maintained without concomitant evidence of temporal control by RT interval length. Although each RT interval was in effect for a comparatively large number of sessions during the present study, the number necessary for this type of control to develop (if it does reliably develop) is at the present time unknown. It is clear from the present results that such control did not develop rapidly. However, since RT intervals were changed during the present study without regard to the distribution of IRTs, it is possible that extended exposure to each value would have resulted in increased temporal control over responding. It may be of interest in this regard that P-7820 (who most consistently evidenced some degree of temporal control over responding) was generally exposed to each RT interval longer than the other subjects.

In any event, it is clear that the vast majority of IRTs fell withing the range specified by the first bin in each distribution. It has been suggested that certain topographical characteristics of key pecking may result in the transduction of extremely short (less than 0.8 sec) IRTs which do not appear to be subject to control by positive reinforcement contingencies (e.g., Blough, 1966; Shimp, 1973). Whether this is the case here is difficult to ascertain given the relatively large class intervals used in the IRT analysis.

Although the present results suggest comparability between free-operant avoidance of time-out and avoidance of other aversive events, other interpretations are possible. First, the absence of a delay between a key peck and subsequent presentation of food may have led to the "superstitious" maintenance of key pecking. Although this claim cannot be refuted directly, it is difficult to see how decreases in the RT interval could produce increases in the frequency of accidental correlations between responses and food presentations necessary to account for the systematic increases in response rate observed at progressively shorter RT intervals. It might, in fact, be easier to argue the converse. That is, the frequency of spurious correlations might be expected to increase with increases in the amount of time-in time (and, hence, at longer RT intervals). However, it is possible that response rate increases initially produced by decreases in RT interval length may subsequently increase the probability of close contiguity or frequency of differential accidental correlations between responses and food presentations. These correlations may then further increase response rate, thus tending to overestimate the increase produced by the postponement contingency alone. However, such effects depend on the initial modification of behavior by the postponement contingency, and cannot, therefore, suggest that the avoidance contingencies were of little importance.

A second alternative interpretation of the present results involves the role of elicited key pecking under procedures involving differential stimulus-reinforcer contingencies. As previously discussed, food-deprived pigeons will peck at stimuli differentially correlated with the delivery of food. Additionally, the rate of pecking appears to increase as the duration of a signal differentially correlated with food presentation decreases relative to the duration of stimuli signalling either the absence of food (e.g., Baldock, 1974; Terrace, Gibbon, Farrell & Baldock, 1975) or a decreased frequency of food presentation (Spealman, 1976). Applied to the present situation, the relative duration of the time-in stimulus (signalling imminent food presentation) decreased with increases in the number of time-outs (signalling the absence of food) presented. Since the number of time-outs delivered tended to increase with decreases in the RT interval (and thus the relative "time-in" time decreased), the increased rates of responding at shorter RT intervals might be ascribed solely to increases in the rate of elicited key pecking. Although the large differences noted in response rates under the different RT interval values in the presence of similar rates of time-out presentation (see Figs. 1 and 2, particularly data for P-7820 at RT interval=5 and 10 sec and for P-6441 at

RT interval=5 and 20 sec) argue against such an interpretation, it might be argued that, while <u>frequencies</u> of time-out under the different conditions were comparable, the <u>distributions</u> of inter-time-out-intervals (times between successive time-out presentations) may not have been, thus producing differences in the rate of elicited pecking. Data obtained in the second and third experiments suggest, however, that an interpretation based solely on elicited key pecking cannot account for the performance generated under this procedure.

CHAPTER V
EXPERIMENT II

Interpretation of the results of Experiment I solely in terms of elicited key pecking would suggest that the response-contingent postponement of time-out was of little importance in the maintenance of different rates of key pecking except in providing a changing number of time-out presentations. If this interpretation is correct, then presentation of similar distributions of time-out independently of responding should produce little change in the rates of key pecking maintained. Conversely, interpretations based on the negative reinforcement provided by response-contingent delay of aversive stimulation would suggest that removal of such a contingency (i.e., programming "extinction") would result in decreases in response rate.

A number of extinction procedures have been used in the analysis of behavior maintained under free-operant avoidance procedures. The first consists simply of no longer presenting the aversive stimulus, and generally results in fairly rapid reductions in response rate (e.g., Boren & Sidman, 1957b; Schnidman, 1968). Although the effects of this manipulation are similar to extinction of positively reinforced behavior (where responding no longer results in the presentation of reinforcement), it has been argued that such a manipulation decreases responding through behavioral mechanisms other than extinction qua extinction. Davenport, Coger and Spector (1970), for example, have argued that the removal of shock reduces response rates either by removing the "motivation" that usually increases the effectiveness of aversive-stimulus delay as a reinforcer (much as pre-session feeding decreases responding maintained by response-contingent food presentation), or by reinforcing all responses equally, since all responses "delay" aversive stimulation for equal amounts of time. They suggest that a more "proper" extinction procedure would involve elimination of any response-contingent delay to the next aversive event, not elimination of the event itself, since the former, not the latter, presumably constitutes reinforcement under free-operant avoidance paradigms. Thus, for example, they would argue that, after training under a free-operant shock-postponement procedure with an RS interval=15 sec and an SS interval=5 sec, extinction would involve presentation of shock every 5 sec, independent of responding. This procedure does generally decrease response rates (e.g., Davenport, Coger & Spector, 1970; Davenport & Olson, 1968) but also produces a more or less drastic change in the prevailing stimulus conditions, depending on the level of responding maintained originally under the postponement procedure. That is, for an animal reliably responding within the RS interval (and thus reliably delaying shock), the sudden presentation of shock ever 5 sec serves as a highly discriminable change in the prevailing contingencies. Coulson, Coulson and Gardner (1970), recognizing this fact, have suggested a third procedure for the extinction of negatively reinforced behavior, involving the suspension of any response-contingent delay while maintaining comparable frequencies and distributions of response-independent aversive-event delivery. This procedure is also effective in reducing response rates, however, responding generally decreases more slowly and does not cease altogether (Coulson, Coulson & Gardner, 1970; Smith, 1973).

This last procedure is most relevant to the question of the role of elicited key pecking under the time-out delay procedure of Experiment I. To reiterate, key pecking maintained under the time-out-delay procedure should not be greatly affected by response-independent presentation of similar temporal distributions of time-outs if such responding is solely elicited by occasional presentation of the time-in stimulus. If, however, key pecking under this procedure depends on response-contingent delay of time-out, removal of the delay contingency, even in the presence of continued occasional presentation of time-out, should reduce response rates. The present experiment examined responding maintained under such a procedure and provided data on the recoverability of the performance engendered during Experiment I.

Method

Subjects and Apparatus

The subjects and apparatus used were the same as in Experiment I.

Procedure

Directly following exposure to RT interval=5 sec under Experiment I, each subject was returned to a previously examined RT interval; P-7820 to RT interval=10 sec, P-9275 to 40 sec and P-6441 to 20 sec. Exposure to a particular RT interval value was not randomly determined. Subject P-6441 finished the initial series first and subsequently was returned to the first value studied (i.e., RT interval=20 sec). In an attempt to minimize differences in the number of time-outs presented to each subject, P-9275 was subsequently exposed to RT interval=40 sec. Subject P-7820 was exposed to RT interval=10 sec in order to obtain data, albeit between subjects, at each of the three longer RT intervals. Responding was allowed to stabilize at these values according to the stability criterion outlined in Experiment I, and the sequential inter-time-out-intervals during each session were recorded. Subsequently, the delay contingency was suspended, and time-outs were occasionally presented at variable times independently of responding, with distributions "yoked" to those of the previous phase by programming inter-time-out-intervals equivalent to those obtained during the 20th preceding session (when the delay contingency was in effect). That is, the distribution of sequential inter-time-out-intervals from each of the last twenty sessions under the time-out delay contingency was programmed in the same ordinal position for a single session. Since time-out presentations occurred at varying times response-independently and were yoked to presentations under the delay contingency, this condition was termed a "yoked variable-time" (yoked-VT) schedule of time-out presentation. All other parameters of this procedure were equivalent to those in Experiment I. The yoked-VT schedule remained in effect for 20 sessions, at which point the delay contingency was reinstituted at the RT interval value prevailing prior to implementation of the yoked-VT schedule.

Results

Absolute response rates and numbers of time-outs presented under the initial reexposure to the RT interval and the subsequent yoked-VT schedule are presented for each subject in Table 2. For each subject, the rate of responding during reexposure to the RT interval was very similar to that obtained during exposure to that value in Experiment I. The correspondence between the number of time-outs delivered during the first and second exposures was also good, although differences may be noted (e.g., data for P-7820).

Response rates maintained under the postponement procedure and the subsequent yoked-VT procedure are shown, as a percent of the mean response rate under the postponement procedure, in Fig. 6. (Absolute response rates and numbers of time-outs presented during each session shown in Fig. 6 have been included in the Appendix.)

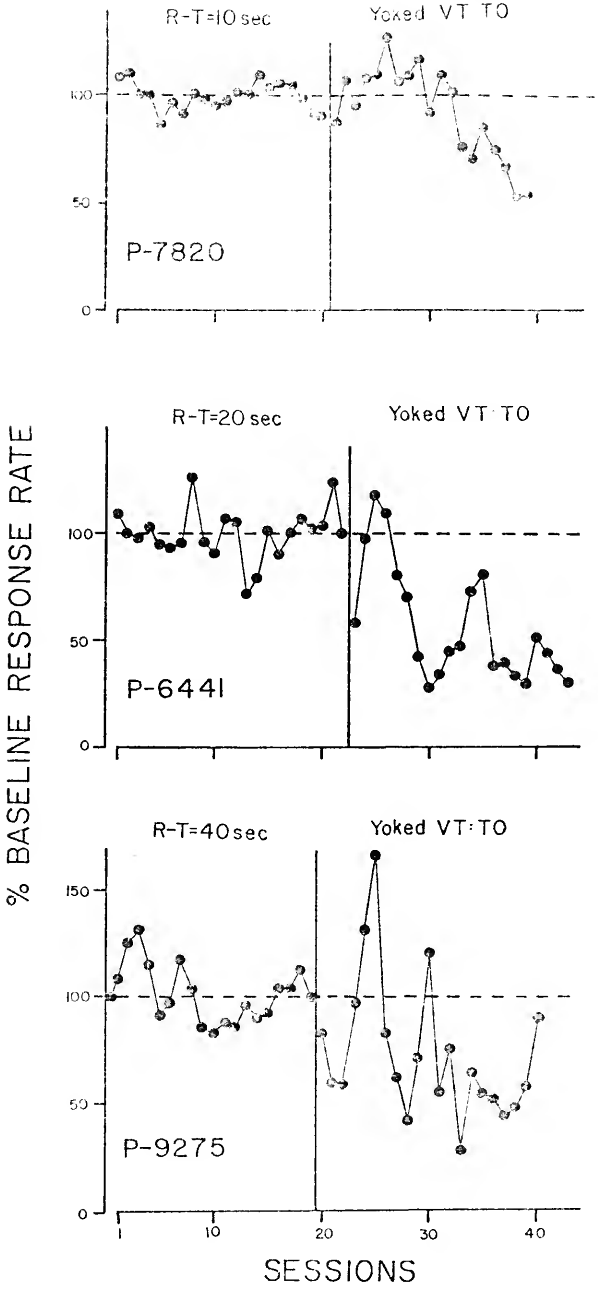
TABLE 2
LIST OF CONDITIONS AND SUMMARY MEASURES FOR EACH SUBJECT DURING EXPERIMENT II

SUBJECT	CONDITION	SESSIONS	RESPONSE RATE (R/min)		TIME-OUTS
			Time-in	Time-out	
P-7820	RT interval=10 sec	(101)	26.56 (22.92-29.22)	0.63 (0.08-1.48)	33.5 (25-46)
	Yoked-VT:time-out	(20)	17.69 (14.10-22.56)	0.39 (0.07-1.12)	----
P-6441	RT interval=20 sec	(118)	14.16 (10.20-18.42)	0.41 (0.00-1.01)	16.3 (7-31)
	Yoked-VT:time-out	(20)	5.62 (4.29-7.32)	0.39 (0.20-0.48)	----
P-9275	RT interval=40 sec	(32)	4.25 (3.36-5.64)	0.08 (0.00-0.25)	27.8 (18-41)
	Yoked-VT:time-out	(20)	2.54 (1.92-3.90)	0.06 (0.00-0.18)	----

---

[a] Values are the means of the last 20 (delay conditions) or 5 (yoked-VT) sessions under each procedure. Ranges are shown in parentheses.

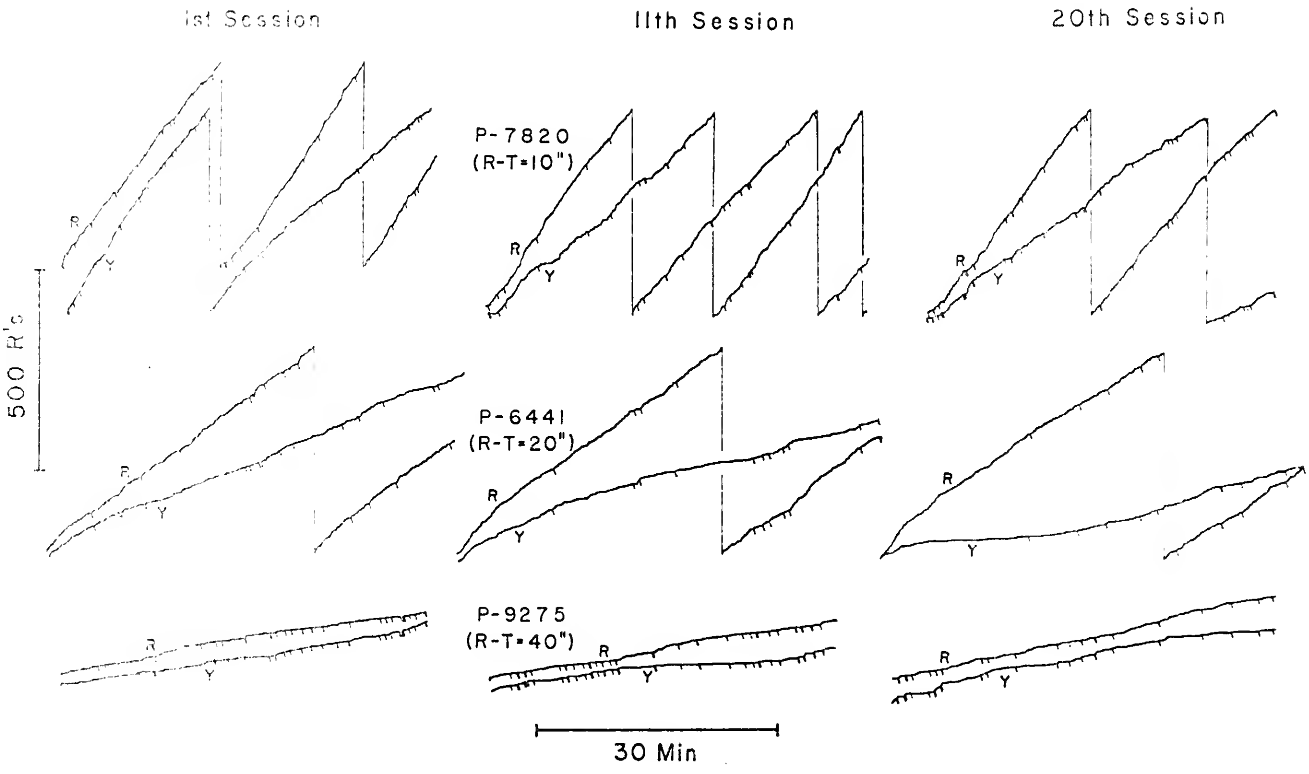
Figure 6. Daily session response rates for each subject under the delay and yoked-VT contingencies. Data were taken from the last 20 sessions under the delay contingency (to the left of the vertical line) for from the 20 sessions the yoked-VT contingency was in effect (to the right). Response rates are expressed as a percentage of the mean rate during the last 20 sessions under the delay contingency.


R-T=10 sec
Yoked VT TO
P-7820
R-T=20 sec
Yoked VT TO
P-6441
R-T=40 sec
Yoked VT:TO
P-9275
% BASELINE RESPONSE RATE
0
50
100
150
1
10
20
30
40
SESSIONS

Removing the response-contingent delay decreased rates of responding during time-in by at least 50% in every subject within the 20 sessions the yoked-VT schedule was in effect. Neither the degree of relative suppression nor the rate with which responding was suppressed appeared to be systematically related to the RT interval value under the postponement procedure. Absolute response rates under the yoked-VT procedure were, by contrast, inversely related to the RT interval (after 20 sessions exposure to this procedure).

Intrasession patterns of responding maintained in each subject under the delay and the yoked-VT procedures are depicted in Fig. 7. Cumulative response records presented were taken from the last twenty sessions under the delay procedure or from the twenty days the yoked-VT schedule was in effect. Three pairs of records are shown for each subject, taken from the 1st, 11th and 20th session. The pairs of records are from sessions during which the delay contingency was in effect (labelled "R"), and from the sessions under the yoked-VT procedure (labelled "Y") which were matched with respect to time-out presentation to the former. (The records have been overlayed to highlight the correspondence between inter-time-out-intervals under the two procedures.) While response rates under the yoked-VT procedure generally progressively declined with extended exposure to this contingency, no systematic differences were observed in the patterns of responding. The subjects exposed to the two longer RT intervals prior to the yoked phase (i.e., P-6441 and P-9275) both paused for long periods during the middle

Figure 7. Cumulative records from selected sessions under the delay contingency and under the corresponding Yoked-VT session. Records were taken from the 1st, 11th or 20th session of the last 20 sessions the delay contingency was in effect and of the Yoked-VT procedure. Records from sessions under the delay contingency (labeled "R" in the figure) have been overlapped with records from corresponding sessions under the yoked-VT procedure (labeled "Y"). Event pen tracings have been removed fom each record, otherwise recording characteristics are the same as those for Fig. 3. (Occassional extended deflections of the response pen were the result of an infrequent mechanichal failure which did not stop the motor during time-out.)


1st Session
11th Session
20th Session
P-7820
(R-T=10")
P-6441
(R-T=20")
P-9275
(R-T=40")
R
Y
500 R's
30 Min

of the 20th session under the yoked-VT procedure, and responded earlier and later in the session at rates reduced below those under the delay procedure. Such intrasession variations in response rate were not observed with P-7820, who, although responding at rates lower than those under the delay contingency, still responded at substantial rates after 20 days under the yoked-VT procedure.

Reinstatement of the postponement contingency increased response rates to values comparable to or above those observed prior to the yoked-VT procedure. The length of this transition varied between subjects, with P-7820, P-6441 and P-9275 responding at rates equal to or above the mean rate under the postponement procedure after 10, 25 or 1 session, respectively.

Discussion

The results of Experiment II indicated that 1) response rates (and to a lesser degree time-out rates) obtained under reexposure to an RT interval value were highly comparable to those obtained under initial exposure to that value during Experiment I, and 2) the delay contingency was essential in maintaining the rates of responding observed under free-operant avoidance procedures when time-out is used as an aversive stimulus. The decreases in response rate observed when distributions of response-independent time-outs were exactly matched to those of the immediately preceding response-contingent delay procedure argue against the notion that key pecking observed under the delay procedure was governed solely by stimulus-reinforcer contingencies.

Although the present results indicate that the delay contingency was crucial in determining the rates of responding engendered, they do not rule out the possibility that elicited key pecking directed at the time-in stimulus occurred and thus contributed to the overall rate of responding. Recall that the absolute rate of responding under the yoked-VT procedure was inversely related (after 20 sessions exposure) to the value of the preceding RT interval value. At least two interpretations of this effect are possible. First, it might be suggested that shorter delays occur between responses and subsequent response-independent time-outs as the average inter-time-out-interval decreases. This may increase the likelihood that "superstitious" negatively-reinforced responding will occur at higher rates when the yoked distribution is taken from a preceding condition involving a shorter RT interval (and hence, possibly shorter inter-time-out-intervals). Alternatively, it might be argued that decreasing the RT interval increases the number of time-outs delivered (or the probability of short inter-time-out-intervals) and thus engenders more elicited pecking by decreasing the relative amount of "time-in" time (cf., Terrace, Gibbon, Farrell & Baldock, 1975). Both the "superstitious maintenance" and the "elicitation" notions rest on the assumption that the number of time-outs delivered increases with decreases in the RT interval. Although an attempt was made to minimize differences between subjects in the number of time-outs delivered during the yoked-VT condition, some between-subject differences may be noted (see Table 2).

These two interpretations cannot be evaluated independently under the procedures used thus far; either, both or neither could be correct. Assuming the elicitation notion to be true, it is possible that the slopes of the function relating response rate during time-in to RT interval obtained during Experiment I are greater than they would be in the absence of elicited behavior directed at the stimuli on the response key (given the added assumption that shorter RT intervals elicit more signal-directed pecking). It is entirely possible that key pecking is controlled by response-contingent delay of time-out, but not by the length of the consequent delay. Experiment III provided evidence suggesting, however, that this is not the case.

CHAPTER VI
EXPERIMENT III

In food-deprived pigeons, pecking directed at some stimulus typically occurs only when that stimulus signals a higher frequency or probability of food presentation than that signalled in the absence of that stimulus (e.g., Brown & Jenkins, 1968; Gamzu & Williams, 1973; Keller, 1974). Additionally, the probability and/or rate of elicited pecking is inversely related to both the relative and absolute duration of the positively-correlated stimulus (e.g., Baldock, 1974; Spealman, 1978; Terrace, Gibbon, Farrell & Baldock, 1975). Hence, a continuously present stimulus (i.e., one of long duration which is non-differentially correlated with the presentation of food) should be less effective in eliciting pecking than shorter, differentially-correlated stimuli.

Keller (1974) developed a procedure under which key pecks to one operandum (the "food" key) occasionally resulted in the presentation of food while responses to a second key had no scheduled consequences. Presented on this latter key (the "signal" key) were stimuli correlated with the availability of reinforcement contingent on responses to the food key which was continuously illuminated with a single stimulus. Keller argued that responses to the signal key were predominantly elicited key pecks, since they only occurred when the two stimuli presented on it signalled non-equal frequencies of food presentation, and also since responses were directed primarily at the stimulus signalling a higher frequency of food presentation. He argued further that those occurring on the food key were predominantly operant key pecks maintained by response-contingent reinforcement, since response rates on the food key changed only as a function of the frequency of reinforcement. His procedure, then, allows for the "topographical tagging" (cf., Catania, 1971, 1973) of presumably different response classes; operant responses on the food key and elicited responses to the signal key.

The use of such a procedure may clarify interactions between negatively-reinforced and elicited key pecking under free-operant avoidance procedures involving time-out from response-independent food presentation. To the extent that elicited key pecks to the time-in stimulus combine with those (operant) key pecks maintained by time-out delay, the separate contributions of each may be assessed by relocating the stimuli correlated with time-in or time-out away from the operandum associated with response-contingent delay of time-out. By projecting these correlated stimuli onto another response key, not only may operant responses be recorded in the relative absence of interactions with elicited responses, but also an independent measure of elicited responding may be automatically obtained.

Experiment III examined the effects of response-contingent delay of time-out under such a "two-key" procedure. As in Experiment I, a range of RT intervals was examined while maintaining a contant TT interval. Differences between the results of the first and present experiment (at least possibly) may be taken as evidence for the contribution of elicited key pecking under the first "one-key" procedure.

Method

Subjects

The subjects were the same as in the previous experments.

Apparatus

The same experimental appartus was used, with the exception that plexiglas extensions, similar to the one described earlier, eventually were added to both side keys, located 8 cm (center to center) to either side of and in the same horizontal plane as the center key. Of these, the left key was illuminated and operative. A static force in excess of 0.15 N to this key was recorded as a response. (The plexiglas extension was added to the right key to accomodate another experiment.

Procedure

Each subject was exposed to a different number of "two-key" procedures, depending on when in real time they completed Experiment II. Subject P-9275 was the first pigeon exposed to a two-key procedure. Under this first procedure, responses to the center ("delay") key during time-in produced a "click" and postponed the next time-out for the period of time specified by the RT interval as in Experiment II, but this key was now continuously illuminated amber. The left ("signal") key was illuminated white or red, correlated as before with time-in and time-out, respectively. Responses to this key, however, like responses to the delay key during time-out, produced no experimentally-arranged consequences. After 40 sessions under this procedure, the side keys, to this point recessed behind the front panel, were modified by the addition of the plexiglas extensions described above. Following this modification, P-9275 and P-6441 were exposed to this procedure for 14 and 9 sessions, respectively, at which point the stimuli on the keys were altered. The delay key was now continuously illuminated white, while the signal key alternated from blue ("time-in") to green ("time-out"). (The variables responsible for these procedural variations are discussed below.) All subjects were then exposed to this "revised" procedure, and the RT interval was manipulated across the same range of values as in Experiment I while the TT interval remained constant at 5 sec. All other parameters of this procedure (e.g., time-out duration, frequency and duration of grain presentations, etc.) were the same as in the previous experiments. The number of days exposure and order of exposure to the different RT interval values are presented for each subject in Table 3. After extended exposure to these procedures, P-9275 responded only infrequently, and was not subsequently exposed to other RT interval values.

TABLE 3

LIST OF CONDITIONS AND SUMMARY MEASURES FOR EACH SUBJECT DURING EXPERIMENT III

SUBJECT	RT INTERVAL (sec)	SESSIONS (ORDER)	RESPONSE RATES (R/min)[a]				TIME-OUTS
			DELAY KEY		SIGNAL KEY		
			Time-in	Time-out	Time-in	Time-out	
P-7820	5	71 (3)	50.33 (45.40-55.57)	1.33 (0.66-1.68)	0.02 (0.00-0.13)	0.01 (0.00-0.07)	74.4 (58-83)
	10	118 (1)	28.61 (22.86-35.15)	1.01 (0.55-1.62)	0.00 ------	0.00 ------	41.4 (25-56)
	40	253 (2)	14.43 (10.74-18.72)	1.37 (0.00-3.30)	0.01 (0.00-0.06)	0.00 (0.00-0.06)	23.5 (8-41)
P-9275	20	94 (2)	3.27 (0.00-5.59)	1.82 (0.00-4.85)	2.42 (0.53-4.04)	0.06 (0.00-0.22)	113.2 (95-143)
	40	254 (1)	2.40 (1.80-3.06)	0.97 (0.00-2.22)	1.36 (0.81-2.70)	0.05 (0.00-0.37)	85.0 (68-105)
P-6441	5	33 (2)	27.90 (24.48-32.76)	4.20 (1.93-11.76)	0.00 ------	0.89 (0.00-1.05)	89.6 (75-93)
	10	133 (3)	15.90 (11.94-19.86)	4.33 (0.17-8.88)	36.27 (15.57-67.25)	4.74 (1.33-11.04)	85.8 (73-109)
	20	47 (1)	12.48 (10.92-14.40)	1.94 (0.72-7.20)	0.03 (0.00-0.55)	0.29 (0.00-3.53)	22.0 (14-30)
	40	67 (4)	10.02 (7.74-14.40)	2.86 (0.61-4.50)	0.14 (0.00-1.74)	0.06 (0.00-0.36)	11.7 (6-18)

Distribution of Signal-Key Pecks as a Function of Post-Time-Out-Time
for P-6441 at RT Interval=10 sec

	SEC POST-TIME-OUT					
	1	2	3	4	5	>5
R/min	[illegible].42 ([illegible].38- 78.[illegible])	73.03 (15.11- 137.20)	94.02 (30.00- 215.[illegible])	100.05 (33.70- 210.[illegible])	101.61 (9.95- 193.60)	21.72 (5.70- 51.[illegible])

---

[a] Values shown are means of values observed during the last 20 sessions under each condition. Ranges of these values are shown in parentheses.

Results

Summary measures for each subject under each condition are presented in Table 3.

Under the initial two-key procedure (i.e., delay key lit amber, signal key lit white or red), P-9275 never pecked the signal key, and pecked the delay key only at a very low rate (never more than 1.3 R/min). However, he did reliably peck the delay key at a higher rate during time-in than during time-out. The addition of the plexiglas extension resulted in substantial rates of signal-key pecking during time-in (range 6.0-19.5 R/min), whereas this key was pecked very infrequently during time-out. Response rates on the delay key, however, subsequently dropped to near zero, and responding no longer reliably occurred at higher rates during time-in than during time-out. Subject P-6441 behaved in like manner under this procedure, responding on the signal key during time-in at rates in excess of 90 R/min and less than 12 R/min during time-out, while responding on the delay key, during both time-in and time-out, ceased after 6 sessions.

Under the revised two-key procedure (i.e., delay key continuously lit white, signal key lit blue/green), both subjects immediately pecked the delay key, and responding on the signal key occurred only rarely. Response rates on the delay key were, with the exception of two sessions, always higher during time-in than during time-out for P-6441, whereas P-9275 showed such differential responding after the initial 12 sessions (with the exception of a single rate reversal during the 22nd session). When P-7820 was exposed to this procedure, higher rates on the delay key during time-in than during time-out occurred during every session, and signal-key pecking occurred extremely infrequently.

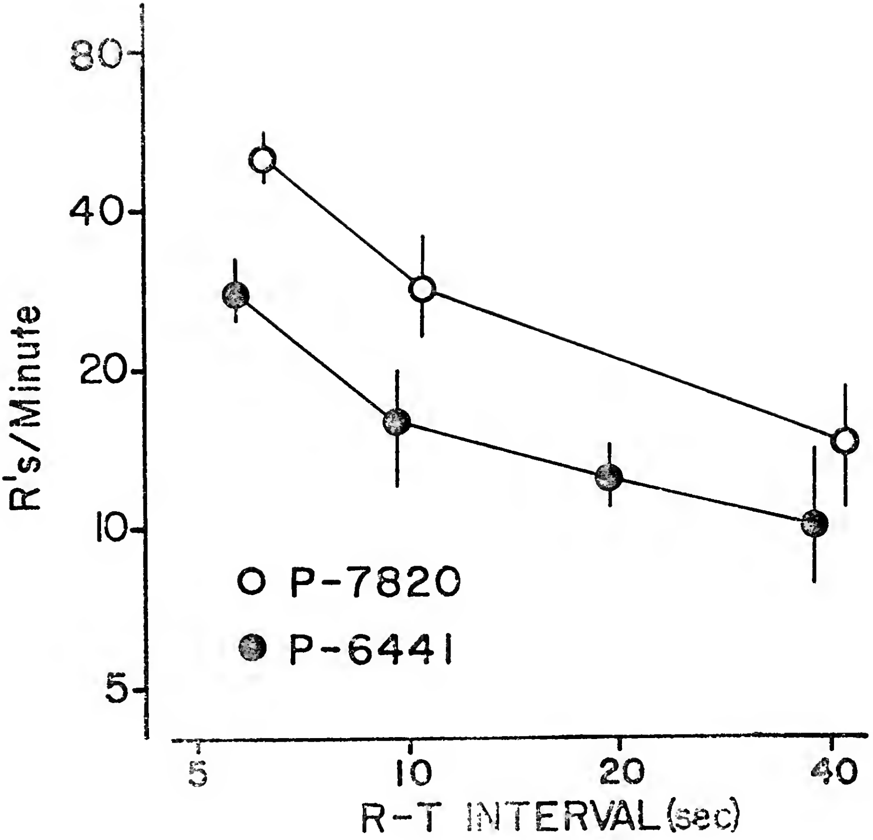
Responding subsequently maintained under this procedure was different for P-9275 than for the other subjects, and as such will be discussed separately. During the first 108 sessions under this procedure, P-9275 responded almost exclusively on the delay key, and response rates were (with the exception of the 78th session) consistently higher during time-in than during time-out. The number of time-outs delivered per session during this period was highly variable, ranging between 27 and 81. Beginning with the 88th session, the number of time-outs delivered began to increase steadily across sessions, reaching a maximum of 120 on the 108th session. During this and all subsequent sessions, this subject reliably pecked the signal key during time-in. Also during this session, response rates on the delay key did not differ during time-in and time-out. Reliable stimulus control over delay-key responding never reappeared. Subject P-9275 susequently also responded on the signal key during time-out, but less reliably and at a much lower rate than during time-in. After 88 additional sessions exposure to the two-key procedure, the RT interval was decreased from 40 to 20 sec. This value remained in effect for 60 sessions. At that point, the rates of responding on both the signal and delay keys were not appreciably different from those obtained when the RT interval equalled 40 sec, and the subject was dropped from the experiment.

For the other two subjects, manipulation of the response-contingent delay length produced orderly changes in response rates on the delay key. Figure 8 shows rates of responding on the delay key during time-in for both remaining subjects. As in Experiment I, response rates on the delay-key during time-in were (slightly less linear) monotonically decreasing functions of RT interval (again, on double-log axes). The slopes of these functions were slightly lower than those obtained during Experiment I. However the changes in response rate responsible for this change in slope was not systematic across subjects. Except at RT interval=5 sec subject P-7820 showed higher rates of responding under the two-key procedure. In contrast, P-6441 showed slightly reduced rates at the shorter RT intervals (i.e., 5 and 10 sec), but response rates comparable to those obtained under the one-key procedure of Experiment I at the longer RT intervals.

Unlike responding on the delay key during time-in, responding during time-out was not systematically related to RT interval. Rates of responding were also consistently lower during time-out than during time-in.

Subject P-7820 did not reliably peck the signal key at any RT interval value, and never pecked at substantial rates (i.e.,

Figure 8. Response rates on the delay-key during time-in for P-7820 and P-6441 as a function of the RT interval. Characteristics of this figure are the same as those for Fig. 1, with the exception that medians are not presented.


80
40
20
10
5
R's/Minute
○ P-7820
● P-6441
5
10
20
40
R-T INTERVAL(sec)

never more than 5 responses during any single one hour session). Signal-key responding for P-6441 depended on the RT interval, but not in a simple manner. At RT interval=20 sec, signal-key responding was not reliably observed, and when observed occurred at only extremely low rates. Surprisingly, there was a tendency for signal-key responding to occur more reliably and frequently during time-out than during time-in. This difference was very slight, however, due to the low overall rates of signal-key pecking. When the RT interval was reduced to 5 sec, signal-key responding all but ceased, with no responses whatsoever observed during the final 14 sessions. After 32 sessions of exposure to RT interval=10 sec,however, signal-key pecking reliably occurred during both time-in and time-out, with consistently higher rates during time-in. During this phase signal-key responding showed a great deal of variability across sessions, and after 102 additional sessions exposure showed no signs of becoming less so. Response rates on the signal key ranged between 15.57-67.25 R/min during time-in and 1.33-11.04 R/min during time-out across the last 20 sessions under RT interval=10 sec. (Responding on the delay key following the appearance of signal-key pecking decreased drastically, but subsequently recovered (after 34 sessions of diminished rates) and stabilized at the values depicted in Table 3 and Fig. 8) Table 3 presents the temporal distribution of time-in signal-key pecks during this phase as a function of post-time-out time. The rate of pecking typically increased across the first 5 sec after a time-out, and was lower thereafter (i.e., greater than 5 sec post-time-out). Finally, when exposed to RT interval=40 sec, P-6441 pecked the signal-key during both time-in and time-out less reliably and at rates much lower than those observed when the RT interval was 10 sec.

Figure 9 shows representative cumulative records of responding for P-7820 and P-6441 obtained under each RT interval value. Patterns of responding on the delay key were comparable to those observed under the single-key procedure, with the exception of a decreased response rate (and subsequent increased time-out rate) early in the session. Note that under RT interval=10 sec for P-6441 (during which substantial signal-key pecking occurred) the frequency of signal-key pecking was much higher early in the session.

Figure 10 shows the number of time-outs delivered under each RT interval for both subjects. As in Experiment I, there was a tendency for the frequency of time-out presentation to decrease with increases in RT interval length, but in a less systematic manner than delay-key response rates during time-in. Both subjects received more time-outs at the shorter RT intervals (i.e., RT interval=5 sec for P-7820 and RT interval=5 and 10 sec for P-6441) under the two-key than under the one-key procedure, whereas the frequency of time-out presentation under longer RT intervals was comparable under the two procedures.

Figure 9. Representative cumulative records for P-7820 and P-6441 under the RT intervals of the two-key procedure. Recording characteristics for the response pen are the same as Figs. 3 and 8, but momentary deflections of the event pen represent signal key pecks during both time-in and time-out.

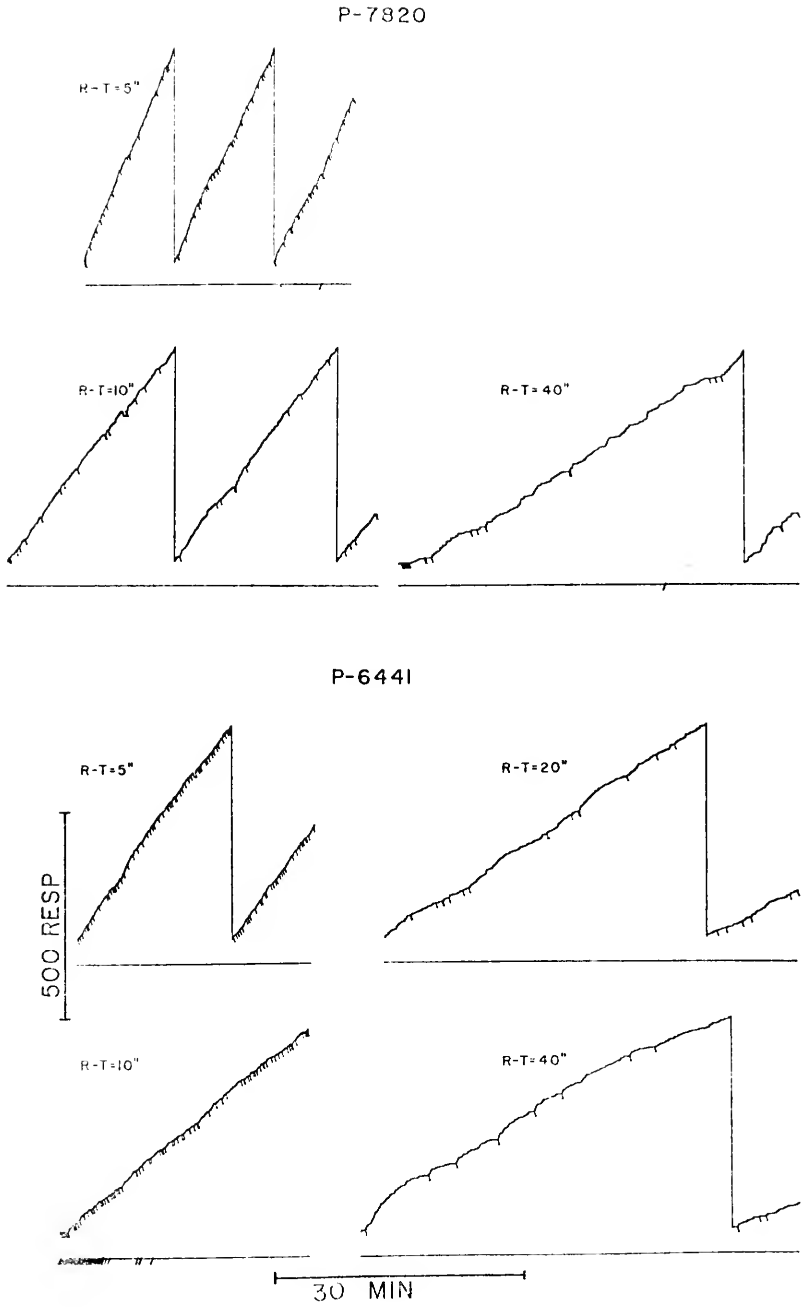

P-7820
R-T=5"
R-T=10"
R-T=40"
P-6441
R-T=5"
R-T=20"
500 RESP
R-T=10"
R-T=40"
30 MIN

Figure 10. Numbers of time-outs delivered to P-7820 and P-6441 under the two-key procedure as a function of the RT interval. Characteristics for this figure are the same as those for Fig. 8.

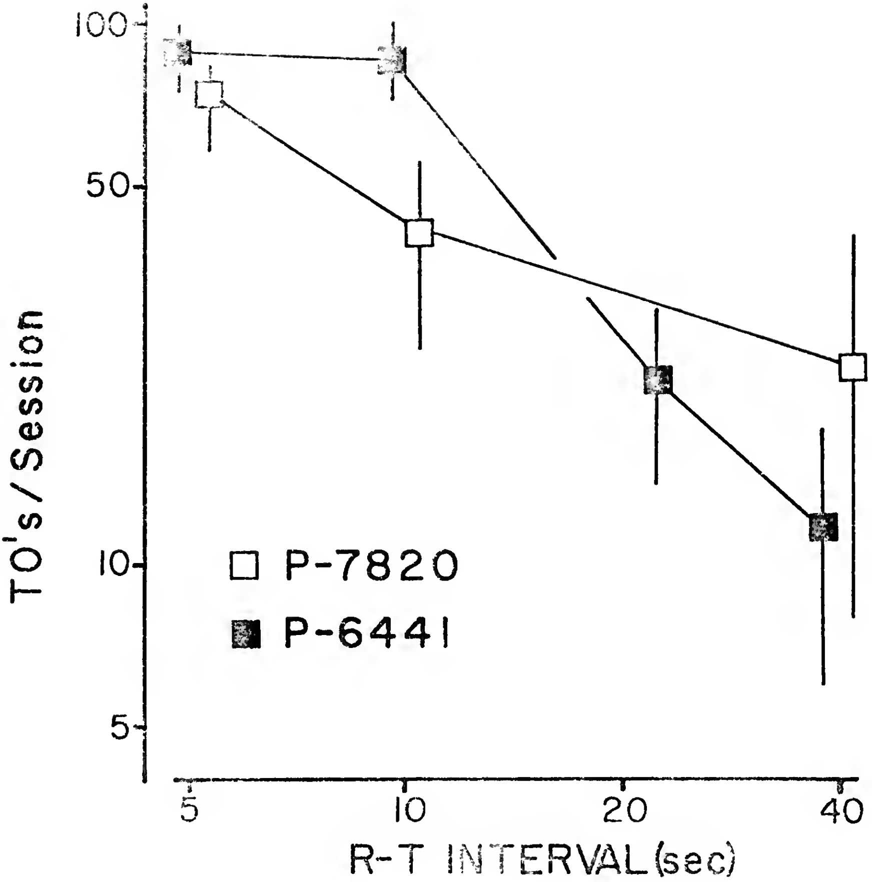

100
50
10
5
TO's/Session
5
10
20
40
R-T INTERVAL (sec)
□ P-7820
■ P-6441

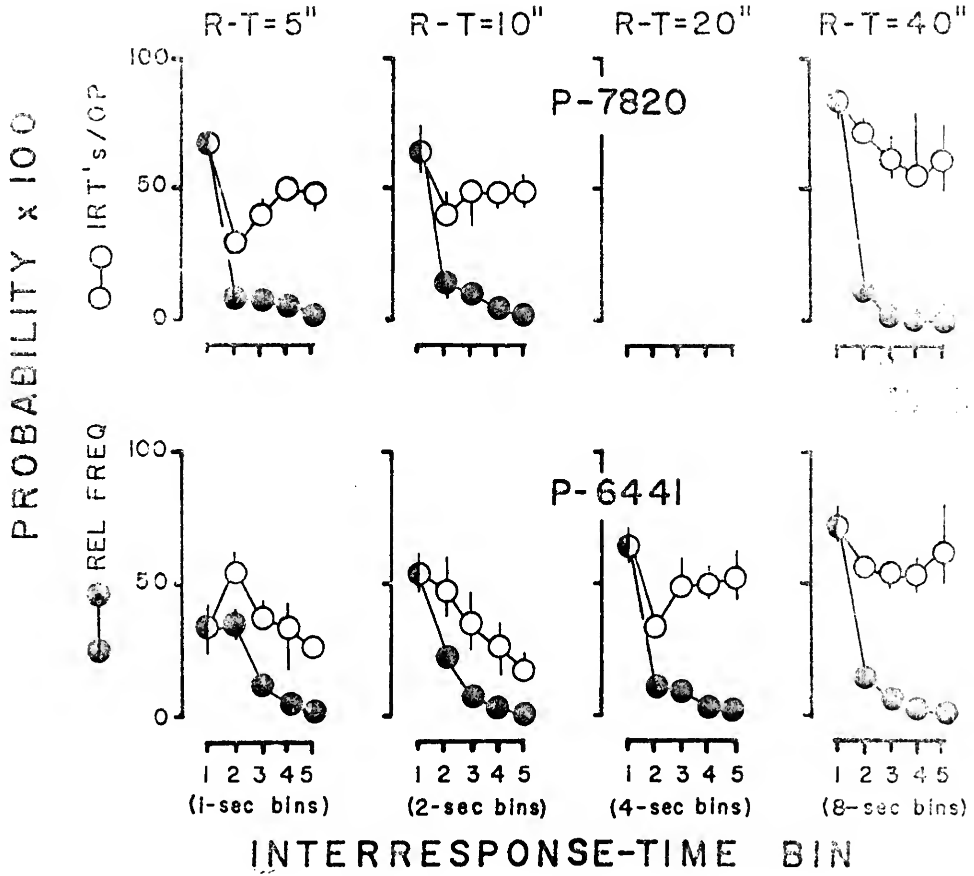
Figure 11 shows the relative frequencies and conditional probabilities (i.e., IRTs/OP) of IRTs during fifths of each RT interval for both subjects. Both subjects emitted predominantly short IRTs. Subject P-7820 consistently showed greater conditional probabilities of long than intermediate IRTs, whereas for P-6441, this relationship was true only at the two longest RT intervals. Under shorter RT intervals, the conditional probability of an IRT decreased monotonically with increasing IRT lengths for this subject.

Discussion

Presenting the stimuli associated with time-in/time-out on an operandum other than the one associated with response-contingent delay of time-out had qualitatively different effects on responding with different subjects. Subjects P-7820 and P-6441 demonstrated functional relations between response rate during time-in and RT interval length similar in form to those obtained during Experiment I. Response rate during time-in decreased monotonically as the RT interval was lengthened, and this relation was very roughly linear when plotted on double-log arithmetic axes. Responding during time-out, in contrast, occurred much less frequently and was not systematically related to RT interval value. As in Experiment I, temporal control of responding during time-in by RT interval length only occasionally developed.

The differences in response rate during time-in and time-out for these subjects provide evidence that the signal-key stimuli

Figure 11. Relative frequency (closed circles) and conditional probability (open circles) distributions of IRTs in fifths of the RT interval under the two-key procedure for P-7820 (upper distributions) and P-6441 (lower distributions). Characteristics of this figure are the same as those for Fig. 4.


R-T=5"
R-T=10"
R-T=20"
R-T=40"
P-7820
P-6441
PROBABILITY x 100
IRT's/OP
REL FREQ
100
50
0
1 2 3 4 5
(1-sec bins)
(2-sec bins)
(4-sec bins)
(8-sec bins)
INTERRESPONSE-TIME BIN

exercised control over delay-key pecking. Response rates on the delay key for both subjects were consistently much higher than rates on this key during time-out. Furthermore, the systematic changes in time-in response rate on the (continuously illuminated) delay key strongly suggest that key pecking was controlled predominantly by the length of response-contingent time-out delay and not by any changes in stimulus-reinforcer relations resulting indirectly from manipulations of the RT interval value. The demonstration in the present experiment of systematic control over key pecking by response-contingent time-out delay independent of these other possible sources of control adds credence to the notion that responding of these subjects during the first experiment was similarly controlled.

The behavior maintained under the present procedure was similar in many respects to behavior maintained in other species using more conventional free-operant avoidance paradigms. This similarity arises not only with respect to the response rate _vs._ delay-length function, but also with respect to the patterns of behavior engendered. This is not to suggest, however, that stimulus-reinforcer contingencies do not play a role in key pecking maintained under free-operant time-out-postponement procedures. Evidence of such control over responding, to varying degrees, stems from a number of the present results.

First, there is the behavior of P-9275. This subject's behavior did not show any control over rate of delay-key responding by the RT interval length. After initially revealing control by the signal-key stimuli (i.e., higher time-in than time-out delay-key response rates), this subject subsequently responded indiscriminately on the delay-key while responding on the signal-key primarily during time-in. The gradual development of signal-key pecking may reflect a "catalytic" property with respect to such behavior inherent in the procedure. That is, given that delay-key pecking occurs at some minimal rate, time-out presentations will occasionally be delayed. For example, at the longest RT interval used in the present study, a single response during the TT interval would delay the next time-out presentation for a period slightly longer than twice the time-out duration. Thus, given a single response during each TT interval, the time-in stimulus would typically be illuminated for more than 75% of the session. Accordingly, the relative time-in time will be fairly high, presumably leading to a fairly low (possibly zero) rate of signal-key pecking (cf., Baldock, 1974; Terrace, Gibbon, Farrel & Baldock, 1975). If rates of delay-key pecking should for some reason diminish, however, the number of time-outs delivered would increase, decreasing the relative amount of time-in time, and possible engendering or increasing the rate of signal-key pecking. To the extent that signal-key and delay-key pecking were incompatible responses, increases in the rate of signal-key pecking would further decrease delay-key responding, subsequently increasing time-out deliveries even more, which in turn might lead to more elevated rates of signal-key pecking. Signal-key pecking also developed gradually in P-6441 and only when substantial numbers of time-outs were delivered, providing circumstantial support for an interpretation based on competitive interactions between delay-key and signal-key contingencies.

The positive feedback loop described above may have contributed to the inability to maintain responding under the initial two-key procedure (i.e., delay key lit amber, signal key lit white or red). That is, given the extensive history of pecking a white key, it is likely that presentation of this stimulus on a new key (i.e., the signal key) would control a fair degree of responding. Responding on this key was, of course, ineffective in postponing time-out, and the number of time-outs delivered subsequently increased. This might have led to an increase in signal-key pecking, as outlined above, further hindering the development of delay-key pecking. The control over responding by the white stimulus was evidenced in the immediate transition in responding to the delay (white) key under the revised two-key procedure (i.e., delay key lit white, signal key lit blue or green).

That P-6441 did not peck the signal key under RT interval=5 sec in the presence of overall frequencies of time-out presentation comparable to those under RT interval=10 sec (during which signal-key pecking did occur) is somewhat perplexing. Pecking engendered by stimulus-reinforcer relations develops slowly in some subjects (cf., Brown & Jenkins, 1968), but usually is observed within a single session. Since RT interval=10 sec was in effect for a relatively small number of sessions, it is possible, but not highly plausible, that such behavior would have developed with extended exposure to the RT interval value. Alternatively, it might be argued that the high rate of delay-key pecking engendered under the shortest RT interval precluded the occurrence of signal-key pecking, in that delay-key and signal-key pecking are mutually exclusive responses which "compete" for the time available to respond. Such a notion has, for example, been suggested to account for the decreases in the rate of behaviors "induced" by the intermittent presentation of positive reinforcement when the frequency of reinforcement increases beyond that which induces the highest rate of such behaviors (e.g., Staddon, 1977, see particularly p. 133). The temporal distribution of signal-key pecking for P-6441 questions the validity of such a "competition" account. Recall that rates of signal-key pecking were highest shortly after a time-out and decreased thereafter. Since the contingencies in effect directly after time-out (i.e., the TT interval) were constant throughout the experiment, it is not clear why signal-key pecking under the different RT interval values should be different, at least with respect to the high rates of pecking observed shortly after time-out. Such competitive effects would more likely be observed under conditions involving manipulation of the _TT_ interval length, not the _RT_ interval.

It is possible that behavior directed at, but not contacting, the signal-key occurred under all RT intervals at rates in accordance with the relative time-out time. The occurrence of such unrecorded behavior could possibly have produced the decreases between Experiments I and III in the slope of the functions relating delay-key response rates during time-in and the RT interval by at least two means. First, since the stimuli associated with time-in or time-out were removed from the delay-key during Experiment III, responding elicited by these stimuli during Experiment I (and thus contributing to the overall rate of responding observed) could no longer occur. Hence, any "additive" interactions between negative reinforcement and stimulus-reinforcer contingencies during Experiment I were removed during Experiment III. In addition, the presentation of stimuli correlated with time-in or time-out away from the delay-key may have resulted in an antagonistic interaction between the two contingencies, to the extent that behavior directed at the delay-key and signal-key were mutually exclusive response classes. Both these effects would tend to decrease the slope of the response rate vs. RT interval function, since more elicited behavior would be expected to occur at shorter RT interval values (values where the frequency of time-out presentation was relatively high).

Although the slopes of these functions did decrease between Experiments I and III, the changes in absolute response rates responsible for the changes in slope are inconsistent with the notion just outlined. Specifically, both process-interactions described above would produce lower absolute response rates at shorter RT intervals under the two-key than the one-key procedure, either by the removal of any elicited key pecking and/or a competitive interaction between negative reinforcement and stimulus-reinforcer contingencies. Changes in absolute response rates for P-6441 are consistent with this prediction. However, those for P-7820 are not. Although the slope of the function under the two-key procedure for P-7820 was in fact slightly reduced, absolute response rates were never lower than rates under the one-key procedure, and were occasionally much higher. How accounts stressing stimulus-reinforcer relations would handle these increases is anything but clear.

Despite the interpretive difficulties encountered with the behavior of these two subjects, the absence of any control over delay-key responding under the two-key procedure for P-9275 questions the source of such control during Experiment I. It is possible that for this subject the apparent control by delay length primarily reflected changes in stimulus-reinforcer and not response-reinforcer contingencies. Several aspects of this subject's behavior indicate that this may have been the case. Only this subject showed a strictly monotonically decreasing function between RT interval length and the number of time-outs delivered during Experiment I. Response rates during time-in for this subject were also consistently lower than those for the other subjects. To the extent that response rates during Experiment I reflected the additive control over responding by response-contingent delay of time-out and by the occurrence of pecking directed towards stimuli correlated with the delivery of food, the absence of control by the former might predict the occurrence of lower overall response rates. A better analysis of this notion would be provided by comparing response rates at each RT interval value with rates obtained under yoked-VT conditions for each value. This subject did show the smallest absolute change in response rate during Experiment II when the response contingency governing delay of time-out was suspended. Whether such small differences would have been observed under other RT interval values is, however, unknown.

Informal observation of response topography suggests additional differences between the behavior of P-9275 and the other subjects. While both P-7820 and P-6441 most typically directed forceful, open-beaked pecks at the keys while standing directly in line with them, P-9275 more often "nibbled" around the side of the keys, only occasionally with a force sufficient to record a response. The degree to which the plexiglas extensions used in the present study contributed to the development of this topography cannot currently be determined. Although initially employed to increase the probability of response acquisition, such a modification may have retarded the development of control by response-contingent time-out delay, since a large number of P-9275's "pecks" went unrecorded, and thus unreinforced.

Finally, P-9275 was the only subject to never show any temporal control over responding during RT intervals. It is possible that the random distribution of conditional IRT probabilities, rather than merely reflecting the absence of control by RT interval length, represents control exercised by the random schedule of food presentation used during the present set of experiments. It would be interesting in this regard to compare temporal control (with respect to food presentation) under a comparable delay procedure but using a periodic schedule of food presentation.

Although the particular variables controlling these differences between the behavior of different subjects cannot be delineated at the present time, it appears that responding controlled by delay of time-out may share an additional similarity with other negative reinforcement procedures, that of controlling the behavior of some subjects but not others. Subject selection has become fairly commonplace in studies of negative reinforcement (e.g., see Hineline, 1977; Neffinger & Gibbon, 1975). The present procedures may provide a valuable analytic tool with regard to the variables responsible for inconsistent response acquisition. It has been suggested, for example, that acquisition may depend on the compatability of behaviors elicited by aversive stimulation with the response on which negative reinforcement is made contingent (e.g., Bolles, 1970, 1973; Hineline, 1977). Since the present procedures allow for the independent experimental manipulation of variables responsible for both the elicited as well as operant responses, acquisition and maintenance of either may be examined in the presence or absence of the other. An illustration of this strategy was provided in the present experiment by "topographically tagging" elicited and operant responses. Other possible approaches include manipulations shown to influence signal-directed responding, such as the presence of general illumination (Wasserman, 1973), localized *vs*. diffuse stimulus presentation (e.g., Schwartz, 1974), or the use of an omission procedure, where elicited responses cancel reinforcement presentation (e.g., Williams & Williams, 1974). Results from such manipulations may provide prescriptions for the development of procedures under which responding is more precisely controlled by negative reinforcement contingencies.

Such manipulations might also provide interesting data on the frequently reported, but somewhat less frequently analyzed, phenomenon termed "warmup." These repeated within-session transitions from "ineffective" to "effective" responding have only recently been subject to a descriptive analysis (e.g., Hineline, 1978*a*, 1978*b*), rather than being treated as procedural nuisances and discarded from data analyses. Hineline (1978*a*) suggested that decrements in early session response rates reflect the competing influence of behaviors elicited or otherwise evoked by aversive stimulus presentation which tend to habituate across the session. This may, for example, account for the infrequent reporting of warmup when lever pressing of monkeys is studied under negative reinforcement procedures, since a history of intermittent delivery of aversive stimuli, rather than producing competing responses, has been reported to evoke lever pressing in these subjects (for a review, see Hutchinson, 1977).

Aspects of the present results provide some support for such a "competition" notion. Warmup effects in the present study, although not formally analyzed, appeared to occur more frequently under the two-key procedure than under the one-key procedure of Experiment I. This might be predicted, since any non-operant behavior under the two-key procedure would be directed away from the delay-key and thus more possibly compete with the negatively reinforced response. This competition would less likely be observed under the one-key procedure, since behavior under operant as well as other sources of control would be directed towards the single key. It is additionally interesting that the majority of signal-key pecks for P-6441, under the one condition where such responses were numerous (i.e., RT interval= 10 sec), occurred directly following the onset of the session and diminished thereafter. This is exactly the pattern suggested by Hineline. Whether the diminuation of signal-key pecking during the session represents a process akin to habituation cannot be determined on the basis of the present results, however. It is equally plausible to argue competition in the opposite direction. That is, non-operant behaviors decrease in frequency due to an increase in the frequency of a competing operant response. Again, the present procedure may be especially helpful in providing data relevant to these interpretations. For example, signal-key pecking under the two-key delay procedure could be compared with such responding under a two-key procedure with yoked response-independent time-out presentations. If the decrement in signal-key pecking observed across the session is solely related to habituation, changes in the "time-course" of signal-key pecking under the two procedures should be minimal. Alternatively, competition from negatively reinforced key pecking might be expected to decrease the frequency of late session signal-key pecking under the delay- but not the yoked - procedure.

The within-session patterns of responding during Experiment II (see Fig. 7) do not provide evidence for or against either of these interpretations. Rates of responding for P-7820 were constant throughout the session. However stable rates of responding had not developed by the 20th session for this subject, so it is possible that within-session patterns may have been different under the delay- and yoked-procedures with extended exposure to the latter. The other two subjects showed slightly more stable rates of responding during the last several sessions of the yoked phase, and also showed slight differences in within-session response rates. Both subjects evidenced long pauses during the middle of the session, with responding occurring both earlier and later in the session. In that the time-in and time-out stimuli were projected on the key during this experiment, and thus, stimulus-reinforcer and possible "superstitious" avoidance contingencies were therefore inseparable, the source of control over this responding is uninterpretable. A number of hypotheses may be ventured to account for this within session pattern of responding. For example, it might be suggested that responding early in the session represents the occurence of non-operant behavior like that Hineline suggested occurs during the early portions of sessions involving shock-postponement contingencies. The diminished response rates observed as the session progresses might then reflect the "habituation" of these responses to time-out presentations. Responding later in the session might be primarily operant in nature, and may have been engendered in response to heightened "motivational" variables arising from the repeated presentation to response-independent time-out. Alternatively, responding early in the session might reflect "spontaneous recovery" (cf., Catania, 1968) of extinguished negatively-reinforced operant behavior, while responding later in the session might reflect "facilitation" of non-operant behavior through repeated presentation of the aversive stimulus (cf., Hutchinson, 1977, particularly pp. 422 ff.). The two-key procedures outlined above allow these hypotheses to be tested, by separating control over operant and non-operant behaviors to a degree unobtainable under the one-key procedure of Experiment II. The validity of these hypotheses, as well as any others which might be posited to account for the within-session patterns of responding, awaits experimentation involving comparisons between behavior maintained under two-key delay and yoked-VT contingencies.

CHAPTER VII
GENERAL DISCUSSION

The key pecking maintained under the free-operant avoidance of time-out procedure in the present study was comparable in many regards to behavior maintained under comparable stimulus-postponement procedures, independent of the particular species, response or aversive stimulus employed (see Hineline (1977) for a review). Thus, the present results strongly suggest that behavior was maintained under the present procedure in ways similar to responding under comparable procedures, while recognizing the possible contribution of non-operant variables. These variables must always be accounted for when studying behavior maintained by response-contingent time-out delay to avoid the possibility of attributing changes in behavior to independent variables other than the ones actually functioning to control behavior.

The assessement of separate sources of control over responding may prove to be an important benefit of time-out-postponement procedures. Just as the analysis of behavior maintained by positive reinforcement has benefited by analysis of concomitant non-operant responses engendered by these procedures, the analysis of negative reinforcement may do likewise. The possibility of the experimental manipulation of the degree of warm-up observed, through direct manipulation of elicited or induced behaviors stands as an illustrative example. The present procedure may prove to be invaluable in this regard, in that behaviors engendered by negative reinforcement and other contingencies may be more easily separated, measured, and independently manipulated than procedures involving other species, responses and/or aversive stimuli. Although non-operant behavior engendered by the present procedure may or may not be the result of behavioral mechanisms similar to those which engender elicited or induced behaviors under more conventional negative reinforcement paradigms, the functional effects of such behavior may be very similar. That is, responding engendered by the signalled presentation of reinforcement and by unsignalled intermittent presentation of aversive stimuli may involve contrasting behavioral processes. However, the functional contribution of such responses to behavior maintained by negative reinforcement may be parallel, to the extent that both interfere to some degree with the emission of the negatively-reinforced operant. The utility of this assumption, of course, can only be expressed in terms of the increase in the precision of prediction and control of behavior under negative reinforcement procedures such an interpretation provides. The possibilities discussed above, although suggestive, await experimental verification.

Even should efforts prove responding elicited by signalled reinforcement presentation functionally dissimilar to responding evoked by intermittent aversive stimulation, characteristics of the present procedure should make it especially useful in the analysis of negative reinforcement. It provides for the rapid acquisition of responding in pigeons, an inexpensive yet hearty and long-lived experimental subject. It provides for the continued extension of the analysis of negative reinforcement not only to another species, increasing the "interspecies generality" (Sidman, 1960) of functional relations between behavior and environmental events, but to a highly studied response of this species--key pecking. In that a vast literature exists on the control of key pecking by a host of variables, differences between negatively-reinforced key pecking of pigeons and for example, lever pressing of rats, may be analyzed without questions arising as to possible constraints resulting from some peculiar topographical characteristic of the response. Finally the present procedure involves no special subject preparation, and is available to investigators currently studying positive reinforcement contingencies without requiring any additional experimental apparatus. This may well prove to be the most attractive aspect of the present procedure (at least with respect to controlling the behavior of researchers), in that it allows for the immediate analysis of negative reinforcement contingencies by persons currently studying only positive ones.

One last possible point of relevance for behavior maintained under contingencies involving time-out-postponement pertains to current conceptualizations regarding the variables considered necessary and sufficient for the acquisition, and to a lesser degree the maintenance, of behavior by negative reinforcement. An implicit assumption regarding negative reinforcement held by many investigators is that any response class may come under the control of negative reinforcement contingencies largely independent of any extra-experimental variables. Although it has been recognized that some responses more readily come under control of negative reinforcement than others, these differences have generally been attributed to differences in the history of reinforcement for such responses prior to experimental study (e.g., Hineline, 1977) or to the use of non-optimal stimulus and response parameters when studying different responses (e.g., Sidman, 1960, in particular pp. 54 ff.). Recently, a number of investigators, primarily Bolles (e.g., Bolles, 1970, 1973), have taken exception to this view, arguing that the nature of negative reinforcement contingencies "in the wild" is usually not conducive to the gradual acquisition of a response from some highly malleable repertoire. Animals requiring multiple "trials" to learn to escape from a predator not only do not, they also leave fewer progeny, suggesting that natural selection would not favor the continued survival of species requiring multiple encounters. Thus, reponses emitted in the face of impending aversive stimulation cannot be selected by a previous history of reinforcement, except in the trivial sense that prior occurrences of "successful" responses allow the organism to continue behaving. Rather, it is argued, responses observed are innate reactions, the so-called species-specific-defense-reactions (SSDRs), or at best slight modifications thereof, which are elicited by aversive stimulation. Differences in the rate of acquisition of any individual experimentally-specified response do not depend on differences in the history of reinforcement for that response, but rather on the initial probability of each as an SSDR when first tested. Responses are not "selected for" by negative reinforcement contingencies, but rather are "selected against" by the presentation of aversive stimuli ("punishment") following an ineffective SSDR. Thus, running may more readily be acquired than bar pressing as a negatively-reinforced operant in that it has a higher initial probability of occurrence than other SSDRs; that is, it is a preeminent SSDR. The occurrence of a bar press, presumably an initially less probable SSDR, depends on the punishment of initially more probable, but ineffective SSDRs. Once these SSDRs have been sufficiently suppressed, bar pressing may be reliably observed.

Experimental evidence offered to support this notion is generally in the form of failures to acquire, or differences in the rate of acquisition of two or more experimentally specified responses. Although such differences may no doubt be observed, the controlling variables responsible for such differences are no further delineated by appeals to innate SSDRs. Rather, such appeals are more likely to halt prematurely the search for important differences in environmental controlling variables, by engendering a false sense of analytic completeness. For example, the SSDR interpretation begins by assuming that aversive stimuli are life-threatening, and thus not amenable to response acquisition through "trial and error." While many aversive stimuli "in the wild" are no doubt lethal, this need not imply that they all are. Poikilotherms need not always "run from the sun" to survive, but responses which monentarily terminate or reduce exposure to the sun do occur. More relevant to the present experiment, animals may learn, in foraging for food, to avoid locations void of nutritional resources (i.e., learn to avoid geographically defined "time-outs," so to speak) without instantly sucumbing to the possible lethal effects of remaining in such locations for extended periods of time.

It is becoming increasingly clear that modifications of immediately accessible environmental antecedent and consequent events play an important role in determining the reliability and/or speed of response acquisition under the control of negative reinforcement contingencies. Responses which are more readily learned may be more fuitfully thought of as "species-typical" (Hineline, 1977) than species-specific. This distinction is more than mere semantics, in that SSDRs imply a degree of constraint in the genetic history of the species not implied by the "species-typical" label. The species-typical classification promotes the search for commonalities in the histories of species and/or responses with respect to enviromental events, and suggests that modifications of discriminative or consequent stimulus control may produce orderly changes in the probability of a responses which would not be predicted a priori by SSDR accounts. For example, in the example previously discussed comparing acquisition of running and bar pressing as avoidance responses, it is possible that environmental variables may play a more important role than that attributed to them by SSDR accounts. Rather than reflecting differences in inherent tendencies to respond to aversive stimuli in certain ways, running may be acquired more readily because running, in addition to terminating or postponing primary aversive stimulation, may also remove stimuli paired with aversive stimulation--the physical surroundings in which aversive stimulation occurred in the past. Bar pressing, while postponing primary aversive stimulation, does not usually remove situational stimuli. Baron, DeWaard & Lipson (1977) demonstrated that subjects would preferentially respond on one of two levers concurrently available when, in addition to postponing shock, responses on one lever produced a "safe place" (i.e., a retractable shelf on which the subjects were never shocked) for a fixed period of time. Whether addition of this contingency would enhance acquisition of a bar-press avoidance response remains at present an interesting question.

That key pecking was readily and reliably acquired under the present procedure supports the species-typical notion. While it is plausible that pecking at conspecifics may be thought of as an SSDR, the biological significance of pecking the aversive stimulus used in the present study, a stimulus differentially correlated with the absence of food. is not readily discernable. Such stimuli would seem to invite withdrawal (e.g., Hearst & Jenkins, 1974) and serach in areas away from the stimulus, not approach and contact with it. This appeared to be the case in the present studies; subjects generally turned away from the front wall of the experimental unit during time-out.

In any case, responding was engendered primarily in the *absence* of the aversive stimulus, not elicited by its *presence* (i.e., subjects rarely pecked the time-out stimulus). As such, it would be difficult to interpret key pecking under the present procedure as an SSDR. How such behavior subsequently came under control of time-out delay is, from an SSDR orientation, *a fortiorti*, anything but clear. The present results suggest that it may be more useful to argue that control of key pecking through one set of contingencies (i.e., stimulus-reinforcer relations) was transferred to a second set, namely negative reinforcement through time-out-delay.

APPENDIX
DAILY SESSION DATA FOR EACH SUBJECT DURING EXPERIMENT II

SUBJECT P-7820

RESPONSE RATE				TO's
Time-in		Time-out		
Delay	Yoked-VT	Delay	Yoked-VT	
28.33	23.32	0.08	0.36	32
29.24	24.96	0.29	0.42	33
26.66	28.51	1.26	1.82	43
26.41	25.37	0.23	1.70	33
23.05	28.49	0.57	0.77	46
25.96	29.15	1.23	1.00	40
24.28	33.78	0.28	2.23	36
27.00	28.07	0.08	0.33	25
26.22	28.82	0.23	1.26	32
25.39	23.94	0.85	0.32	30
26.03	30.87	1.48	0.31	27
26.94	29.12	0.46	0.90	32
26.68	26.98	0.15	0.80	31
28.96	20.98	0.17	0.32	27
27.60	18.57	0.45	1.69	31
28.06	22.64	0.44	1.12	33
28.01	20.01	1.11	0.14	35
27.13	17.70	1.14	0.33	35
24.47	14.16	1.01	0.07	36
24.35	14.16	0.56	0.30	39

SUBJECT P-6441

RESPONSE RATE (R/Min)				TO's
Time-in		Time-out		
Delay	Yoked-VT	Delay	Yoked-VT	
15.60	8.88	0.23	0.25	15
14.51	15.82	1.30	1.01	20
13.93	16.82	2.07	0.84	19
14.61	15.43	0.28	0.13	12
13.55	11.56	0.22	0.22	16
13.42	9.83	0.13	0.53	13
13.68	5.95	0.26	0.63	14
18.51	3.92	0.00	0.63	7
14.38	4.86	0.00	0.60	11
12.95	6.52	0.57	0.38	22
15.34	6.77	0.56	1.08	11
15.03	10.33	1.19	0.68	17
10.16	11.58	0.74	0.39	36
14.40	5.39	0.49	0.51	16
12.97	5.81	0.51	0.44	19
14.29	4.82	0.42	0.29	13
15.38	4.29	0.24	0.48	14
14.58	7.51	0.60	0.40	22
14.71	6.39	0.52	0.20	19
17.65	5.23	0.28	0.44	11
14.06	4.39	0.14	0.42	11

SUBJECT P-9275

RESPONSE RATE (R/Min)				TO's
Time-in		Time-out		
Delay	Yoked-VT	Delay	Yoked-VT	
10.61	3.58	0.00	0.14	24
5.41	2.62	0.00	0.00	20
5.70	2.57	0.17	0.00	27
5.04	2.57	0.00	0.09	26
3.88	5.64	0.16	0.08	29
4.26	7.26	0.00	0.25	28
4.29	3.88	0.08	0.09	27
5.09	2.93	0.11	0.00	18
3.67	2.01	0.08	0.11	31
3.59	2.58	0.00	0.00	31
3.49	5.23	0.00	0.15	41
3.56	2.58	0.13	0.12	39
3.49	3.37	0.00	0.00	38
4.23	2.90	0.07	0.00	25
4.01	2.53	0.08	0.07	26
4.02	2.28	0.09	0.00	24
4.35	1.93	0.00	0.18	19
4.54	2.01	0.25	0.10	27
5.04	2.58	0.20	0.00	20
4.37	3.92	0.08	0.00	26

REFERENCES

Alves de Moraes, A. B., & Todorov, J. C. Signalled free-operant avoidance of shock by pigeons pecking a key. Journal of the Experimental Analysis of Behavior, 1977, 27, 281-291.

Anger, D. The role of temoral discriminations in the reinforcement of Sidman avoidance behavior. Journal of the Experimental Analysis of Behavior, 1963, 6, 447-506.

Azrin, N. H. A technique for delivering shock to pigeons. Journal of the Experimental Analysis of Behavior, 1959, 2, 161-163.

Azrin, N. H., & Holz, W. C. Punishment. In W. K. Honig (Ed.), Operant behavior: Areas of research and application. Englewood Cliffs, N. J.: Prentice-Hall, Inc. 1966. Pp. 380-447.

Badia, P., Coker, C., & Harsh, J. Choice of higher density signalled shock over lower density unsignalled shock. Journal of the Experimental Analysis of Behavior, 1973, 20, 47-55.

Badia, P., Culbertson, S., & Harsh, J. Choice of longer or stronger signalled shock over shorter or weaker unsignalled shock. Journal of the Experimental Analysis of Behavior, 1973, 19, 25-32.

Badia, P., Harsh, J., Coker, C. C., & Abbott, B. Choice and the dependability of stimuli that predict shock and safety. Journal of the Experimental Analysis of Behavior, 1976, 26, 95-111.

Baldock, M. D. Trial and intertrial interval durations in the acquisition of autoshaped key pecking. Paper presented at the meetings of the Eastern Psychological Association, Philadelphia, 1974.

Baron, A., DeWaard, R. J., & Lipson, J. Increased reinforcement when timeout from avoidance includes access to a safe place. Journal of the Experimental Analysis of Behavior, 1977, 27, 479-492.

Baron, A., & Galazio, M. Clock control of human performance on avoidance and fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 1976, 26, 165-180.

Baron, A., & Kaufman, A. Human, free-operant avoidance of "time-out" from monetary reinforcement. Journal of the Experimental Analysis of Behavior, 1966, 9, 557-565.

Baum, W. M. Time allocation and negative reinforcement. Journal of the Experimental Analysis of Behavior, 1973, 20, 313-322.

Bechterev, B. M. Objective psychologie. Leipzig and Berlin: Teubner, 1913.

Benedict, J. O. Response-shock delay as a reinforcer in avoidance behavior. Journal of the Experimental Analysis of Behavior, 1975, 24, 323-332.

Bersh, P. J., & Alloy, L. B. Avoidance based on shock intensity reduction with no change in shock probability. Journal of the Experimental Analysis of Behavior, 1978, 30, 293-300.

Bersh, P. J., & Alloy, L. B. Reduction of shock duration as negative reinforcement in free-operant avoidance. Journal of the Experimental Analysis of Behavior, 1980, 33, 265-273.

Blough, D. S. The reinforcement of least-frequent interresponse-times. Journal of the Experimental Analysis of Behavior, 1966, 9, 581-591.

Boakes, R. A. Performance on learning to associate a stimulus with positive reinforcement. In H. Davis and H. M. B. Hurwitz (Eds.), Operant-Pavlovian interactions. Hillsdale, N. J.: Lawrence Erlebaum Associates, 1977. Pp. 67-101.

Bolles, R. C. Species-specific defense reactions and avoidance learning. Psychological Review, 1970, 77, 32-48.

Bolles, R. C. The avoidance learning problem. In G. H. Bower, (Ed.), The psychology of learning and motivation (Vol. 6). New York: Academic Press, 1973. Pp. 97-145.

Bolles, R. C., & Popp, R. J. Parameters affecting the acquisition of Sidman avoidance. Journal of the Experimental Analysis of Behavior, 1964, 7, 315-321.

Bolles, R. C., Stokes, L. W., & Younger, M. S. Does CS termination reinforce avoidance behavior? Journal of Comparative and Physiological Psychology, 1966, 62, 201-207.

Boren, J. J. Isolation of post-shock responding in a free operant avoidance procedure. Psychological Reports, 1961, 9, 265-266.

Boren, J. J., & Sidman, M. A. A discrimination based upon repeated conditioning and extinction of avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1957, *50*, 19-22.(a)

Boren, J. J., & Sidman, M. A. Maintenance of avoidance behavior with intermittent shocks. *Canadian Journal of Psychology*, 1957, 11, 185-192.(b)

Brogden, W. J., Lipman, E. A., & Culler, E. The role of incentive in conditioning and extinction. *American Journal of Psychology*, 1938, *51*, 109-117.

Brown, P. L., & Jenkins, H. M Auto-shaping of the pigeon's keypeck. *Journal of the Experimental Analysis of Behavior*, 1968, *11*, 1-8.

Byrd, L. D. Responding in the squirrel monkey under fixed-ratio schedules of stimulus termination. *Journal of the Exoerimental Analysis of Behavior*, 1977, *27*, 495-506.

Catania, A. C. *Contemporary research in operant behavior*. Glenview, Ill.: Scott, Foresman and Co., 1968.

Catania, A. C. Reinforcement schedules: The role of responses preceding the one that produces reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, *15*, 271-287.

Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 517-526.

Clark, F. C., & Hull, L. D. Free-operant avoidance as a function of the response-shock=shock-shock interval. *Journal of the Experimental Analysis of Behavior*, 1966, *9*, 641-647.

Clark, F. C., & Smith, J. B. Schedules of food postponement: II. Maintenance of behavior by food postponement and effects of the schedule parameter. *Journal of the Experimental Analysis of Behavior*, 1977, *28*, 253-269.

Coulson, G., Coulson, V., & Gardner, L. The effect of two extinction procedures after acquisition on a Sidman avoidance contingency. *Psychonomic Science*, 1970, *18*, 309-310.

D'Andrea, T. D. Avoidance of timeout from response-independent reinforcement. *Journal of the Experimental Analysis of Behavior*, 1971, *15*, 319-325.

Davenport, D. G., Coger, R. W., & Spector, O. J. The redefinition of extinction applied to Sidman free-operant avoidance responding. Psychonomic Science, 1970, 19, 181-182.

Davenport, D. G., & Olson, R. D. A reinterpretation of extinction in discriminated avoidance. Psychonomic Science, 1968, 13, 5-6.

deVilliers, P. A. Reinforcement and response rate interaction in multiple random-interval avoidance schedules. Journal of the Experimental Analysis of Behavior, 1972, 18, 499-507.

deVilliers, P. A. The law of effect and avoidance: A quantitative relationship between response rate and shock-frequency reduction. Journal of the Experimental Analysis of Behavior, 1974, 21, 223-235.

deVilliers, P. A. Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1977. Pp. 233-287.

Dinsmoor, J. A. Punishment: I. The avoidance hypothesis. Psychological Review, 1954, 61, 34-46.

Dinsmoor, J. A. Escape from shock as a conditioning technique. In M. R. Jones (Ed.), Miami symposium on the prediction of behavior: 1967; Aversive stimulation. Coral Gables, Fla.: University of Miami Press, 1968.

Dinsmoor, J. A. Escape, avoidance, punishment: Where do we stand? Journal of the Experimental Analysis of Behavior, 1977, 28, 83-95.

Dinsmoor, J. A., & Sears, G. W. Control of avoidance by a response-produced stimulus. Learning and Motivation, 1973, 4, 284-293.

Dinsmoor, J. A., & Winograd, E. Shock intensity in variable-interval escape schedules. Journal of the Experimental Analysis of Behavior, 1958, 1, 145-148.

Ellen , P., & Wilson, A. Two patterns of avoidance responding. Journal of the Experimental Analysis of Behavior, 1964, 7, 97-98.

Ferrari, E. A., & Todorov, J. C. Concurrent avoidance of shocks by pigeons pecking a key. Journal of the Experimental Analysis of Behavior, 1980, 34, 329-333.

Ferrari, E. A., Todorov, J. C., & Graeff, F. G. Nondiscriminated avoidance of shock by pigeons pecking a key. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 211-218.

Ferster, C. B. The use of the free operant in the analysis of behavior. *Psychological Bulletin*, 1953, *50*, 263-274.

Ferster, C. B. Control of behavior in chimpanzees and pigeons by time-out from positive reinforcement. *Psychological Monographs*, 1958, *72*, No. 8 (Whole No. 461).

Ferster, C. B., & Skinner, B. F. *Schedules of reinforcement*. New York: Appleton-Century-Crofts, 1957.

Field, G. E., & Boren, J. J. An adjusting avoidance procedure with multiple auditory and visual warning stimuli. *Journal of the Experimental Analysis of Behavior*, 1963, *6*, 537-543.

Flye, B. L., & Gibbon, J. Partial avoidance contingencies: absolute ommission and punishment probabilities. *Journal of the Experimental Analysis of Behavior*, 1979, *31*, 351-371.

Foree, D., & LoLordo, V. M. Signalled and unsignalled free-operant avoidance in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 283-290.

Foree, D., & LoLordo, V. M. Transfer of control of the pigeon's key peck from food reinforcement to avoidance of shock. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 251-259.

Freud, S. *The problem of anxiety*. New York: Psychoanalytic Quarterly and Norton, 1936.

Galbicka, G., & Branch, M. N. Selective punishment of interresponse times. *Journal of the Experimental Analysis of Behavior*, 1981, *35*, 311-322.

Gamzu, E., & Williams, D. R. Classical conditioning of a complex skeletal act. *Science*, 1971, *171*, 923-925.

Gamzu, E. R., & Williams, D. R. Associative factors underlying the pigeon's key pecking under autoshaping procedures. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 225-232

Gardner, E. T., & Lewis, P. Negative reinforcement with shock-frequency increase. *Journal of the Experimental Analysis of Behavior*, 1976, *25*, 3-14.

Gardner, E. T., & Lewis, P. Paramaters affecting the maintenance of negatively reinforced key pecking. *Journal of the Experimental Analysis of Behavior*, 1977, *28*, 117-131.

Gibbon, J., Berryman, R., & Thompson, R. L. Contingency spaces and measures in classical and instrumental conditioning. *Journal of the Experimental Analysis of Behavior*, 1974, *21*, 585-605.

Guthrie, E. R. *The psychology of learning*. New York: Harper, 1935.

Hake, D. F., & Campbell, R. L. Characteristics and response-displacement effects of shock-generated responding during negative reinforcement procedures: Pre-shock responding and post-shock aggressive responding. *Journal of the Experimental Analysis of Behavior*, 1972, *17*, 302-323.

Harsh, J., & Badia, P. Choice for signalled shock as a function of shock intensity. *Journal of the Experimental Analysis of Behavior*, 1975, *23*, 349-355.

Hearst, E. Multiple schedules of time-correlated reinforcement. *Journal of the Experimental Analysis of Behavior*, 1960, *3*, 49-62.

Hearst, E., & Jenkins, H. M. Sign-tracking: The stimulus-reinforcer relation and directed action. *Psychonomic Society Monograph*, 1974.

Herrnstein, R. J. Method and theory in the study of avoidance. *Psychologogical Review*, 1969, *76*, 49-69.

Herrnstein, R. J., & Hineline, P. N. Negative reinforcement as shock-frequency reduction. *Journal of the Experimental Analysis of Behavior*, 1966, *9*, 421-430.

Hineline, P. N. Negative reinforcement without shock reduction. *Journal of the Experimental Analysis of Behavior*, 1970, *14*, 259-268.

Hineline, P. N. Negative reinforcement and avoidance. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1977. Pp. 364-414.

Hineline, P. N. Warmup in avoidance as a function of time since prior training. *Journal of the Experimental Analysis of Behavior*, 1978, *29*, 87-103.(a)

Hineline, P. N. Warmup in free-operant avoidance as a function of the response-shock=shock-shock interval. Journal of the Experimental Analysis of Behavior, 1978, 30, 281-291.(b)

Hineline, P. N., & Herrnstein, R. J. Timing in free-operant and discrete-trial avoidance. Journal of the Experimental Analysis of Behavior, 1970, 13, 113-126.

Hineline, P. N., & Rachlin, H. Notes on fixed-ratio and fixed-interval escape responding in the pigeon. Journal of the Experimental Analysis of Behavior, 1969, 12, 497-401.(a)

Hineline, P. N., & Rachlin, H. Escape and avoidance of shock by pigeons pecking a key. Journal of the Experimental Analysis of Behavior, 1969, 12, 533-538.(b)

Hoffman, H., & Flescher, M. Aversive control with the pigeon. Journal of the Experimental Analysis of Behavior, 1959, 2, 213-218.

Hull, C. L. Principles of behavior: An introduction to behavior theory. New York: Appleton-Century-Crofts, 1943.

Hunter, W. S. Conditioning and extinction in the rat. British Journal of Psychology, 1935, 26, 135-148.

Hurwitz, H. M. B., & Millenson, J. R. Maintenance of avoidance behavior under temporally defined contingencies. Science, 1961, 133, 284-285.

Hutchinson, R. R. By-products of aversive control. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1977. Pp. 415-431.

Hyman, A. Two temporal parameters of free operant discriminated avoidance in the rhesus monkey. Journal of the Experimental Analysis of Behavior, 1969, 12, 641-648.

Jowaisas, D. B. The behavior of pigeons under free-operant schedules of shock avoidance and shock frequency reduction. Ph.D. dissertation, University of Florida, 1977.

Kadden, R. M., Schoenfeld, W. N., & Snapper, A. G. Aversive schedules with independent probabilities of reinforcement for responding and not responding by Rhesus monkeys: II. Without signal. Journal of Comparative and Physiological Psychology, 1974, 87, 1189-1197.

Kamin, L. J., Brimer, C. J., & Black, A. H. Conditioned suppression as a monitor of fear of the CS in the course of avoidance training. Journal of Comparative and Physiological Psychology, 1963, 56, 497-501.

Kelleher, R. T., & Morse, W. H. Escape behavior and punished behavior. *Federation Proceedings*, 1964, *23*, 808-817.

Keller, K. The role of elicited responding in behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1974, *21*, 249-257.

Klein, M., & Rilling, M. Effects of response-shock interval and shock-intensity on free-operant avoidance responding in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1972, *18*, 295-303.

Klein, M., & Rilling, M. Generalization of free-operant avoidance behavior in pigeons. *Journal of the Experimental Analysis of Behavior*, 1974, *21*, 75-88.

Knutson, J. F., & Bailey, M. I. Free-operant escape-avoidance of noise by rats. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 219-229.

Krasnegor, N. A., Brady, J. V., & Findley, J. D. Second-order optional avoidance as a function of fixed-ratio requirements. *Journal of the Experimental Analysis of Behavior*, 1971, *15*, 181-187.

Lambert, J. V., Bersh, P. J., Hineline, P. N., & Smith, G. D. Avoidance conditioning with shock contingent upon the avoidance response. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 361-367.

Leaf, R. C. Acquisition of Sidman avoidance responding as a function of S-S interval. *Journal of Comparative and Physiological Psychology*, 1965, *59*, 298-300.

Leander, J. D. Shock intensity and duration interactions on free-operant avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 481-490.

Lewis, P., Gardner, E. T., & Hutton, L. Integrated delays to shock as negative reinforcement. *Journal of the Experimental Analysis of Behavior*, 1976, *26*, 379-386.

Lewis, P., Gardner, E. T., & Lopatto, D. Shock-duration reduction as negative reinforcement. *The Psychological Record*, 1980, *30*, 219-228.

Lewis, P., Lewin, L., Stoyak, M., & Muehleisen, P. Negatively reinforced key pecking. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 83-90.

Libby, M. E., & Church, R. M. Timing of avoidance responses by rats. Journal of the Experimental Analysis of Behavior, 1974, 22, 513-517.

Logue, A. W., & deVilliers, P. A. Matching in concurrent variable-interval avoidance schedules. Journal of the Experimental Analysis of Behavior, 1978, 29, 61-66.

MacPhail, E. M. Avoidance responding in pigeons. Journal of the Experimental Analysis of Behavior, 1968, 11, 629-632.

McMillan, D. E. A comparison of the punishing effects of response-produced time-out. Journal of the Experimental Analysis of Behavior, 1967, 10, 439-449.

Morse, W. H., & Kelleher, R. T. Determinants of reinforcement and punishment. In W. K. Honig and J. E. R. Staddon (Eds.), Handbook of operant behavior. Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1977. Pp. 174-200.

Mowrer, O. H., & Lamoreaux, R. R. Avoidance conditioning and signal duration--a study of secondary motivation and reward. Psychological Monographs, 1942, 54 (5, Whole No. 247).

Neffinger, G. G., & Gibbon, J. Partial avoidance contingencies. Journal of the Experimental Analysis of Behavior, 1975, 23, 437-450.

Pavlov, I. P. Conditioned Reflexes. London: Oxford University Press, 1927.

Powell, R. W., & Peck, S. Persistent shock-elicited responding engendered by a negative-reinforcement procedure. Journal of the Experimental Analysis of Behavior, 1969, 12, 1049-1062.

Rachlin, H. Autoshaping of keypecking in pigeons with negative reinforcement. Journal of the Experimental Analysis of Behavior, 1969, 12, 521-531.

Rachlin, H., & Herrnstein, R. J. Hedonism revisted: On the negative law of effect. In B. A. Campbell and R. M. Church (Eds.), Punishment and aversive behavior. New York: Appleton-Century-Crofts, 1969. Pp. 83-109.

Rachlin, H., & Hineline, P. N. Training and maintenance of keypecking in the pigeon by negative reinforcement. Science, 1967, 157, 954-955.

Rescorla, R. A. Pavlovian conditioned fear in Sidman avoidance learning. *Journal of Comparative and Physiological Psychology*, 1968, *65*, 55-60.

Rescorla, R. A. Establishment of a positive reinforcer through contrast with shock. *Journal of Comparative and Physiological Psychology*, 1969, *67*, 260-263.

Reynolds, G. S. Behavioral contrast. *Journal of the Experimental Analysis of Behavior*, 1961, *4*, 57-71.

Pilling, M., & Budnick, J. E. Generalization of excitation and inhibition after different amounts of training of an avoidance baseline. *Journal of the Experimental Analysis of Behavior*, 1975, *23*, 207-215.

Schlosberg, H. Conditioned responses in the white rat. *Journal of Genetic Psychology*, 1934, *45*, 303-335.

Schoenfeld, W. N. An experimental approach to anxiety, escape and avoidance behavior. In R. H. Hoch and J. Zubin (Eds.), *Anxiety*. New York: Grune and Stratton, 1950.

Schoenfeld, W. N., & Cole, B. K. *Stimulus schedules: the t-T systems*. New York: Harper and Row, 1972.

Schwartz, B. Autoshaping and behavioral contrast: the key to contrast is on the key. Paper presented at the meetings of the Eastern Psychological Association, Philadelphia, 1974.

Schwartz, B., & Coulter, G. A failure to transfer control of key pecking from food reinforcement to escape from and avoidance of shock. *Bulletin of the Psychonomic Society*, 1971, *1*, 307-309.

Schwartz, B., & Gamzu, E. Pavlovian control of operant behavior: An analysis of autoshaping and its implications for operant conditioning. In W. K. Honig and J. E. R. Staddon (Eds.), *Handbook of operant behavior*. New York: Prentice-Hall, Inc., 1977. Pp. 53-97.

Shimp, C. P. Synthetic variable-interval schedules of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 311-330.

Shimp, C. P., & Wheatley, K. L. Matching to relative reinforcement frequency in multiple schedules with short component duration. *Journal of the Experimental Analysis of Behavior*, 1971, *15*, 205-210.

Shnidman, S. R. Extinction of Sidman avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1968, *11*, 153-156.

Shull, R. L., Spear, D. J., & Bryson, A. E. Delay or rate of food delivery as a determinant of response rate. *Journal of the Experimental Analysis of Behavior*, 1981, *35*, 129-143.

Sidman, M. Two temporal parameters in the maintenance of avoidance behavior by the white rat. *Journal of Comparative and Physiological Psychology*, 1953, *46*, 253-261.

Sidman, M. Some properties of the warning stimulus in avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1955, *48*, 444-450.

Sidman, M. Conditioned reinforcing and aversive stimuli in an avoidance situation. *Proceedings of the New York Academy of Sciences*, 1957, 534-544.

Sidman, M. *Tactics of scientific research*. New York: Basic Books, 1960.

Sidman, M. Classical avoidance without a warning stimulus. *Journal of the Experimental Analysis of Behavior*, 1962, *5*, 245-257.(a)

Sidman, M. An adjusting avoidance schedule. *Journal of the Experimental Analysis of Behavior*, 1962, *5*, 271-277.(b)

Sidman, M. Avoidance behavior. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application*. New York: Appleton-Century-Crofts, 1966. Pp. 448-498.

Sidman, M. A., & Boren, J. J. The use of shock-contingent variations in response-shock intervals for the maintenance of avoidance behavior. *Journal of Comparative and Physiological Psychology*, 1957, *50*, 282-287.(a)

Sidman, M. A., & Boren, J. J. The relative aversiveness of warning signal and shock in an avoidance situation. *Journal of Abnormal and Social Psychology*, 1957, *55*, 339-344.(b)

Sidman, M. A., & Boren, J. J. A comparison of two types of warning stimulus in an avoidance situation. *Journal of Comparative and Physiological Psychology*, 1957, *50*, 282-287.(c)

Skinner, B. F. "Superstition" in the pigeon. *Journal of Experimental Psychology*, 1948, *38*, 168-172.

Skinner, B. F. *Science and human behavior*. New York: MacMillan, 1953.

Smith, G. D. Extinction of free-operant avoidance in rats. Ph.D. dissertation, Temple University, 1973.

Smith, J. R., & Clark, F. C. Two temporal parameters of food postponement. *Journal of the Experimental Analysis of Behavior*, 1972, *18*, 1-12.

Smith, R. F., Gustavson, C. R., & Gregor, G. L. Incompatibility between the pigeons' unconditioned response to shock and the conditioned key-peck response. *Journal of the Experimental Analysis of Behavior*, 1972, *18*, 147-153.

Smith, R., & Keller, F. Free-operant avoidance in the pigeon using a treadle response. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 211-214.

Snapper, A. G., & Inglis, G. *SKED software system: Time-shared superSKED*. Kalamazoo, Mich.: State Systems, 1978.

Snapper, A. G., Stephens, K. R., & Lee, D. M. *The SKED software system*. Kalamazoo, Mich.: State Systems, 1974.

Spealman, R. D. Interactions in multiple schedules: the role of the stimulus-reinforcer contingency. *Journal of the Experimental Analysis of Behavior*, 1976, *26*, 79-93.

Terrace, H. S., Gibbon, J., Farrell, L., & Baldock, M. D. Temporal factors influencing the acquisition of an autoshaped key peck. *Animal Learning and Behavior*, 1975, *3*, 53-62.

Thomas, J. R. Time-out avoidance from a behavior-independent contingency. *Psychonomic Science*, 1965, *3*, 217-218.(a)

Thomas, J. R. Discriminated time out avoidance in pigeons. *Journal of the Experimental Analysis of Behavior*, 1965, *8*, 329-333.(b)

Thorndike, E. L. *Educational psychology: Briefer course*. New York: Columbia University, 1914.

Todorov, J. C. Component duration and relative response rates in multiple schedules. *Journal of the Experimental Analysis of Behavior*, 1972, *17*, 45-59.

Todorov, J. C., Ferrari, E. A. M., & de Souza, D. G. Key pecking as a function of response-shock and shock-shock intervals in unsignalled avoidance. *Journal of the Experimental Analysis of Behavior*, 1974, *22*, 215-218.

Ulrich, R. E., Holz, W. C., & Azrin, N. H. Stimulus control of avoidance behavior. *Journal of the Experimental Analysis of Behavior*, 1964, *7*, 129-133.

Verhave, T. Technique for differential reinforcement of rate of avoidance responding. *Science*, 1959, *129*, 959-960.

Wasserman, E. A. The effect of redundant contextual stimuli and autoshaping the pigeon's keypeck. *Animal Learning and Behavior*, 1973, *1*, 198-206.

Weisman, R. C., & Litner, J. S. Positive conditioned reinforcement of Sidman avoidance behavior in rats. *Journal of Comparative and Physiological Psychology*, 1969, *68*, 597-603.

Weiss, B., & Laties, V. G. Titration behavior on various fractional escape programs. *Journal of the Experimental Analysis of Behavior*, 1959, *2*, 227-248.

Weiss, B., & Laties, V. G. Characteristics of aversive thresholds measured by a titration schedule. *Journal of the Experimental Analysis of Behavior*, 1963, *6*, 563-572.

Williams, D. R., & Williams, H. Automaintenance in the pigeon: Sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, *12*, 511-520.

Zeigler, H. P., Levitt, P. W., & Levine, R. R. Eating in the pigeon (*Columba livia*): Movement patterns, stereotypy, and stimulus control. *Journal of Comparative and Physiological Psychology*, 1980, *94*, 783-794.

Zener, K. The significance of behavior accompanying conditioned salivary secretion for theories of the conditioned response. *American Journal of Psychology*, 1937, *50*, 384-403.

BIOGRAPHICAL SKETCH

Gregory Galbicka was born in El Paso, Texas, on September 6, 1956. Since then he has gotten much taller. His father, Joseph A. Galbicka, was a career Army man, and as such Greg spent the first eighteen years of his life vacationing around the world at the expense of the United States Government, which he would like to thank publicly at the present time. Following this, he "was the victim of a series of accidents," deciding to become a psychologist in 1974. He attended the University of Florida, attaining a B.A. with High Honors in 1977, an M.S. in 1980, and finally a Ph.D in 1981, attempting to uncover the variables responsible for this unfortunate choice of career. He was less than successful.

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Marc N. Branch

Marc N. Branch, Chairman
Associate Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Edward F. Malagodi

Edward F. Malagodi
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Henry S. Pennypacker
Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, is scope and quality, as a dissertation for the degree of Doctor of Philosophy.

Robert J Waldbillig

Robert J. Waldbillig
Assistant Professor of Psychology

I certify that I have read this study and that in my opinion it conforms to acceptable standards of scholarly presentation and is fully adequate, in scope and quality, as a dissertation for the degree of Doctor of Philosophy.

John A. Cornell

John A. Cornell
Professor of Statistics

This dissertation was submitted to the Graduate Faculty of the Department of Psychology in the College of Liberal Arts and Sciences and to the Graduate Council, and was accepted as partial fulfillment of the requirements for the degree of Doctor of Philosophy.

August, 1981

Dean for Graduate Studies and Research