Developing and Maintaining Precurrent Behavior That Affects the Reinforcement Probability of Another Behavior

by

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We accept this thesis as conforming to the required standard

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ABSTRACT

The present study was concerned with the development and maintenance of (precurrent) behavior that increases the probability of reinforcement for another (current) behavior. A single-subject methodology was employed. Nine human subjects responded on a computer mouse that contained two buttons. One (current) button was reinforced according to a probability schedule (p = .02 or a minor deviation thereof). Depending on the condition, the other button either had no scheduled consequence (i.e., the precurrent contingency was absent) or increased the probability of reinforcement (p = .08) for current responding for 15 s (i.e., the standard precurrent contingency was present). Generally, with the precurrent contingency absent, precurrent responding quickly dropped to near zero levels; with the precurrent contingency present, precurrent responding maintained at enhanced levels. Between- and within-subject replications suggest that the precurrent contingency was responsible for the maintenance of precurrent responding. Initial exposure to the precurrent contingency resulted in the acquisition of precurrent responding for four of eight subjects. For the four other subjects, a special conditioning procedure was employed,

which included either: (1) increasing the degree to which a precurrent response raised the probability of reinforcement for current responding; or (2) decreasing the probability of reinforcement for current responding to zero unless a precurrent response had occurred within the previous 15 s. Both of these procedures produced enhanced levels of precurrent responding which eventually maintained when the standard precurrent contingency was reintroduced.

For four subjects, a COD was later imposed onto the precurrent contingency. Specifically, a precurrent response produced a brief timeout followed by the period of enhanced reinforcement probability for current responding. In two cases, the COD reduced precurrent responding to near zero levels, suggesting that reinforcement for current responses immediately following a precurrent response can play an important role in maintenance. In another experiment, the acquisition of precurrent responding was observed when the COD was part of the precurrent contingency from the beginning, suggesting reinforcement for current responses immediately following a precurrent response is not necessary for acquisition.

Current responding generally occurred at a high stable rate within sessions, between sessions, and between conditions. Efficiency (defined as the proportion of current responses in a session emitted under the enhanced probability state) rarely approached maximal levels and

generally did not improve with extended exposure to the precurrent contingency. Post-session verbal reports were recorded for six subjects. The conditioning and extinction of precurrent responding was demonstrated in the absence of "awareness" of the precurrent contingency. The accuracy of the reports varied both between- and within-subjects, and like efficiency, did not improve with extended exposure to the precurrent contingency.

Some issues considered in the discussion include (1) the role of frequency of contact with the precurrent contingency in acquisition and (2) discriminative control by the reinforcement schedules. Directions for future research are also discussed.

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DEDICATION

WHAT MIGHT HAVE BEEN[1]

Once I saw a poem my father
had written when he was young.
It was about The Resurrection and Christ's
last encounter with His friends.
I'd also come across a notebook
in which my mother, as a girl, had
recorded her impressions of some
of Dickens' characters and their effect on her.

Although, in a fashion, the pieces were
quite good, I never spoke to either
one about it all. Possibly I thought
this would have been a kind of adolescent
patronizing or caused embarrassment--
my discovering childish things they'd put away.

But now, reminded on that silence
I sense regret,
despite the fact that this is ridiculous.
My late praise could never have made
public authors of them. All that,
if it were possible, should have been
attempted years earlier and by others.

Still, I say it is a little sad
their talents were (it seems) so casually lost
and wonder if there might have been
a place in other worlds for them
and what it was I might have done.

Written by my father, Donald Munro Polson, in whose memory I dedicate this dissertation.

[1]Polson, D. (1979). Lone Travellers. Fredericton, N.B: Fiddlehead.

INTRODUCTION

Contingencies are the heart of behavior analysis. As Lee (1988) recently noted, "Contingencies are the basic independent variables, and...behavior is of interest...only to the extent that it participates in contingencies and is affected by them" (p. 73). The basic three-term reinforcement contingency studied by behavior analysts can generally be described as follows. A stimulus change (e.g., the addition or removal of a stimulus) is more likely following particular responses than in their absence; consequently, responses increase in frequency. The responses are grouped together on the basis of these two common properties and are called the operant response class. The functional consequential stimulus is called the reinforcer, and the process reinforcement. Reinforcement may occur more often in the presence of a particular stimulus and, if so, operant responding is more frequently emitted in the presence of that stimulus than in its absence. The functional stimulus correlated with reinforcement is called the S^D, and the process discrimination. The net result is a three-term reinforcement contingency (sometimes called a discriminated operant; cf., Catania, 1984), consisting of (1) the S^D, (2) the operant response class, and (3) the reinforcer.

Consider an example. Our subject is an aspiring guitarist. Performing songs is a behavior that sometimes produces praise. Praise increases the likelihood of performing songs, and thus praise functions as a reinforcer. Over time he is exposed to a contingency whereby praise for his guitar playing is more likely when someone requests that he perform; as a result, he does not perform unless asked to do so. The result is the three-term reinforcement contingency, consisting of (1) an S^D (request), (2) the operant response class (performing songs), and (3) the reinforcer (praise).

In another less studied and more subtle contingency, responses can affect the conditions controlling the operant response class. We will call such responses "precurrent" to distinguish them from responses within the "current" operant class. When responses produce a common effect on a condition controlling the current operant and change in probability because they do so, we will group these responses together and call them a <u>precurrent operant</u> response class.

A general concern of the present paper is the conditions under which a precurrent operant develops and maintains. Here is a list of some possibilities:

1. Precurrent behavior increases the probability that a current operant response occurs.
    a. Precurrent behavior produces an establishing operation (EO) that evokes current operant responding (the evocative effect of the EO; see

Michael, 1982; 1986).

b. Precurrent behavior produces a discriminative stimulus that occasions current operant responding.

c. Precurrent behavior produces a stimulus that elicits a response within the reinforced response class.

d. The emission of precurrent behavior itself becomes a condition that enhances current operant responding.

2. Precurrent behavior alters the reinforcer component of the current operant.

a. Precurrent behavior increases the reinforcer magnitude of a current operant response.

b. Precurrent behavior reduces the reinforcer delay of a current operant response.

c. Precurrent behavior increases the reinforcement probability of a current operant response.

d. Precurrent behavior produces an EO that alters the value of a reinforcer (the function-altering effect of an EO; see Michael, 1982; 1986).

Note that in (1), if we hold the response-reinforcer contingency constant, an increased likelihood of current operant responding would result in an increased frequency of reinforcer delivery. In (2), the reinforcer component can be altered directly while holding current operant responding constant.

Reconsider our example. In terms of producing a discriminative stimulus, suppose that prior to a visitor's arrival our subject places his guitar in full view of where his guest will be sitting. This precurrent behavior makes it more likely that friends will request that he perform on his guitar, i.e., friends will produce the S^D in the presence of which reinforcement is more likely.

In terms of precurrent behavior itself becoming a condition controlling the current behavior, let us make the additional assumption that our subject must perform above a certain criterion level to produce praise. Praise is rarely forthcoming when he makes too many mistakes. Taking a few deep breaths before beginning each song (precurrent behavior) makes it more likely that he will perform at a criterion level that results in praise.

In terms of altering the reinforcer component of the current operant, suppose that if our subject tells a story about a song (precurrent behavior) prior to performing it, then his friends are more likely to give praise as a consequence of his song performance than if no story was told.

The precurrent behaviors identified in the above examples include placing a guitar in a specific location, taking a few deep breaths, and telling stories. Note that none of these behaviors produce the reinforcer (i.e., praise) directly; rather, they function by changing the conditions affecting the current operant of performing songs. And in each case it is possible that the precurrent behavior maintains because of such a consequence.

Skinner on the Precurrent Operant

There are four major sources from Skinner's works in which precurrent behavior is given considerable attention:

(1) Science and Human Behavior (1953), Section III, The Individual As A Whole

(2) Verbal Behavior (1957), Section IV, The Manipulation of Verbal Behavior (The Autoclitic)

(3) The Technology of Teaching (1968), Chapter 6, Teaching Thinking

(4) Contingencies of Reinforcement (1969), Chapter 6, An Operant Analysis of Problem Solving.

How relevant does Skinner judge the precurrent operant to be? He writes:

> A special kind of chaining is represented by behavior which alters the strength of other behavior and is reinforced because it does so. Such behavior could be said to distinguish the human organism from all others. (1953, p. 224; emphasis Skinner's)

Initially, Skinner wrote in terms of a "controlling response" affecting variables in such a way as to change the probability of a "controlled response" (1953, p. 231). In later works, the term "precurrent behavior" was emphasized which "changes either our environment or ourselves in such a way that 'consummatory' behavior occurs" (1968, p. 121), "makes subsequent behavior more effective" (1968, p. 124), and "furthers the reinforcement of subsequent behavior" (1969, p. 137).

Precurrent behavior can occur as verbal behavior. (Verbal behavior can generally be defined as behavior reinforced through the mediation of other persons [Skinner, 1957, p. 2]). Consider Skinner's (1957) "autoclitic". Included are "such 'propositional attitudes' as assertion, negation, and quantification, the design achieved through reviewing and rejecting or emitting responses, the generation of quantities of verbal behavior as such, and the highly complex manipulations of verbal behavior" (Skinner, 1957, p. 313). According to Skinner, "the autoclitic component acts upon the listener to strengthen his [the listener's] reaction to the response which it accompanies" (1957, p. 326). Within the present framework, the autoclitic is a verbal example of precurrent behavior that alters the reinforcer component of the current operant. This is illustrated by the following two examples:

(1) A closed door may be a reinforcing event for me at a particular moment. I could say to my partner, sitting beside the door, "Close the door", and she may or may not comply. However, I say, "Please close the

door", because reinforcement has been more likely for similar requests when prefaced with saying "please". Saying "please" functions as an autoclitic, or more generally, a precurrent operant.

(2) Suppose it's a bright sunny afternoon. I could say, "It will rain this afternoon", but the probability of producing a reinforcing reaction from a listener (e.g., agreement) would be low. Reinforcement has been more probable, however, when I have stated the conditions under which my vague verbal responses are emitted, e.g., "The newspaper predicts that it will rain this afternoon". Saying the frame "The newspaper predicts that" is an example of an autoclitic, or again, more generally, a precurrent operant.

It is clear that there are many examples of precurrent behavior, but what is less clear is how such behavior is developed and maintained. Skinner's discussion of the behavior of "deciding" provides some clues.

> When we look a situation over carefully in the course of making a decision [precurrent behavior], we presumably increase the probability that the response eventually made [current behavior] will achieve maximal reinforcement. In the long run the net gain may be enough to maintain the strength of the [precurrent] behavior of looking over the situation....Escape from indecision or the net advantage of a deliberated

> response may seem inadequate to explain the origin and maintenance of the [precurrent] behavior of deciding. They are certainly defective reinforcers, for they may be long delayed and their connection with a [precurrent] response may be obscure. We may readily admit these deficiencies, however, for the [precurrent] behavior of making decisions is also usually deficient. It is not present in any degree in the behavior of lower organisms or of many people. When present it is usually the result of special reinforcements provided by the community. Though the individual may accidentally hit upon various ways of deciding [precurrent behavior], it is more likely that he will be taught the relevant techniques. (1953, p. 244)

What Skinner appears to be saying here, a theme repeated elsewhere in his writings (e.g., Skinner, 1969), is that precurrent behavior may be maintained by its effect on the current contingency of reinforcement, once established. While it is possible that precurrent behavior may be what he calls "automatically reinforced" by its initial effects, such cases are probably rare; reinforcement directly contingent upon the precurrent behavior is often necessary to set up a precurrent operant (cf., Parsons, Taylor, & Joyce, 1981).

Surprisingly, little research has resulted from

Skinner's speculative discussions of precurrent behavior. A rare exception includes research conducted by Joe Parsons and his students (e.g., Parsons, 1973; Taylor, 1980; Parsons, Taylor, & Joyce, 1981; see also the Literature Review in Appendix A). Skinner's writings suggest that understanding the precurrent operant is essential to understanding the basic processes involved in complex behavior such as self-control (Skinner, 1953), verbal behavior (Skinner, 1957), thinking (Skinner, 1953; 1957; 1968; 1974), and problem solving (Skinner, 1969). The present study considered variables which might affect both the development and maintenance of a precurrent operant; it was concerned with the special case in which precurrent responding changes the reinforcement probability for a current operant response.

Taylor (1980)

The present study was modeled after a paradigm employed by Taylor (1980). In that study, five undergraduates served as subjects. A subject was seated in front of a console containing two telegraph keys and a point counter. Every two counts on the point counter was worth one cent. Subjects were paid a $10 bonus at the end of experiment. There were two, 20-min sessions a day, separated by at least 10 min, scheduled at least three days a week. Points were exchanged for money at the end of the two sessions.

There were three phases, distinguished by the type of function served by right key presses. In all phases, the left key presses produced reinforcers according to a probability (also called random ratio) schedule; specifically, every left key press had the same one in twenty-five chance of advancing the point counter (p = .04). In the first phase, Baseline, there was no programmed consequence for right key presses. In the second phase, Induction, each right key press doubled the probability of reinforcement for left key presses (i.e., p = .08) for 15 s. In the third phase, Reduction, each right key press reduced the probability of reinforcement for left key presses to zero for 15 s. (From here on, the left and right keys will be referred to as the current and precurrent keys, respectively.) Generally, subjects were shifted from phase to phase after being exposed to a phase for six sessions. If unusual data fluctuations occurred, a phase continued until the dependent variables (described below) showed stability or 10 sessions elapsed under that phase.

Two dependent variables were the rates of current and precurrent responding per session. Taylor also calculated the temporal proportion of each session a subject spent under the precurrent-produced reinforcement schedule. This third dependent variable was called the Affected Schedule Proportion.

The results were as follows. For four of the subjects precurrent responding was reduced to near zero levels after approximately two Baseline sessions. When Induction was introduced, precurrent responding increased for these subjects immediately or very soon after the first contact was made between current responding and the precurrent-affected reinforcement schedule, and then generally maintained at the enhanced level for the remaining Induction sessions. The behavior of S5 followed a different pattern: extremely high precurrent response rates were observed during all six Baseline sessions, decreasing to near zero rates over six Induction sessions, and then increasing to moderate levels for the remaining six Induction sessions. The Affected Schedule Proportion (ASP) followed a pattern similar to each subject's precurrent response rate. It should be noted that ASP did not increase across Induction sessions and never approached 1.0 (100%). In fact, ASP was stable over the last four Induction sessions and averaged .75, .58, .56, .45, and .48 for the five subjects, respectively. With the introduction of Reduction, the precurrent response rate and ASP fell for all subjects and remained at low levels for the remainder of this phase; however, for four subjects these levels were higher than during Baseline, despite the fact that a 15-s time-out from reinforcement for current responding was contingent on each precurrent response under Reduction. The current response rate generally remained stable across all phases for all subjects.

The Paradigm

The changeover-key procedure. The paradigm employed by Taylor (1980) and the present study is a derivative of a procedure used to study concurrent operants called the changeover(CO)-key or Findley procedure (Findley, 1958; cf., Catania, 1966). In the CO-key procedure, a response on one manipulandum (CO-key) changes the schedule and associated stimuli on a second manipulandum (main-key). For example, suppose a pigeon is reinforced for pecking the main-key when red on VI 120 s. If it pecks the CO-key, the main-key turns blue and the main-key reinforcement schedule changes to VI 60 s. In the present framework, CO-key responding can be considered a precurrent behavior which affects both the discriminative stimulus and the reinforcement probability components of the current contingency of reinforcement for responding on the main-key. Because the present study was concerned only with effects of precurrent-induced changes in the reinforcement probability component, explicit discriminative stimuli associated with each schedule on the current key were absent (although they are by no means irrelevant to a precurrent operant analysis).

In the CO-key procedure, an organism may respond exclusively to the "preferred" schedule by emitting no more CO-key responses after producing the schedule of "choice" on the main-key. Findley (1958), interested specifically in "switching" behavior, circumvented this problem by scheduling progressive ratios on the main-key. An example of a progressive ratio schedule would be as follows. Main-key responses under green are reinforced under FR 10 for the first reinforcer, FR 20 for the second, FR 30 for the third, etc. A CO-key response changes the main-key to red and resets the ratio back to FR 10, which now progresses under red until another CO-key response is emitted to change the main key back to green and FR 10. The present study, also interested specifically in "switching" (precurrent) behavior, employed a somewhat similar changing contingency on the main(current)-key, in that a precurrent response altered the schedule for current responding for only 15 s. In this way, the subject could not "lock into" the denser reinforcement schedule; rather, he/she had to work (i.e., emit precurrent responses) to maintain or reinstate it.

The CO-key procedure and its present derivative lend themselves well to the study of precurrent operants for a number of reasons. First, the behavior of switching from one schedule to another, i.e., precurrent responding, is explicit, measurable, and topographically distinguishable from current responding. Second, unidirectional control between precurrent and current responding can be scheduled; i.e., while precurrent responding alters the consequence of current responding, current responding does not alter the consequence of precurrent responding. Third, both precurrent and current responses are "free operants" in the sense that the subject is free to emit either response at any time without waiting for the experimenter. Skinner (1966) notes the advantages of a free operant approach:

> When the organism can respond at any time, its rate of responding varies in many subtle ways over a wide range...Rate of responding is important because it is especially relevant to the principle task of a scientific analysis[:]...the conditions which govern the probability that a given response will occur at a given time. [While] rate of responding is by no means to be equated with the probability of responding, ...[it] is a step in that direction...Changes in rate of responding are directly observed, they have the dimensions appropriate to a scientific formulation, and under skillful experimenter control they show the uniformity expected of biological processes in general. (pp. 15-17)

Probability (random ratio) schedules. In the present study, reinforcement on the current key was programmed according to a probability schedule. Under this schedule, every response has the same probability of producing a reinforcer. This schedule is also known as random ratio (RR) since the number of responses to produce a reinforcer varies from one reinforcer to the next. For present purposes, a RR schedule offers a number of advantages over other schedules. First, the choice has been made not to use interval schedules because Conc VI EXT can produce superstitious responding under the extinction component resulting from adventitious reinforcement (e.g., Catania & Cutts, 1963). This effect has been observed in a design very close to the present one: an unsignalled CO-key procedure employing Conc RI EXT (Serna, 1980). With Conc RR EXT, however, near zero rates of extinction key responding are observed (Taylor, 1980). Thus, by programming an RR schedule on the current key, superstitious responding (due to an adventitious contingency) does not have to be teased out from precurrent operant responding (due to a very real precurrent contingency)--although future research in both areas may show that both are reducible to the same phenomenon, i.e., response-reinforcer contiguities (e.g., see Imam & Lattal, 1988).

Perhaps because of its "randomness", an RR schedule produces fairly consistent responding between reinforcers for any given ratio value, from RR 5 (p = .2) to RR 80 (p = .013); with FR schedules, however, the postreinforcement pause increases across similar ratio values (Crossman, Bonem, & Phelps, 1987; see also Mazur, 1983). Suppose the precurrent response functioned to halve the ratio contingency for current responding from 80 to 40. With FR schedules, the microstructure of current responding would be different under FR 40 than FR 80 (i.e, shorter postreinforcement pauses). If precurrent responding was affected, one could legitimately ask if this change was due to the change in the pattern of current responding. A change from RR 80 to RR 40 would be less of a problem in this regard.

The precurrent contingency. In the present study, the standard precurrent contingency primarily consisted of a precurrent response changing the reinforcement probability for current responding from .04 (and later .02) to .08 for 15 s. These parameters were employed for at least two reasons. First, the research began as a systematic replication of Taylor (1980) and other unpublished research by Joe Parsons and his students at the University of New Mexico. It should be noted that Taylor used these parameters based on the assumption (from the available literature at the time) that response rate is generally stable across probability schedules within the range of .04 and .08. If current response rate is changed by the precurrent-produced probability schedule, then the question can be raised as to whether the changed current response rate can account for changes in precurrent responding. More recent literature is inconsistent on how p values affect rate of responding. Mazur (1983) found that response rate increased across decreasing p values of .1 to .05 and then decreased across .025 and .013. Crossman et al. (1987) found that response rate was approximately constant across p values of .25 and .1, increased at .025 and then slightly decreased at .013. For present purposes, it is instructive to note that current responding did not differ statistically across phases in the Taylor study. Deviating from Taylor's parameters could prove problematic for the reason stated above if the new parameters produced substantial changes in current responding across phases when the precurrent contingency was and was not in effect.

Second, pilot research demonstrated that descriptions of the standard precurrent contingency were often inaccurate, and variable from one session to the next. This is advantageous, since any tendency for subjects to lock into stating a rule regarding precurrent responding and reinforcement could make precurrent responding less sensitive to subsequent changes in the precurrent contingency (see, e.g., Hayes, Brownstein, Zettle, Rosenfarb, and Korn, 1986). Furthermore, the present study sought to document the conditioning and maintenance of precurrent responding in the absence of awareness of the process, which presumably would be more probable with a subtle precurrent contingency. ("Awareness" as used here is limited to meaning an accurate post-session verbal report of the within-session contingencies.) While this effect was demonstrated long ago with a single response (e.g., Hefferline & Keenan, 1963), one might question whether responding can come under the control of subtle and complex precurrent contingencies in the absence of intervening verbal behavior (i.e., accurate rules), especially in light of Skinner's contention that precurrent operants may be unique to humans (1953, p. 224). However, common experience would suggest otherwise. For example, the public speaker who clears his throat frequently may describe his behavior as a nervous habit but if this behavior increases the likelihood that people actively listen to what he has to say, then it is possible that throat clearing is a precurrent operant. Perhaps this is the type of behavioral phenomenon addressed within the present paradigm.

Outline

The present study began as a systematic replication of Taylor (1980). As the data were collected, changes in procedure were required to produce results comparable to Taylor. Questions arose during the course of the study which produced new experiments to answer basic questions. For the most part, the experiments are described in order of occurrence, which allows the reader to follow the rationale of each experiment.

The present study represents an extension of Taylor (1980) in a number of ways:

(1) Taylor relied exclusively on between-subject replications of the effect that precurrent responding is enhanced and then maintained by the precurrent contingency. The present study employed both between- and within-subject replications of this effect by alternating conditions whereby the precurrent contingency was and was not present. As Sidman (1960) notes:

> Intrasubject replication...provides a unique demonstration of a technique's reliability. When an organism's behavior can be manipulated in a qualitatively consistent fashion, the phenomenon is question is a real one and the experimenter has the relevant variables well under control. (p. 85)

(2) The present study examined different methods to develop a precurrent operant when the standard precurrent contingency was ineffective in this regard. Two methods included: (i) increasing the magnitude of the precurrent contingency, i.e., the degree to which a precurrent response enhanced the probability of reinforcement for current responding; and (ii) decreasing the probability of reinforcement for current responding to zero in the absence of a recent precurrent response.

(3) The present study examined a variable that might

affect the development and maintenance of the precurrent operant, the inclusion of a changeover-delay (COD) as part of the standard precurrent contingency. The COD is defined as a period of time following precurrent responding during which reinforcement for current responding is unavailable. If immediate reinforcement for current responding following precurrent responding is a major factor in the development and maintenance of the precurrent operant, then one would expect the COD to be disruptive.

(4) Interesting anecdotal post-session verbal behavior about the within-session contingencies was cause for including a post-session written verbal report as part of the experimental procedure during later experiments. This allowed an assessment of whether subjects could accurately describe the contingencies and whether changes in post-session verbal behavior accompanied changes in contingencies and/or changes in within-session responding.

GENERAL PROCEDURE

Apparatus. The response manipulandum was a computer mouse (Logitech Serial Mouse Model #C7-3F-9F). An IBM computer (Model #5150) and a Zenith Data Systems computer (Model #2F-158-42) generated the contingencies and stored the resultant data for Subjects 1-3 and Subjects 4-9, respectively. A Precurrent Operant Program, written and compiled in Turbo Basic, was designed by J. Parsons and slightly modified by the present author. A Precurrent Analysis Program, also written and compiled in Turbo Basic, was designed by the author to perform various analyses on the obtained data. A third program, written by T. Allen, was used to generate cumulative records of the subjects' performances.

The Precurrent Operant Program allowed for the following parameters to be manipulated: the normal probability schedule for current responding (i.e., the normal probability state, *Pn*); the probability schedule for current responding immediately following a precurrent response (i.e., the immediate probability state, *Pi*); the duration of *Pi* (i.e., *Di*); the probability schedule for current responding following *Di* (i.e., the changed probability state, *Pc*); the duration of *Pc* (i.e., *Dc*); the session duration; and the points/money exchange ratio.

The contingency programming environment of the Precurrent Operant Program can be conceptualized in the following way. There were three mutually exclusive states: _Pn_, _Pi_, and _Pc_. The normal resting state was _Pn_. A precurrent response always initiated the _Pi_ state. Under the _Pi_ state, if no precurrent response occurred for a period of time equal to the specified _Di_ value, the _Pc_ state was begun. Under the _Pc_ state, if no precurrent response occurred for a period of time equal to the specified _Dc_ value, the _Pn_ state was resumed. Figure 1 illustrates how the various states would be produced as a function of an uneven distribution of precurrent responses over time, with _Di_ and _Dc_ set at three and six seconds, respectively.

Insert Figure 1 here

The cumulative record on top shows precurrent responding. Each precurrent response is represented by a vertical increment. The three state lines (_Pn_, _Pi_, and _Pc_) are shown below. A state is in effect when the state line is in the up position. _Pn_ is the active state prior to the first precurrent response (see [a] in Figure 1). When the first precurrent response is emitted, _Pi_ becomes the active state (b). No precurrent response occurs for the duration of _Di_, and thus _Pc_ becomes the active state (c). No precurrent response occurs for the duration of _Dc_, and thus _Pn_ becomes the active state (d). The second precurrent

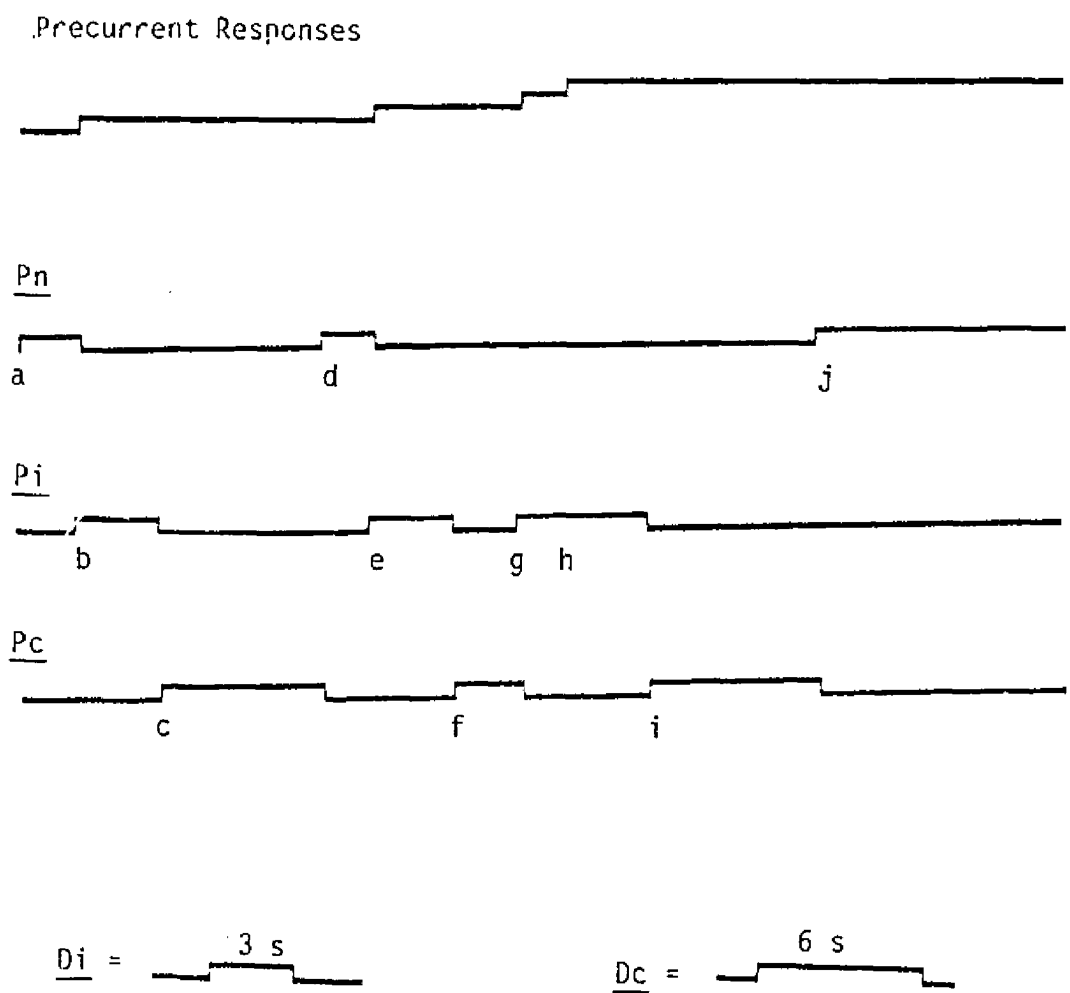


Figure 1. An example of changes in state as a function of precurrent responding. The cumulative record on top shows precurrent responding. Each precurrent response is represented by a vertical increment. The three state lines (Pn, Pi, Pc) are shown below. A state is in effect when the state line is in the up position.

response initiates the _Pi_ state (e). No precurrent response occurs for the duration of _Di_, and thus _Pc_ becomes the active state (f). About half way through _Dc_, the third precurrent response is emitted, and thus the active state is changed from _Pc_ to _Pi_ (g). Then, about half way through _Di_, the fourth precurrent response occurs, and thus _Di_ resets and the active _Pi_ state is prolonged (h). No precurrent response occurs for the duration of _Di_, and thus _Pc_ becomes the active state (i). No precurrent response occurs for the duration of _Dc_, and thus _Pn_ becomes the active state for the remainder of the session (j).

During a session, the following events and their corresponding time of occurrence (to the nearest tenth of a second) were recorded: a current response, a precurrent response, the beginning of _Pn_, _Pi_, and _Pc_, and the start and finish of the session.

The computer mouse had three response keys. At all times one of these keys was covered. Pressing one of the uncovered keys--the current response--intermittently advanced a money counter according to a probability schedule; pressing the other exposed key--the precurrent response--either had no function or functioned to alter the probability schedule for current responding, depending on the phase of the experiment.

Procedure. Immediately prior to Session 1, the subject read and signed the contract included in Appendix B, and then read a set of task-related instructions (see Experiments 1 and 2 for details). The experimenter asked for and answered any questions related to the contract and the instructions.

The subject was seated at a small table in an experimental chamber. The computer mouse was situated within easy reach on this table. The computer monitor faced the subject, and read: "Session begins when money box appears". To begin a session, the experimenter pressed a key on the keyboard and left the chamber. The key press produced a long beep and a small box appearing in the middle of the screen, surrounding the characters "$0.000". Reinforcer delivery entailed the computer emitting a short beep and the counter incrementing by .005 (i.e., .5 cents). During a session, the experimenter could hear, but not see, the subject. A session ended with another long beep and a flashing statement appearing on the screen under the money box, reading: "Session completed. Please wait for experimenter". The written instructions were always present in the experimental chamber for reference.

Two, 20-min sessions were scheduled per day with an intervening break of approximately 10 min. Between sessions, the subject was asked to wait in another room while the computer stored the data to diskette. At the end of a day's two sessions, the subject was paid the full amount earned during those sessions. Each subject was promised a dollar bonus for each day of participation to be received at the end of the experiment contingent upon at least 10 days (Subjects 1-3) or six days (Subjects 4-9) of participation.

Data. Like Taylor (1980), the number of precurrent and current responses per session were recorded. As mentioned previously, Taylor's third dependent variable was called the Affected Schedule Proportion (ASP), i.e., the temporal proportion of a session under Pc (there was no independently programmed Pi state in his study). A problem with this measure is that time can be recorded under Pi and Pc even though current responding did not occur and make contact with these states. For example, suppose Di is set at 2 s. With long runs of consecutive precurrent responses, considerable time will be recorded under Pi but the Pi contingency will not be contacted since no current responses occur during these runs. Or, following precurrent responding a subject may consistently pause more than 2 s before responding to the current key, producing the same result. As a response-based alternative to the ASP measure, the present study calculated the proportion of current responses per session (current proportion: CP) emitted under the various states. When Di was greater than zero, there were two measures of interest: the current proportion under Pi (Pi CP) and the current proportion under Pi and Pc combined (PiPc CP); e.g., if Di = 2 s and

Dc = 13 s, then *Pi* CP is the proportion of current responses emitted within 2 s of a precurrent response and *PiPc* CP is the proportion emitted within 15 s. When *Di* was set at zero, only the latter measure needed to be calculated; e.g., if *Di* = 0 and *Dc* = 15 s, then *PiPc* CP is the proportion of current responses emitted within 15 s of a precurrent response. Where possible, the value of *Di* plus *Dc* was matched between conditions for comparison purposes; generally, the conditions were differentiated by varying the *Pn*, *Pi*, and *Pc* values.

Suppose *Di* = 0 and *Dc* = 15 s, and *Pc* = *Pn* = .04. Under this condition there is no precurrent contingency and no advantage to emitting current responses under *Pc* relative to *Pn*; however, if in a subsequent condition *Pc* is raised to .08, then the probability of reinforcement for current responding is doubled for current responses emitted under *Pc*. Thus, under this new condition we might say that a subject responds "more efficiently" the greater the *PiPc* CP.

A measure not considered by Taylor (1980) was the number of *changeovers* (*CO's*) per session. A CO refers to switching from one response alternative to another. In the present study, CO's per session indicate the number of times a subject switched from current to precurrent responding. This measure is important because it gives an indication of response patterns on the two keys and how many times the precurrent contingency (when in effect) was contacted. Suppose there is a precurrent contingency. At one extreme, a subject could emit equal numbers of precurrent and current responses but only one CO response might occur half way through the session; at the other extreme, equal numbers of current and precurrent responses could be emitted with the subject switching after every current and precurrent response. In the first case, no contact is made with the precurrent contingency; in the latter case, the precurrent contingency is contacted repeatedly (albeit in a distorted form since the standard precurrent contingency calls for 15 s of increased reinforcement probability for current responding following a precurrent response).

Detailed CO data are reported in Appendices C1-C9, which include sessional data concerning the mean response run on each key (precurrent responses/CO; current responses/CO) and the variance of these means. A _response run_ is defined as the number of responses that occur on a given key prior to switching to responding on the other key. The measure of variance employed, the _mean deviation_, is defined as the mean of the (absolute value of the) deviations about the mean; the formula is presented in Appendix D (cf., Schmidt, 1979). The mean deviation gives an indication of stereotypy on each key; e.g., little variance would be observed for the mean precurrent response run measure if runs of precurrent responses were approximately equal throughout the session.

In the present experiments, precurrent response runs were very small (relative to current response runs) for all subjects, with generally little variance within sessions (see mean deviation data in Appendices C1-C9), between sessions, or even between conditions. Precurrent responses per session and CO's per session were highly correlated for most subjects; for Subjects 1 through 9, the Pearson r was .87, .66, .98, .27, .80, .78, .78, .97, and .62, respectively. Although CO's are reported in the Results, precurrent responding will be discussed at the exclusion of CO's except in those cases in which a discussion of CO's adds to the description of a subject's performance.

Extensive use is made of cumulative records to illustrate within-session performance and transitions in responding across sessions. Figure 2 presents sample cumulative records from a session.

Insert Figure 2 here

The top and bottom curves show the cumulative records for precurrent (P) and current (C) responding, respectively. Each reinforcer appears as a blip and is shown twice, once above each curve to illustrate its temporal relation to both precurrent and current

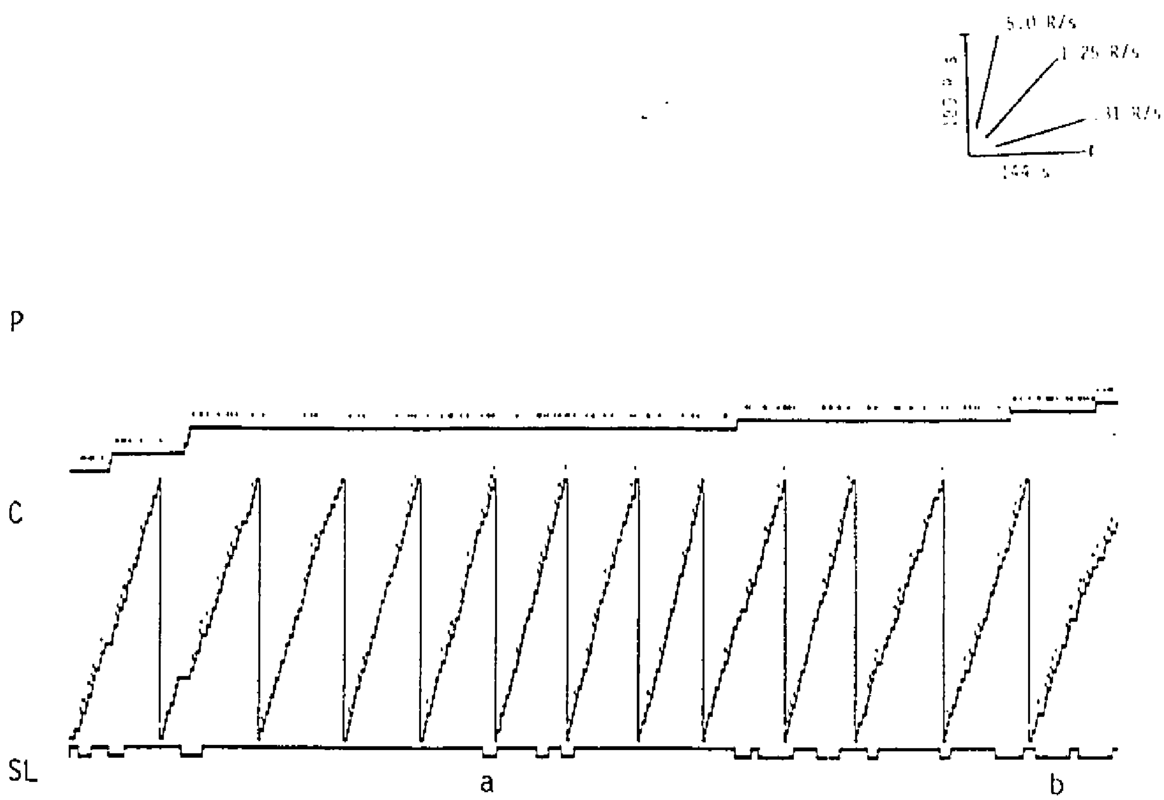


Figure 2. Sample cumulative records for precurrent (P) and current (C) responding during a 20-min session. The Pn state line (SL) is shown at the bottom. Reinforcers are represented by dots above each curve.

responses. Below the current response curve is the state line. Pn is in effect when this line is in the up position and Pi or Pc (PiPc) when the line position is down. It is important to note that because of the scale, not every response produces a vertical increment in its respective cumulative record. This is of special concern when discussing precurrent responding since it often occurred at a low rate. Thus, from the cumulative record alone, variations in precurrent responding (and CO's) are often difficult to discriminate. However, instances of precurrent responding not evident in the cumulative record can be spotted by examining the state line. In Figure 2, when a precurrent response occurs at any given point in that session, the state line switches to the down position if the present state is Pn (a) or is maintained in the down position if the present state is either Pi or Pc (b).

Since probability schedules are based on random numbers, deviations from the Pn, Pi, and Pc values programmed for any given session are to be expected. Appendices E1-E9 show the scheduled versus the obtained reinforcement probabilities for each state in every session for Subjects 1-9, respectively.

In Experiment 2 subjects were asked to comment on what was happening during a session by providing written comments at the end of each session (see Experiment 2 for details). To make sense of these reports, the present study adopts the position of Shimoff (1986):

> Post-session verbal reports are instances of behavior, not causes of behavior, and not necessarily accurate reflections of within-session verbal behavior...The ultimate causes of behavior--at least for a behavioral analysis--are in the environment. (p. 22)

Consistent with Shimoff, Experiment 2 examined how changes in contingencies for within-session non-verbal behavior affected post-session verbal behavior. Of particular interest was the "accuracy" of subjects' reports. While the "objectivity" of this approach might be questioned, as Leigland (1989) notes, such an analysis is consistent with the pragmatic epistemology which characterizes radical behaviorism so long as

> (1) the descriptions of the dimensions of verbal behavior and observed changes, in whatever terms these are presented, are controlled by direct records of actual verbal behavior; (2) the changes may be seen clearly in the records; and (3) the observed changes may be shown to be a function of environmental variables. (p.32)

Thus, complete records of subjects' verbal reports will be provided in the Results from which notable changes in verbal behavior will be described, especially in relation to changes in within-session contingencies and precurrent and current responding.

EXPERIMENT 1A

Experiment 1A attempted to systematically replicate Taylor's (1980) findings.

Subjects

The subjects (S1 and S2) were two undergraduate female students at the University of Victoria.

Procedure

The written instructions presented to each subject to read prior to Session 1 were as follows:

> It is possible to earn money by manipulating the computer mouse. Do not press the covered button on the computer mouse. The amount of money you have earned at any given time will be displayed on the computer monitor. When the screen prints that the session is over, wait for the experimenter to return and write down the amount of money you have earned. Today there will be one session, approximately a 10 minute break, and then another session. Following today's second session you will be paid the total amount earned during both sessions. During a session, do not leave your seat without first informing me. I will be within hearing distance in the other room. If you have a watch, please leave it with me and it will be returned to you following today's two sessions.

During the first phase, Absence of Precurrent Contingency (APC I), both Pn and Pc were set at .04 and Dc was set at 15 s; i.e., every current response had the same 1/25 chance of advancing the money counter, and precurrent responding had no scheduled effect. (Unless otherwise noted, Pi and Di were set at zero.) The APC I phase continued for a comparable period to Taylor's (1980) baseline. Then, the Presence of Precurrent Contingency (PPC I) phase was introduced, the only change being to raise Pc from .04 to .08. Thus, during the PPC I phase a precurrent response changed the reinforcement probability for current responding to .08 for 15 s.

Results

For S1, due to an apparatus malfunction, no reinforcers were delivered during Session 1; i.e., no behavior advanced the money counter. She was told that this was indeed apparatus failure and not part of the experiment. She was paid one dollar for this session.

The top and bottom of Figure 3 present the cumulative records for the first APC I session for S1 (Session 2) and S2 (Session 1), respectively.

Insert Figure 3 here

Figure 3 reveals that for both subjects (1) precurrent responding occurred primarily only at the beginning of the session, and (2) steady high rate current responding developed early and maintained throughout the session.

S1: Session 2

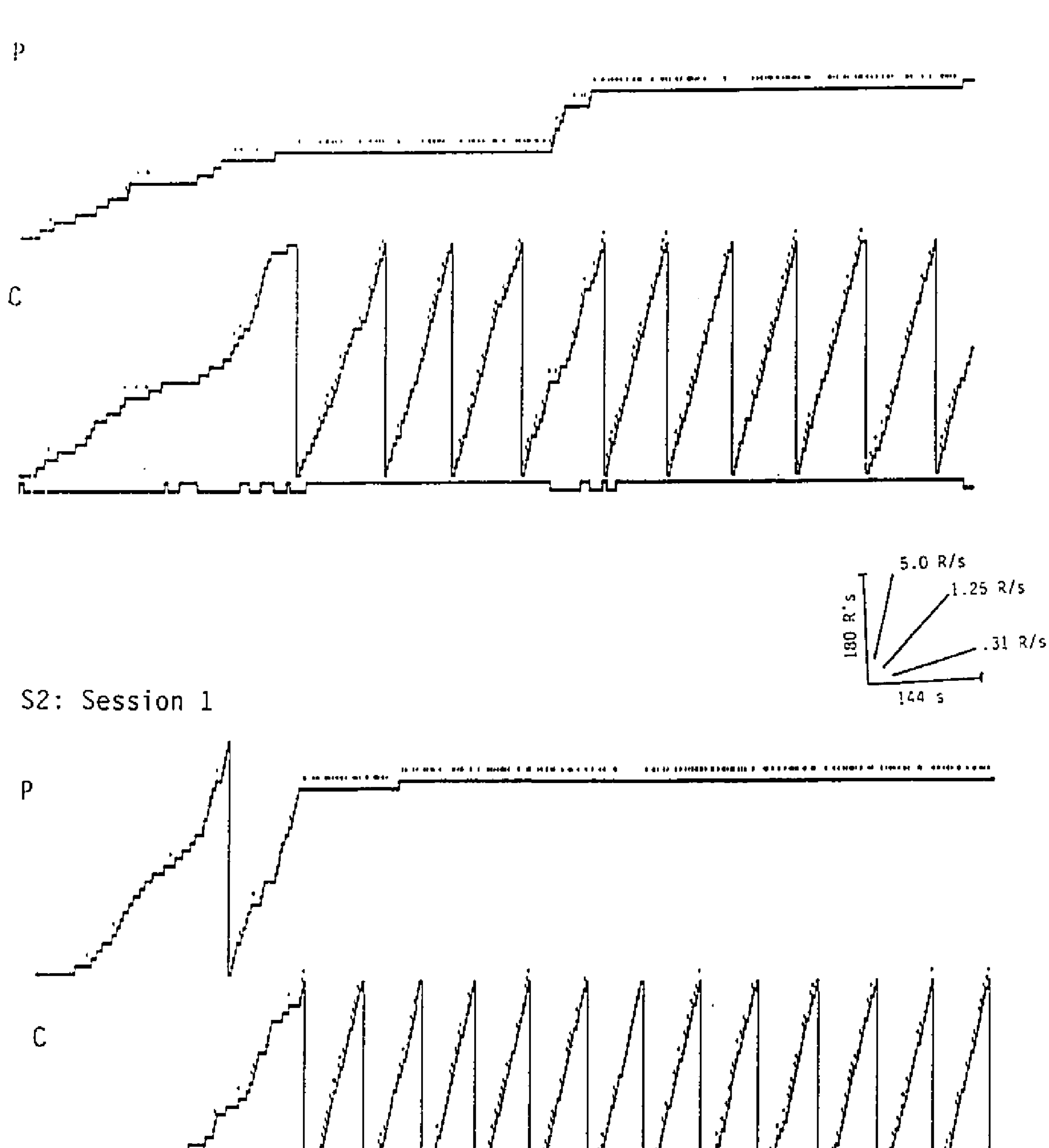


Figure 3. Cumulative records of precurrent (P) and current (C) responding for S1 (top) and S2 (bottom) during the first recorded session (S1: Session 2; S2: Session 1).

Insert Tables 1 and 2 and Figure 4 here

Tables 1 and 2 and Figure 4 reveal that after two sessions for S1 and one session for S2, near zero levels of precurrent responding were observed for the remainder of the APC I phase. For S1, current responding increased across Sessions 1-4 and then stabilized for the remaining three APC I sessions. For S2, current responding increased with each successive APC I session.

Tables 1 and 2 and Figure 4 show no significant changes with the introduction of the precurrent contingency in the PPC I phase for either S1 or S2. The PPC I phase continued for seven sessions for S1 and six sessions for S2. It should be noted that current responding continued to increase across sessions for S2 under the PPC I phase.

At least some current responses were emitted under PiPc during every PPC I session by both S1 and S2, i.e., the PiPc CP was always greater than zero, as seen in Tables 1 and 2. It is possible that the reinforcement probability under PiPc was no greater than under Pn since contacts with PiPc were infrequent and the probability schedules were based on a random number generator. However, Appendices E1 and E2 show that during every PPC I session for both subjects, the obtained reinforcement probability was higher under PiPc relative to Pn, i.e., following precurrent

TABLE 1

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across APC I and PPC I Sessions for S1

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
APC I (Pn=.04; Pc=.04; Dc=15s)					
1		APPARATUS FAILURE			
2	249	3919	.16	53	158
3	180	4474	.13	13	169
4	13	5127	.03	3	221
5	5	5603	.01	1	203
6	0	5549	.00	0	225
7	7	5321	.01	2	224
PPC I (Pn=.04; Pc=.08; Dc=15s)					
8	7	5314	.02	2	229
9	9	4926	.03	2	206
10	64	5101	.06	7	245
11	26	5289	.02	1	206
12	12	5035	.04	5	224
13	9	5380	.03	2	225
14	3	5315	.01	1	222

TABLE 2

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across APC I and PPC I Sessions for S2

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
APC I (Pn=.04; Pc=.04; Dc=15s)					
1	675	4861	.12	44	207
2	5	6405	.03	5	264
3	14	6425	.05	4	254
4	0	6943	.00	0	267
5	3	7187	.03	3	294
PPC I (Pn=.04; Pc=.08; Dc=15s)					
6	2	7460	.03	2	310
7	9	7888	.10	8	366
8	2	7891	.03	2	363
9	1	7942	.01	1	362
10	1	8021	.01	1	343
11	3	7820	.04	3	369

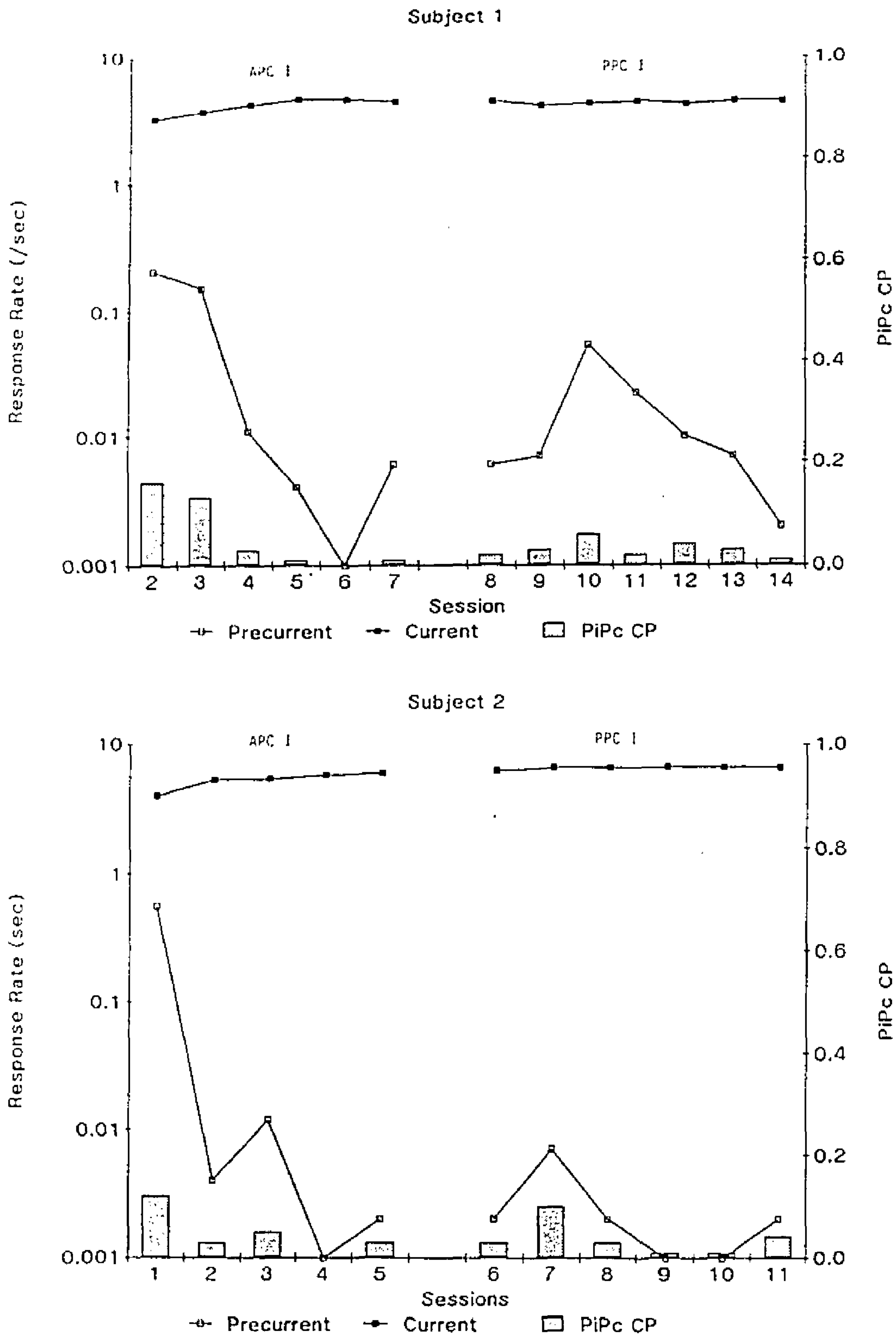


Figure 4. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for APC I and PPC I sessions for S1 and S2.

responding.

Discussion

The APC data are in agreement with Taylor (1980): precurrent responding rarely occurred after 1-2 APC sessions, while current responding maintained at a high constant rate. However, the PPC data differ: when precurrent responding was given the function of changing the reinforcement probability for current responding from .04 to .08 for 15 s, there was no systematic increase in precurrent responding even though the scheduled precurrent contingency was contacted in every PPC session (albeit infrequently) by both subjects. Taylor (1980) reported that for subjects for whom near zero rates of precurrent responding were observed under the APC condition, precurrent responding substantially increased immediately or very soon after the precurrent contingency was first contacted under the PPC condition.

EXPERIMENT 1B

The purpose of Experiment 1B was to examine means of enhancing and maintaining precurrent responding without directly reinforcing it.

Subjects

S1 and S2 from Experiment 1A were two of the three participants. S3 was a male undergraduate student at the University of Victoria.

Procedure and Results

All conditions were identical to Experiment 1A except for the experimental manipulations described below and summarized in Tables 3-5. The procedure and results will be discussed separately for each subject.

S1.

Insert Table 3 here

Table 3 shows that reducing *Pn* to .02 (Sessions 15-18) and then subsequently increasing *Pc* to .12 (Sessions 19-20) produced no sustained effect on precurrent responding or any of the related measures. From Session 21 on, the covered (left) button was uncovered and functioned as the precurrent response while the former precurrent (middle) button was covered. Responses on this new precurrent button occurred at a low rate during Sessions 21-22.

For Sessions 23-24, *Pi* was increased to .32 with *Di* set

TABLE 3

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across Conditions to Induce Precurrent Responding and PPC II Sessions for S1

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
(Pn=.02; Pc=.08; Dc=15s)					
15	12	5549	.05	4	112
16	88	4891	.05	4	114
17	5	5250	.01	1	106
18	3	4917	.03	2	123
(Pn=.02; Pc=.12; Dc=15s)					
19	9	4833	.02	1	102
20	2	5155	.01	1	118
(same parameters but precurrent function given to uncovered button and old precurrent button now covered)					
21	24	4925	.04	4	128
22	15	5234	.02	2	107
(Pn=.02; Pi=.32; Pc=.12; Di=2s; Dc=13s)					
23	32	4407	.06(.00)	5	119
24	17	4692	.03(.00)	2	88
CONDITIONING (Pn=.02; Pi=.5; Pc=.12; Di=2s; Dc=13s)					
25	1172	4152	.66(.34)	179	869
(Pn=.02; Pi=.24; Pc=.08; Di=1s; Dc=14s)					
26	1904	2697	.99(.32)	225	359
(Pn=.02; Pi=.12; Pc=.08; Di=1s; Dc=14s)					
27	1588	3711	.95(.18)	170	301
PPC II (Pn=.02; Pc=.08; Dc=15s)					
28	1190	4120	.82	144	304
29	943	4472	.76	145	314
30	669	4570	.46	76	225
31	897	4373	.62	89	240
32	733	4611	.52	76	245
33[b]	50	2375	.11	4	57
34[b]	273	5008	.21	39	168
35	1766	3884	.86	130	261
36	1440	3896	.70	94	250
37	1493	4070	.68	83	262
38	1794	3747	.85	129	302
39	1823	3819	.84	106	277

TABLE 3 (continued)

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
40	1468	4017	.75	77	248
41	973	4527	.63	54	260

[a]Numbers in parentheses indicate Pi CP.
[b]S1 reported that she fell asleep during Sessions 33-34.

at 2 s. Dc was decreased to 13 s. Table 3 shows that while precurrent responding was unaffected, there was a slight decrease in current responding. The obtained reinforcement probability under Pi was considerably lower than scheduled during both these sessions (see Appendix E1).

Table 3 reveals that in every session to this point, although contacts with the precurrent contingency were infrequent, at least some current responses were emitted under Pi and Pc (i.e., PiPc CP > 0) and the obtained reinforcement probability was always greater under these states than under Pn (see Appendix E1). Thus, in every one of these sessions S1 contacted an approximation of the scheduled precurrent contingency.

During Session 25, Pi was raised to .5. Figure 5 shows the cumulative records for this session.

Insert Figure 5 here

Figure 5 reveals that the first contact with this new precurrent contingency occurred just over a third of the way through the session. Thereafter, precurrent responding maintained at a stable greatly elevated level, and there was a slight reduction in the current response rate. Note the greatly enhanced rate of reinforcement produced by this behavior change. The state line shows that except for one

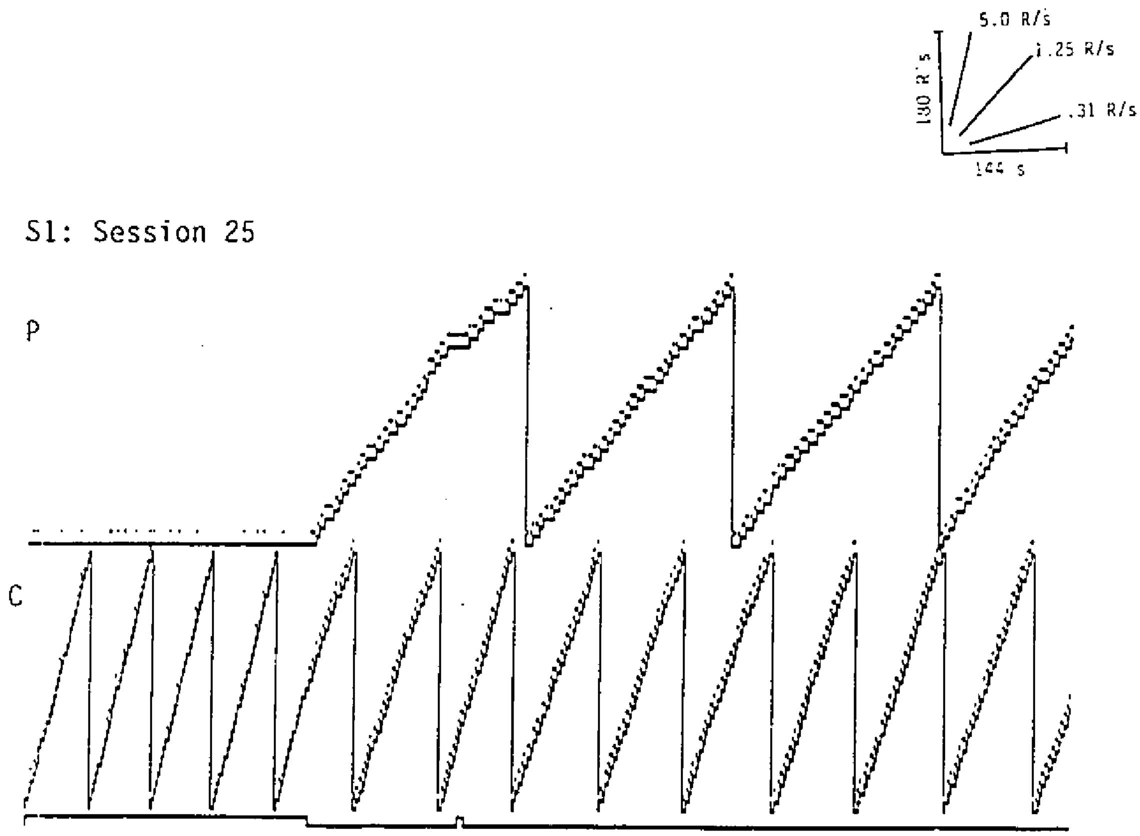


Figure 5. Cumulative records of precurrent (P) and current (C) responding for S1 during Session 25.

very brief span, no current response was emitted under Pn after the first contact with the precurrent contingency. Additional calculation reveals that for the last half of the session, 55% of the current responses were emitted under Pi, i.e., within 2 s of a precurrent response.

The dramatic increases in precurrent responding, the PiPc CP, and obtained reinforcers in Session 25 are seen in Table 3. Current responding decreased to its lowest level since Session 3 (see Table 1).

Now that precurrent responding was occurring at a relatively high stable rate, the magnitude of the precurrent contingency (i.e., the degree to which a precurrent response increased the probability of reinforcement for current responding) was gradually lowered across Sessions 26-27 (see Table 3 for exact parameters) in an attempt to maintain precurrent responding and a high level of the PiPc CP under a condition that previously produced no effect on either measure, i.e., Pn =.02 and Pc =.08. Sessions 25-27 will be referred to as the Conditioning phase. Table 3 shows that during Sessions 26-27 precurrent responding maintained at elevated levels. In Session 26, the PiPc CP was almost 100% (.99), dropping only slightly to 95% in Session 27. The current response rate decreased further during Session 26; although it recovered somewhat during Session 27, it was still lower than during any session prior to the Conditioning phase.

For Sessions 28-41 (PPC II phase), the previously ineffective parameters of Pn = .02 and Pc = .08 were reinstated. Figure 6 plots precurrent and current response rates and the PiPc CP across Conditioning and PPC II sessions.

Insert Figure 6 here

Figure 6 and Table 3 show a reduction in precurrent responding and the PiPc CP in the first PPC II session (Session 28), and even lower levels are observed during Sessions 29-32. It should be noted, however, that these levels were far greater than at any time prior to the Conditioning phase. During these sessions, current responding occurred at enhanced levels relative to the latter two Conditioning sessions (Sessions 26-27).

During Sessions 33-34, S1 reported falling asleep and unusual data fluctuations are observed. Figure 6 and Table 3 show that over Sessions 35-41, precurrent responding and the PiPc CP maintained on average at greater levels than during PPC II sessions prior to Session 33.

S2.

Insert Table 4 here

Prior to introducing a Conditioning phase with S2,

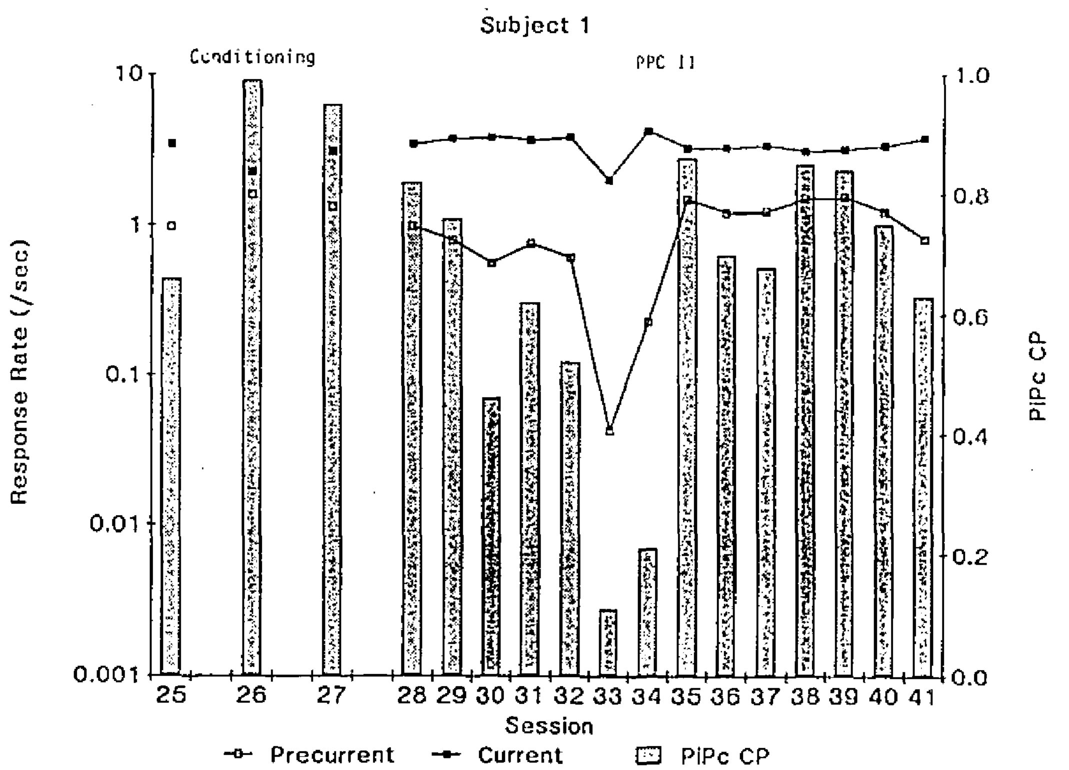


Figure 6. Precurrent and current responses rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the Conditioning phase and the PPC II phase for S1.

TABLE 4

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across Conditions to Induce Precurrent Responding, and PPC Sessions for S2

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
(Pn=.03; Pc=.08; Dc=15s)					
12	0	8036	.00	0	259
13	2	8263	.03	2	255
(Pn=.02; Pc=.08; Dc=15s)					
14	20	8405	.02	3	206
15	2	7726	.01	2	157
16	8	8411	.04	4	169
17	1	8172	.01	1	155
18	2	9072	.02	2	190
(same parameters but precurrent function given to uncovered button and old precurrent button now covered)					
19	13	8944	.06	4	220
20	0	8843	.00	0	169
(Pn=.01; Pc=.08; Dc=15s)					
21	4	8073	.01	3	91
22	3	5945	.03	3	78
23[b]	435	6808	.01	1	72
CONDITIONING (Pn=.01; Pi=.24; Pc.08; Di=2s; Dc=13s)					
24	597	6772	.12(.10)	95	245
(Pn=.01; Pi=.12; Pc=.06; Di=1s; Dc=14s)					
25	504	7193	.92(.14)	197	456
PPC II (Pn=.02; Pc=.06; Dc=15s)					
26	302	8126	.71	121	419
27	260	8456	.64	119	370
28	217	8876	.68	104	396
29	201	8086	.53	91	339
30	106	8442	.42	55	306
31	153	7778	.57	83	362
32	127	7767	.61	81	332
33	123	7815	.64	95	322
34	27	8474	.23	22	271
PPC III (Pn=.02; Pc=.08; Dc=15s)					
35	120	8789	.48	62	415
36	93	8590	.42	57	396

TABLE 4 (continued)

SESSION	PRECURRENT	CURRENT	Pi Pc CP[a]	CO's	SR's
37	241	8316	.64	117	491
38	165	7833	.66	91	467
39	72	7707	.50	46	429
40	126	7707	.61	69	411

[a]Numbers in parentheses indicate Pi CP.
[b]For about the first 100 seconds of Session 23, S2 responded exclusively on the precurrent button. She paused, laughed, and never pressed the precurrent button for the remainder of the session. At the end of the session she volunteered the information that the mouse was turned the wrong way and she thought she was pressing the button that produced the reinforcers.

procedural changes similar to those described for S1 were implemented to strengthen precurrent responding (see Table 4). While contacts with the precurrent contingency were infrequent, in all but two of these sessions, at least some precurrent responding occurred, at least some current responses were emitted under Pc (i.e., the PiPc CP > 0), and the obtained reinforcement probabilities approximated that which was programmed under Pn and Pc (see Appendix E2). Table 4 shows that while precurrent responding continued at near zero levels across these sessions, current responding steadily increased, peaking in Session 18 at 7.5 responses/s. These rates were higher than those observed for S1 or any of Taylor's (1980) subjects. Note the large drop in current response rate during Sessions 22-23 after Pn was changed to .01 in Session 21.

Table 4 reveals that precurrent responding dramatically increased during Session 23 but the PiPc CP continued to be very low. Following this session, S2 voluntarily reported that she had pressed the "wrong" button during the first minute of the session because "the mouse was turned upside down". Indeed, precurrent responding occurred at a sustained high rate during the first 85 s of the session, behavior only previously observed on the current button. There were only two CO's during Session 23 and no precurrent response was emitted after the 85-s mark.

None of the manipulations summarized in Table 4 had a rate-increasing effect on precurrent responding until the magnitude of the precurrent contingency was increased substantially in Session 24 (see Table 4 for exact parameters). The top of Figure 7 presents the cumulative records for this session.

Insert Figure 7 here

Figure 7 shows that the precurrent contingency was first contacted about three-quarters of the way through the session. Soon after there was an abrupt increase in precurrent responding which maintained for the remainder of the session. Current responding maintained at a reduced rate following the first contact with the precurrent contingency. Note the greatly enhanced rate of reinforcement produced by this new response pattern. The state line shows almost no current responses emitted under Pn once precurrent responding began. An additional calculation reveals that over the last four minutes of the session, more than 85% of current responses were emitted under Pi (i.e., within 2 s of a precurrent response) and only 6% were emitted under Pn.

Table 4 shows the increases in precurrent responding, the PiPc CP, and obtained reinforcers that occurred in Session 24. Note that these figures, as an indication of change from previous sessions, are somewhat deceiving since

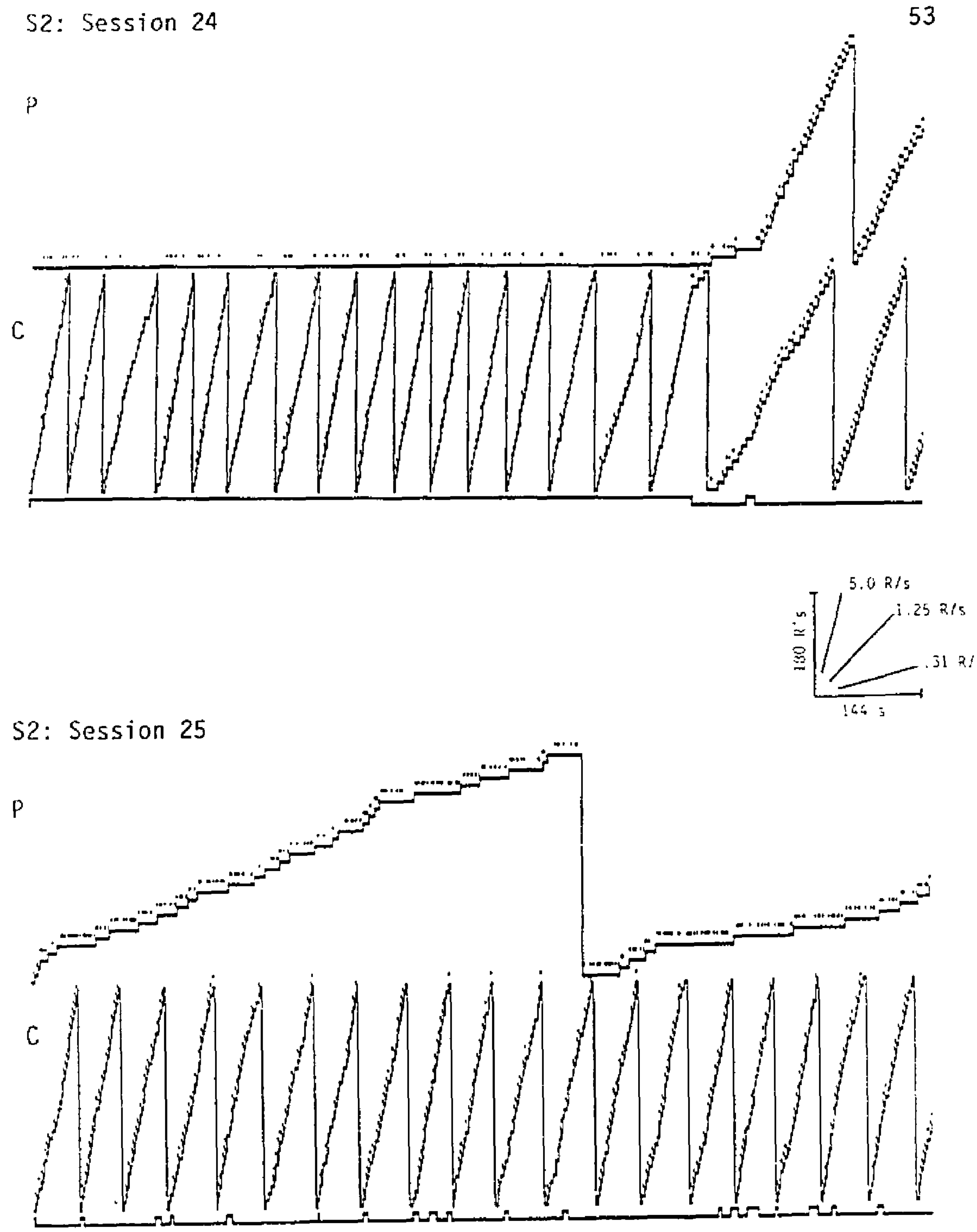


Figure 7. Cumulative records of precurrent (P) and current (C) responding for S2 during Session 24 (top) and Session 25 (bottom).

the first contact with the precurrent contingency did not occur until three-quarters of the way through the session.

In Session 25, the magnitude of the precurrent contingency was reduced--see Table 4 for exact parameters. The bottom of Figure 7 presents the cumulative records for Session 25. Relative to the latter part of Session 24, precurrent responding occurred at a lower rate although it maintained throughout the session. Current responding returned to the high rates observed prior to the first contact with the precurrent contingency in Session 24. The state line shows that the reduced precurrent response rate did not adversely affect the PiPc CP which remained extremely high at .92 (see Table 4).

For Sessions 26-34 (PPC II phase), a precurrent response enhanced the reinforcement probability for current responding from .02 (Pn) to .06 (Pc) for 15 s (Dc). Figure 8 plots the precurrent and current response rates and the PiPc CP across all Conditioning and subsequent PPC sessions.

Insert Figure 8 here

Figure 8 and Table 4 show that precurrent responding and the PiPc CP were reduced during the first PPC I session (Session 26), while there was an increase in current responding. Precurrent responding continued to decline

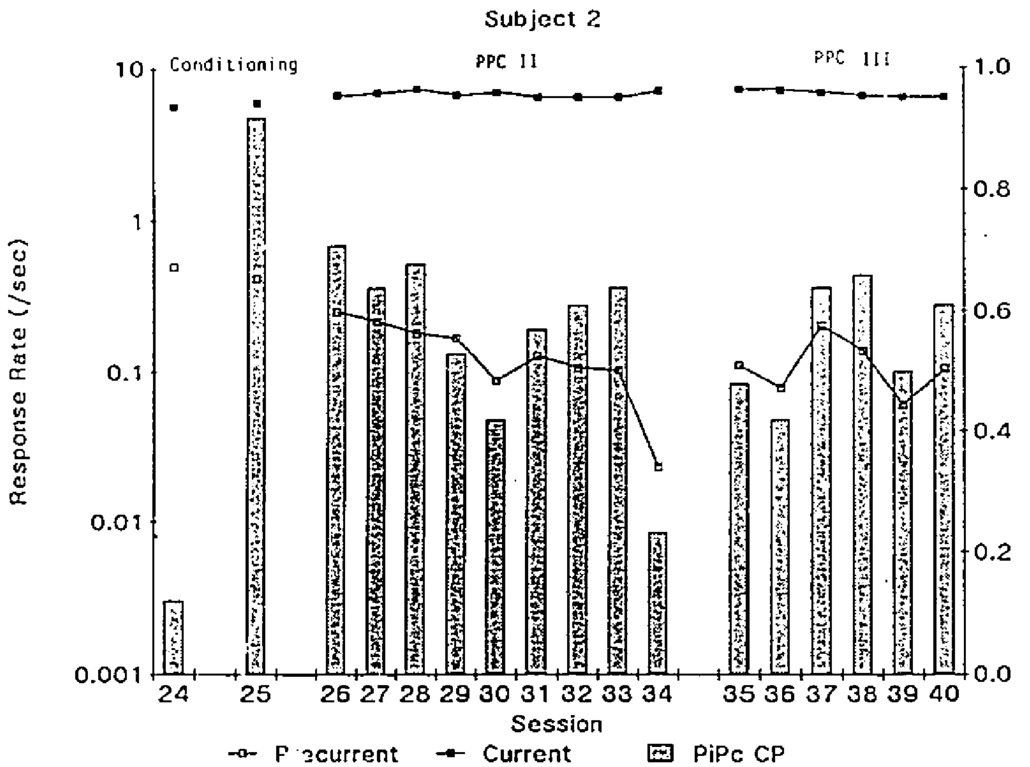


Figure 8. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the Conditioning, PPCII, and PPC III phases for S2.

across PPC II sessions, and current responding maintained at levels greater than during the Conditioning phase.

In Session 34, precurrent responding and the PiPc CP occurred at very low levels relative to previous PPC II sessions (see Table 4 and Figure 8). In an attempt to regain higher levels, Pc was increased to .08 for Sessions 35-40 (PPC III phase). If one were to exclude the data from Session 34, there is little change in any of these measures across these two PPC phases. It is important to note, however, that precurrent responding and the PiPc CP were always greatly elevated during PPC sessions relative to any session prior to the Conditioning phase.

S3.

Insert Table 5 here

During Sessions 1-4, the contingency was as follows: a precurrent response changed the reinforcement probability for current responding from .02 (Pn) to .08 (Pc) for 13 s (Dc); however, the effect was delayed for 2 s (Di). (This contingency was accidentally programmed. The original intent was to begin the experiment under the PPC condition with no delay.) These sessions will be referred to as the Delay phase. Prior to Session 1, S3 was run under this condition for a few minutes, but the session was terminated due to computer malfunction. Ten reinforcers were earned

TABLE 5

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across Conditions to Induce Precurrent Responding, and PPC Sessions for S3

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
DELAY (Pn=.02; Pi=.02; Pc=.08; Di=2s; Dc=13s)					
1	99	4772	.22(.05)	40	174
2	100	5943	.21(.04)	30	194
3	216	5905	.11(.03)	50	158
4	22	6120	.13(.02)	18	166
PPC I (Pn=.02; Pc=.08; Dc=15s)					
5	38	6951	.06	10	149
6	100	7221	.02	11	140
7	13	7154	.07	9	160
8	5	7293	.05	5	164
(Pn=.02; Pi=.16; Pc=.08; Di=2s; Dc=13s)					
9	4	6949	.03(.00)	4	149
10	5	7197	.06(.01)	5	179
(Pn=.02; Pi=.20; Pc=.08; Di=2s; Dc=13s)					
11	4	6610	.05(.01)	4	167
12	68	6302	.22(.07)	54	277
13[b]	6	2274	.18(.02)	6	85
14	3	6245	.03(.00)	3	147
(Pn=0; Pc=.08; Dc=15s)					
15	1321	4882	.35	1003	137
(Pn=.01; Pc=.08; Dc=15s)					
16	38	6280	.19	27	157
(Pn=0; Pc=.08; Dc=15s)					
17	728	4773	.40	497	152
PPC II (Pn=.01; Pc=.08; Dc=15s)					
18	148	4722	.58	139	234
19		APPARATUS FAILURE			
20[c]	781	4824	.91	699	352
21	368	4957	.69	368	292
22	329	5801	.55	322	322

[a]Numbers in parentheses indicate Pi CP.
[b]Only data available from initial 445 s of session.
[c]Prior to Session 20, S3 was told not to move the mouse.

during this time.

Figure 9 presents cumulative records of S3's performance during Session 1.

Insert Figure 9 here

Figure 9 reveals that unlike the previous two subjects, stable high rate current responding predominated even at the beginning of the session (although recall that S3 had 5 min of previous unrecorded exposure to this contingency). Precurrent responding occurred at a relatively low level throughout the session.

Table 5 reveals an increasing trend in current responding across Delay sessions. In Session 4, precurrent responding and the _PiPc_ CP occurred at relatively low levels.

For Sessions 5-8 (PPC I phase), _Pi_ was raised to .08; thus, the parameters were identical to those used during the PPC II phase for S1 and the PPC III phase for S2. Table 5 shows that precurrent responding and the _PiPc_ CP occurred at near zero levels over Sessions 7-8 and that current responding was considerably higher under the PPC I phase than under the Delay phase. It should be noted that the obtained reinforcement probability under _PiPc_ was less than .08 in every PPC I session (see Appendix E3).

For Sessions 9-10, _Pi_ was further raised to .16, with

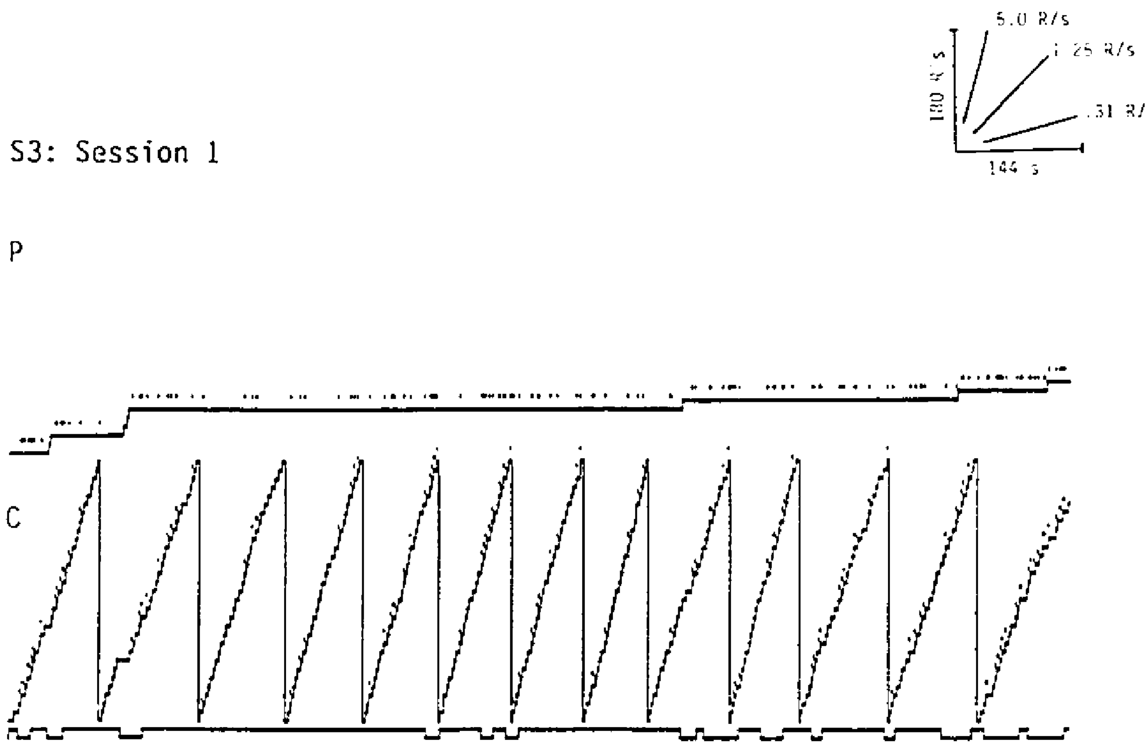


Figure 9. Cumulative records of precurrent (P) and current (C) responding for S3 during Session 1.

no effect on any of the dependent measures. Since a total of only nine CO's occurred across these two sessions, contact with the precurrent contingency was infrequent. Again, note from Appendix E3 that the obtained reinforcement probabilities under Pi and Pc were lower than programmed in both of these sessions.

For Sessions 11-14, Pi was raised to .2. While there were no apparent changes in Session 11, in Session 12 precurrent responding and the PiPc CP levels increased, and many more reinforcers were obtained (see Table 5). After 425 s into Session 13 the computer ceased delivering reinforcers and recording data. (The Session 13 data presented in Table 5 and Appendices C3 and E3 are based on this time only.) Thus, for the final 775 s of Session 13, S3 was run under extinction.

The top and bottom of Figure 10 show cumulative records for Session 12 and the portion of Session 13 prior to the computer malfunction, respectively.

Insert Figure 10 here

Figure 10 shows that (1) no precurrent responses occurred during the last 200 s of Session 12, and (2) precurrent responding was infrequent during the first 445 s of Session 13. Thus, the changes reported for Session 12 were temporary; they maintained neither during that session

S3: Session 12

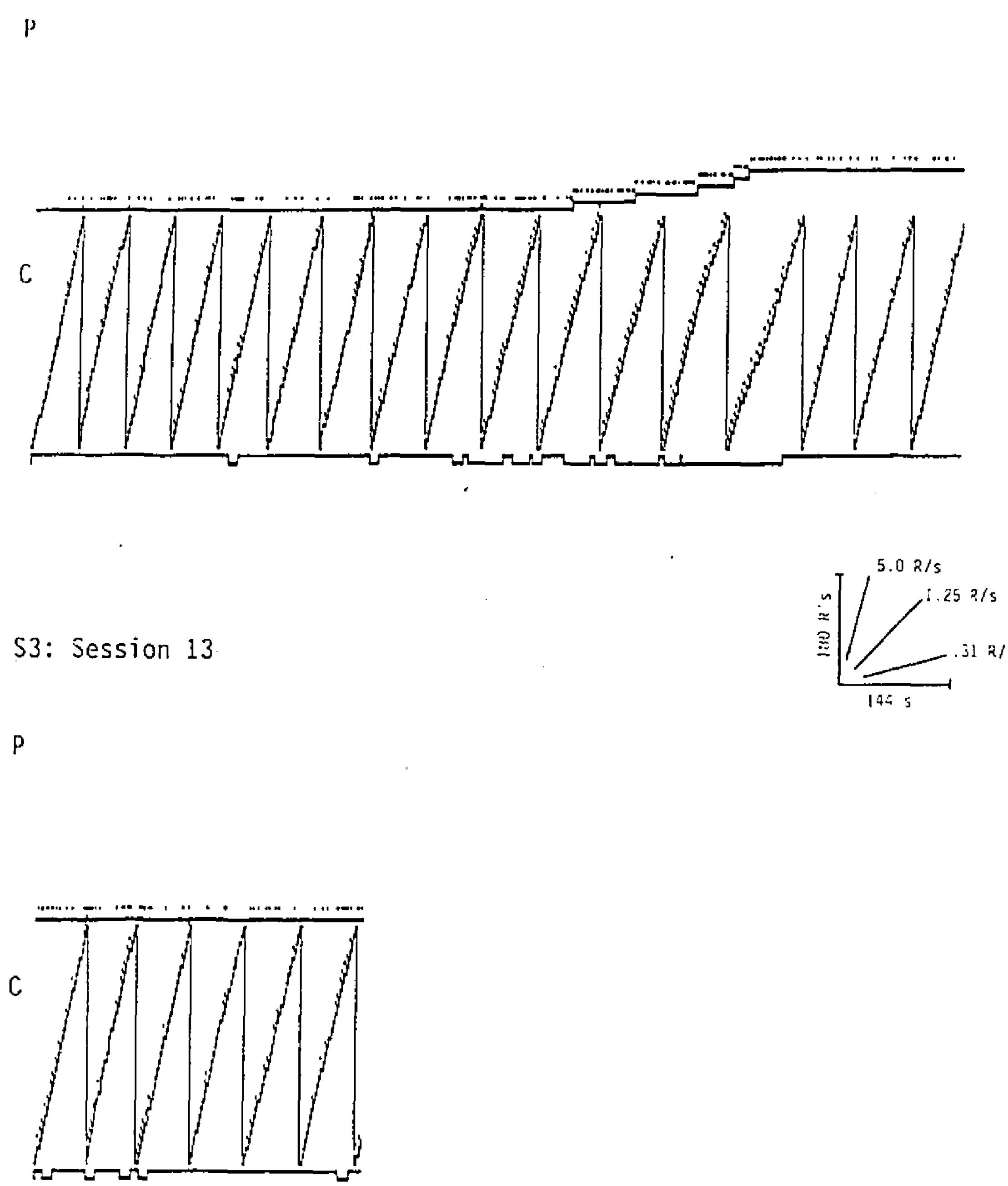


Figure 10. Cumulative records of precurrent (P) and current (C) responding for S3 during Session 12 (top) and the only recorded portion (initial 445 s) of Session 13 (bottom).

nor into the next. The data for Session 14 are very similar to those observed for Sessions 9-11 (see Table 5).

For Session 15, Pn was reduced to zero and Pi was set at .08. Thus, a reinforcer would not be delivered for current responding unless a precurrent response had occurred at least once within the previous 15 s. The top of Figure 11 shows the cumulative records for Session 15.

Insert Figure 11 here

Figure 11 reveals that only stable high rate current responding occurred for about the first 1.5 min of the session (characteristic of previous sessions), and thus reinforcement did not occur. As the session progresses, two noticeable periods of high rate precurrent responding are observed, producing some reinforcers and disruption of stable high rate current responding. However, in both cases exclusive high rate current responding returned, and thus reinforcer delivery ceased. Then, at about 10.5 min, a stable pattern of high rate switching between current and precurrent responding developed, resulting in a sustained high rate of precurrent responding and a reduced (relative to earlier in the session) but stable rate of current responding. For the remainder of the session, every current response was emitted under Pc (see state line). The substantial increases in precurrent responding, and the

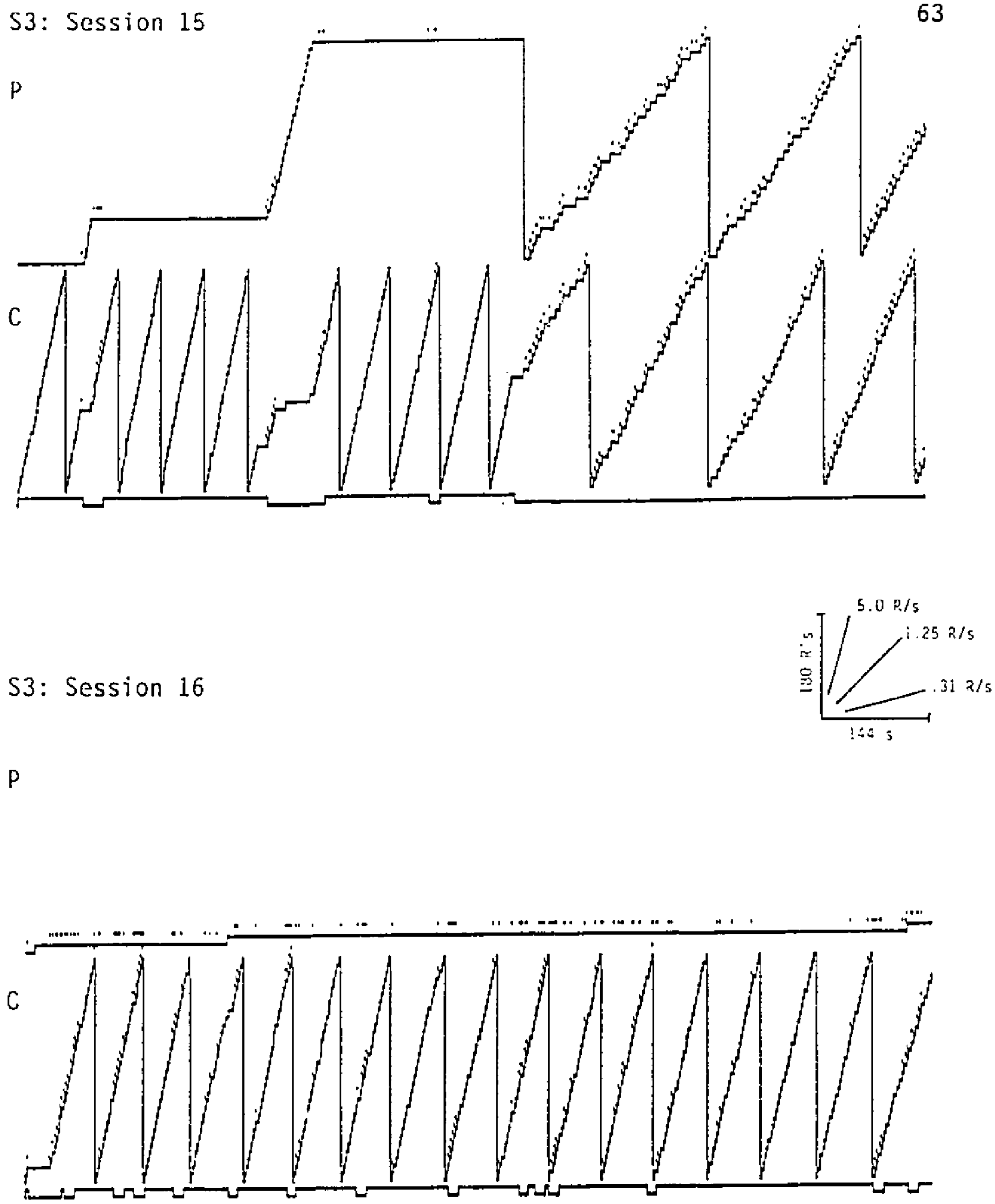


Figure 11. Cumulative records of precurrent (P) and current (C) responding for S3 during Session 15 (top) and Session 16 (bottom).

PiPc CP, and the reduction in current responding that occurred in Session 15 are reflected in the summary statistics in Table 5.

For Session 16, Pn was increased to .01. Again the changes were dramatic. The bottom of Figure 11 presents cumulative records for Session 16. The pattern of responding was altered almost from the beginning of the session. Stable high rate current responding is observed, and although CO's to precurrent responding continued throughout the session, they were relatively infrequent and consequently most current responses were emitted under Pn.

Table 5 shows that the precurrent responding and the PiPc CP declined substantially across Sessions 15 and 16, while current responding increased. Thus, the changes observed during Session 15 were reversed with a return to Session 14 parameters. These changes are even more striking considering that the summary statistics in Table 5 are made on a per session basis and that responding was not significantly altered during Session 15 until the last half of the session. The cumulative records in Figure 11 best reflect the behavior change across Sessions 15 and 16.

For Session 17, Pn was again reduced to zero. The top of Figure 12 shows the cumulative records for Session 17.

Insert Figure 12 here

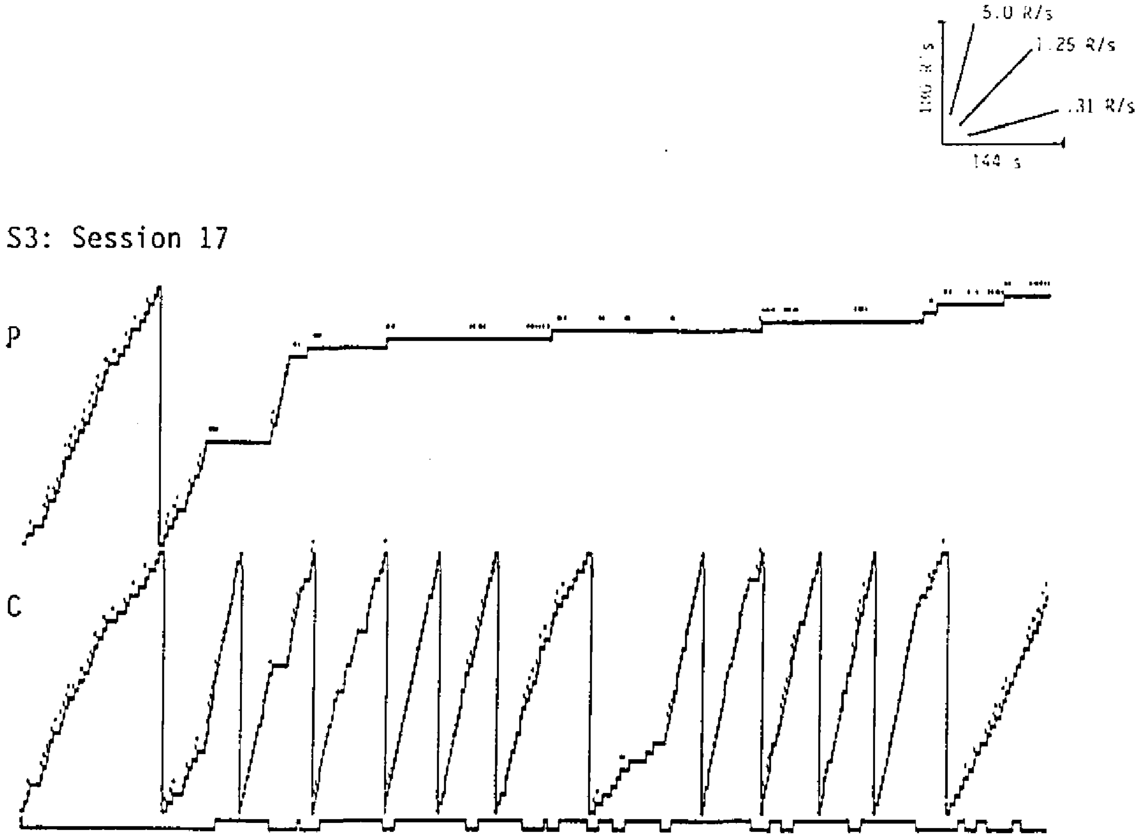


Figure 12. Cumulative records of precurrent (P) and current (C) responding for S3 during Session 17.

Figure 12 shows that the pattern of responding during the first 3.5 min resembles very closely the pattern observed during the last half of Session 15 when the same parameters were operating, i.e., high rate switching (see top part of Figure 11). But then, exclusive high rate current responding was emitted, interrupted briefly by a period of high rate precurrent responding. For the remainder of the session, CO's to precurrent responding occurred consistently but relatively infrequently, resulting in a majority of current responses being emitted under Pn where the probability of reinforcement was zero; current responding occurred at a high rate but some fluctuations are observed.

Table 5 shows that in Session 17, with identical parameters to Session 15, precurrent responding and the PiPc CP increased substantially. Fewer reinforcers were obtained than in Session 16, however, because current responding was considerably lower.

For Session 13, Pn was again increased to .01. Table 5 reveals that although precurrent responding was less frequent than during Session 17, the PiPc CP increased. The same parameters were scheduled for Sessions 19-22 (PPC II phase) but during Session 19 a computer malfunction produced extinction conditions for almost 20 min. No data were recorded. There was evidence to suggest that S3 moved the mouse almost continuously in every session up to this point in the experiment. This behavior was deemed responsible for each computer malfunction that occurred during S3's participation. Thus, in Session 20, S3 was told that moving the mouse had no effect on the likelihood of obtaining money. Table 5 shows that during Session 20, there was a considerable increase from Session 18 in precurrent responding. Perhaps an even more striking change is noted for the _PiPc_ CP; over 91% of current responses were emitted under _PiPc_ (relative to 58% during Session 18). Far more reinforcers were earned in Session 20 than in any previous session.

Across PPC II sessions (Sessions 20-22), precurrent responding and the _PiPc_ CP declined; current responding increased, especially during Session 22 (see Table 5). It should be noted, however, that during Session 22, precurrent responding occurred at a rate far exceeding that in any session prior to Session 20, except for sessions during which _Pn_ was set at zero; and, the _PiPc_ CP was higher than in any session prior to Session 18.

Discussion

Levels of precurrent responding and the _PiPc_ CP were enhanced for all three subjects in Experiment 1B. This was accomplished in two ways. First, for S1 and S2, the magnitude of the precurrent contingency was increased, particularly during a 2-s period immediately following a precurrent response (_Pi_). This procedure produced little effect on the dependent measures for S3, although it was not pursued and *Pi* was not raised to the same extent as for S1 and S2. Rather, for S3, a second procedure was employed: the *Pn* value was decreased to zero; i.e., precurrent responding elevated the current response reinforcement probability to .08 as it had done earlier, but the reinforcement probability for current responding was zero unless a precurrent response had occurred within the previous 15 s.

When the magnitude of the precurrent contingency was gradually reduced across Conditioning sessions for S1 and S2, relatively high but reduced levels of precurrent responding and the *PiPc* CP continued under a condition that prior to the Conditioning phase failed to have any effect (i.e., *Pn* = .02; *Pc* = .08; *Dc* = 15 s).

For S3, an attempt to maintain precurrent responding when current responding could be reinforced in the absence of precurrent responding (i.e., *Pn* > 0) initially proved unsuccessful. When *Pn* was elevated from zero (Session 15) to .01 (Session 16), precurrent responding and the *PiPc* CP returned to very low levels. Reinstating the *Pn* = 0 condition during Session 17 once again enhanced the levels of precurrent responding and the *PiPc* CP. A second attempt produced different results: elevating *Pn* to .01 during Session 18 reduced precurrent responding (but not nearly to the extent as in Session 15), but the *PiPc* CP and reinforcers obtained were higher than in any previous session.

For S3, the factors responsible for the continuation of the relatively high levels of precurrent responding and the PiPc CP across Session 20-22 are unclear (although note the declining trend in all three measures). Perhaps precurrent responding was maintained during Sessions 20-22 because of the precurrent contingency; but it is also possible that the extinction conditions in Session 19, the instructions not to move the mouse prior to Session 20, or any combination of these factors may have played a role. For example, mouse movement may have repeatedly been reinforced (albeit adventitiously) which somehow attenuated the effects of the precurrent contingency. This speculation is consistent with the concurrent operant literature: increases in the rate of one response reduce the rate of other responses (Catania, 1984, p. 184).

For S1 and S2, the PiPc CP was consistently lower during PPC sessions following the Conditioning phase than during the Conditioning sessions. It is interesting to note that this measure showed no systematic increase across 14 PPC sessions for S1 and 15 PPC sessions for S2. Considering these data further, for S1, 79% of current responses were emitted under PiPc during the first two PPC sessions (Sessions 27-28) compared to 69% during the last two (Sessions 40-41); for S2, 68% of current responses were emitted under PiPc during the first two PPC sessions (Sessions 26-27) compared to 56% during the last two (Sessions 39-40). The PiPc CP never exceeded .86 for S1 (Session 35) and .71 for S2 (Session 26). With S3, the PiPc CP showed a steady decline across the three PPC II sessions. Thus, this so-called efficiency measure did not improve across PPC sessions for any subject, and within PPC sessions never approached 100%, a result consistent with Taylor (1980).

It is clear from the various manipulations required to condition precurrent responding for the three subjects that a few contacts with the "beneficial" consequences of a precurrent response were not sufficient to alter precurrent responding in any noticeable way. For example, in Session 23, S1 had five contacts with a contingency under which precurrent responding elevated the current response reinforcement probability 16-fold for 2 s and then 6-fold for the next 13 s; in Session 21, S2 had four contacts with a contingency under which precurrent responding elevated the current response reinforcement probability 8-fold for 15 s; in Session 11, S3 had four contacts with a contingency under which precurrent responding elevated the current response reinforcement probability 10-fold for 2 s and then 4-fold for 13 s. In each of these cases, precurrent responding was unaltered.

EXPERIMENT 1C

The purpose of Experiment 1C was to demonstrate that precurrent responding was being maintained under the PPC condition as a result of the precurrent contingency. Consistent with single-subject methodology and rationale, a reversal design was used (cf., Sidman, 1960).

Subjects

S1 from Experiments 1A and 1B was the sole participant.

Procedure

All conditions were identical to the two previous experiments except for the following parametric manipulations. First, as described in Experiment 1B, the PPC II phase continued through Sessions 28-41, such that a precurrent response increased the current response reinforcement probability from .02 (*Pn*) to .08 (*Pc*) for 15 s (*Dc*). Then, the precurrent contingency was withdrawn for Sessions 42-45 (APC II phase) such that both *Pn* and *Pc* were set at .02. Finally, the precurrent contingency was reintroduced for Sessions 46-50 (PPC III phase).

Results

The top half of Figure 13 presents the cumulative records for the final PPC II session (Session 41) which was fairly typical of responding throughout the PPC II phase.

Insert Figure 13 here

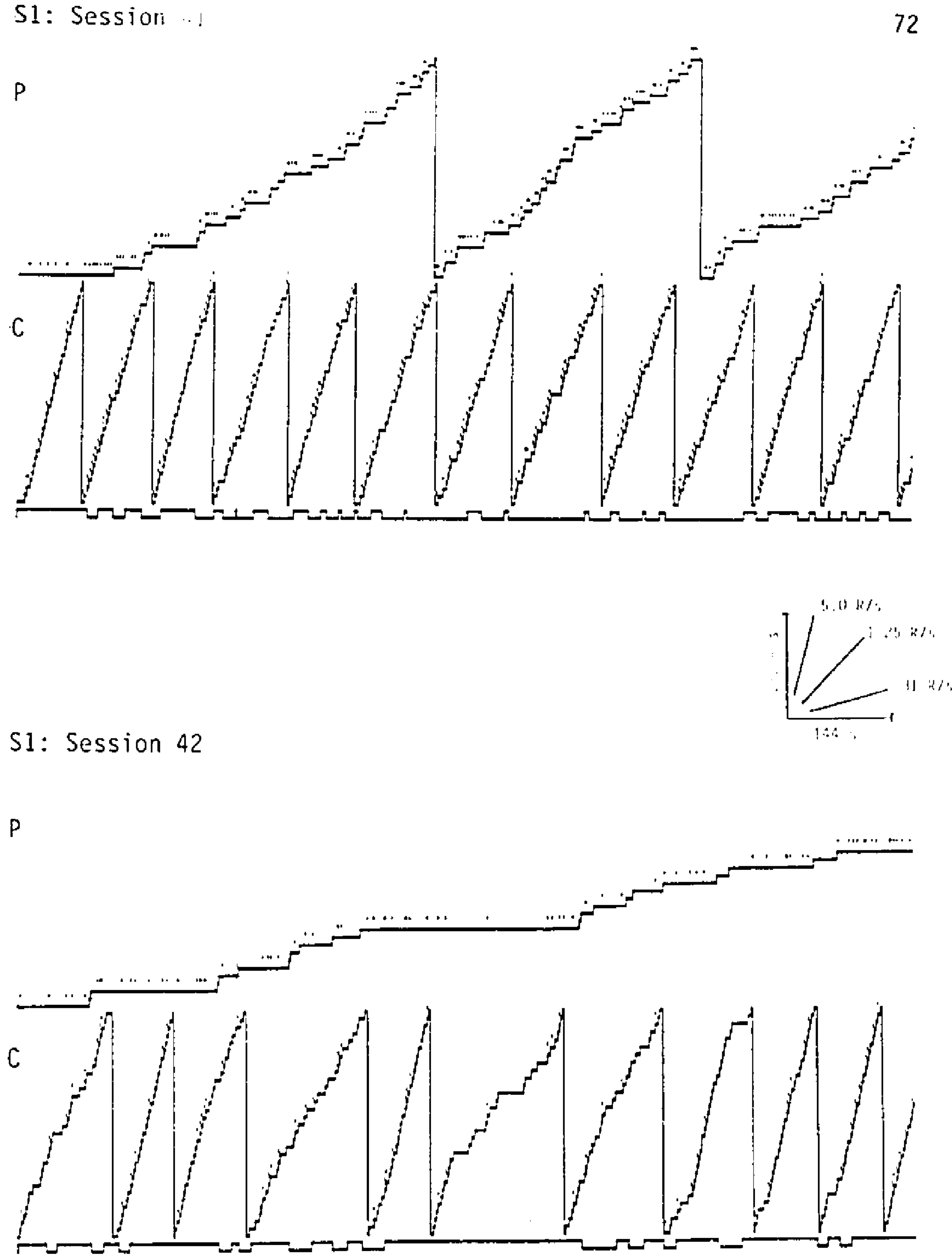


Figure 13. Cumulative records of precurrent (P) and current (C) responding for S1 during Session 41 (top) and Session 42 (bottom).

Figure 13 shows that current responding occurred at a high steady rate; precurrent responding occurred in smaller intermittent bursts, reflected in the step-like precurrent response gradient. Consequently, a large proportion (63%) of current responses were emitted under PiPc. The bottom of Figure 13 presents the cumulative records for the first APC II session (Session 42). Long periods without precurrent responses are noted, resulting in a relatively low PiPc CP statistic for that session (24%). Additional response-based calculations reveal that in Session 41, 32.7% (18/55) of current response runs were greater than 90 responses; in Session 42, this figure increased to 50% (11/22). Current responding fluctuated throughout most of Session 42 in contrast to the typical PPC II pattern observed in Session 41; however, stable high rate current responding did return during the last four minutes.

Insert Table 6 and Figure 14 here

Table 6 and Figure 14 show that in the first APC II session (Session 42) there were substantial decreases in precurrent and current responding, and the PiPc CP. In the second APC II session, all these measures returned to levels more comparable to PPC II sessions. In next and last two APC II sessions, however, precurrent responding and the PiPc CP occurred at levels substantially reduced from the

TABLE 6

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC and APC Sessions for S1

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
PPC II (Pn=.02; Pc=.08; Dc=15s)					
28	1190	4120	.82	144	304
29	943	4472	.76	145	314
30	669	4570	.46	76	225
31	897	4373	.62	89	240
32	733	4611	.52	76	245
33[a]	50	2375	.11	4	57
34[a]	273	5008	.21	39	168
35	1766	3884	.86	130	261
36	1440	3896	.70	94	250
37	1493	4070	.68	83	262
38	1794	3747	.85	129	302
39	1823	3819	.84	106	277
40	1468	4017	.75	77	248
41	973	4527	.63	54	260
APC II (Pn=.02; Pc=.02; Dc=15s)					
42	245	3935	.24	21	85
43	962	4323	.47	47	83
44	127	4914	.09	7	93
45	172	4632	.13	13	101
PPC III (Pn=.02; Pc=.08; Dc=15s)					
46	1267	4269	.52	76	238
47	532	4745	.27	27	177
48	936	4064	.55	71	235
49	33	5038	.04	3	122
50	1	5377	.01	1	125

[a]S1 reported that she fell asleep during Sessions 33-34.

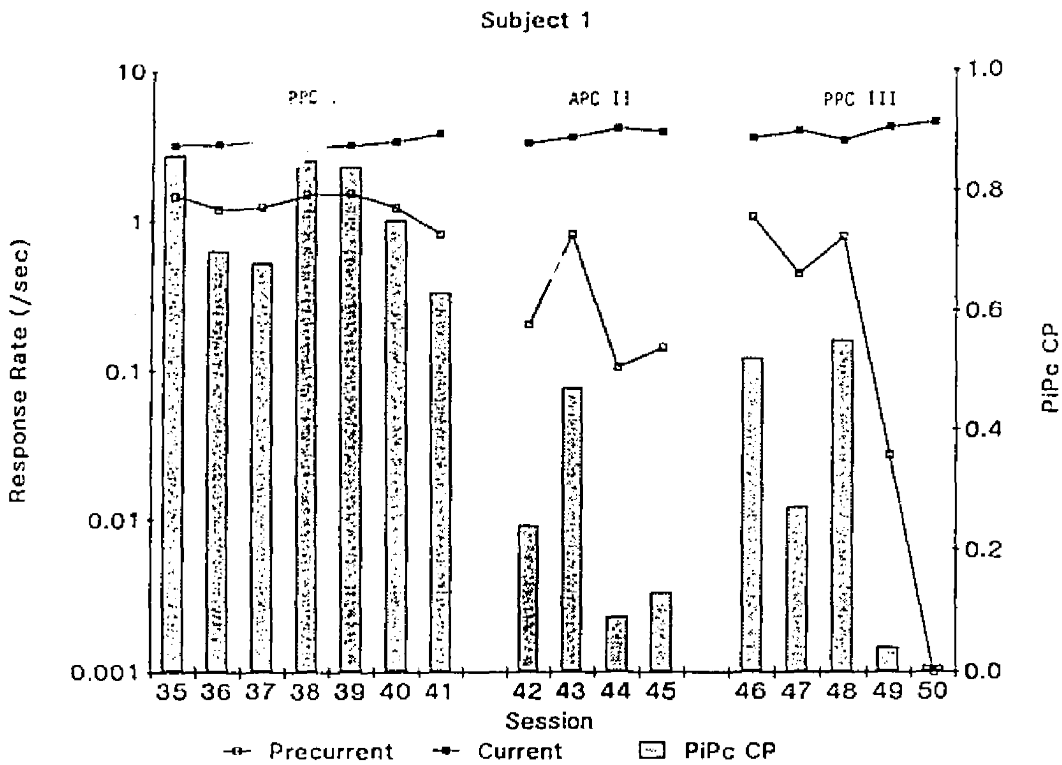


Figure 14. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC II, APC II, and PPC III phases for S1.

PPC II phase. Comparing the means of the last two PPC II sessions (Sessions 40-41) with those of the last two APC II sessions (Session 44-45), reductions are observed in precurrent responding (from 1.02 to .12 responses/s) and the PiPc CP (from .69 to .11); current responding increased slightly from 3.56 to 3.98 responses/s.

The top of Figure 15 presents cumulative records for the first session when the precurrent contingency was reintroduced (Session 46).

Insert Figure 15 here

Figure 15 shows that precurrent responding was absent during the first 190 s. Then, when precurrent responding did occur it did so at a high sustained rate for about a 6 min period, during which current responding was reduced (though the rate was still greater than for precurrent responding) and almost all current responses were emitted under PiPc. For the remainder of the session, precurrent responding maintained at a high but more variable rate, with slight fluctuations in current responding also noted.

Table 6 and Figure 14 show that for the first three PPC sessions (Sessions 46-48), precurrent responding and the PiPc CP were substantially greater than during either of the prior two APC sessions (Sessions 44-45). During the last two PPC sessions (Sessions 49-50), however, these

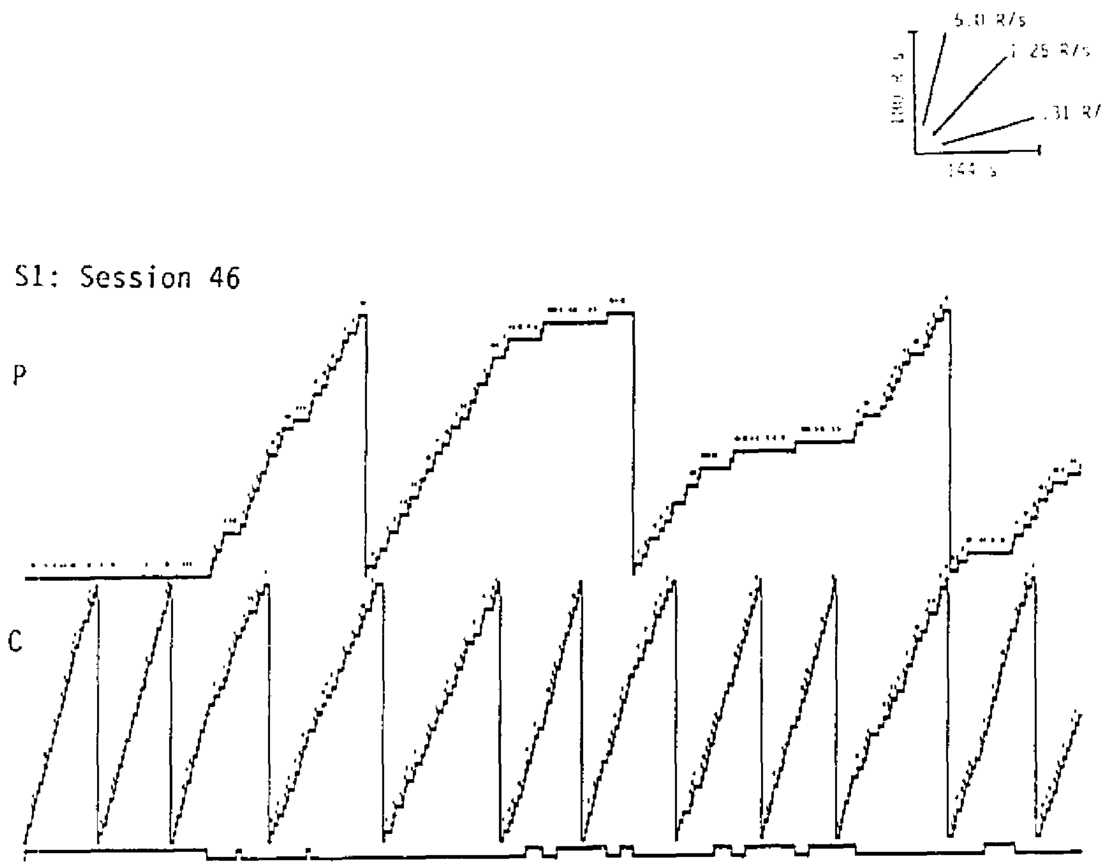


Figure 15. Cumulative records of precurrent (P) and current (C) responding for S1 during Session 46.

measures dropped to near zero levels.

Discussion

As described in Experiment 1B for S1, relatively high levels of precurrent responding and the PiPc CP maintained when precurrent responding functioned to increase the reinforcement probability for current responding from .02 to .08 for 15 s during Sessions 28-41. In this experiment, when the precurrent contingency was withdrawn, the eventual result was substantial reductions in both of these measures. However, even during the last two APC II sessions, precurrent responding and the PiPc CP were still much greater than during any session prior to the Conditioning phase (see Tables 1 and 3).

Reintroducing the precurrent contingency resulted in a transient and variable increase in precurrent responding and the PiPc CP for three sessions, but near zero levels were observed for the next, and final, two PPC II sessions. It is unclear whether near zero levels would have continued with more exposure to the PPC II phase. Recall that these same PPC parameters produced no effect when introduced prior to the Conditioning phase in Experiment 1B (see Table 3, Sessions 15-18). Thus, while suggestive, these results do not entirely support the conclusion that the precurrent contingency was responsible for the maintenance of precurrent responding in the PPC II phase.

EXPERIMENT 1D

The purpose of Experiment 1D was to examine the effects of adding a changeover-delay (COD) to a precurrent contingency that maintained precurrent responding. A COD is defined as a period of time following a changeover from one behavior (precurrent) to another (current) during which reinforcement for the latter behavior is not possible (cf., Catania, 1966). A COD is often employed in concurrent operant research to ensure that the concurrent operants are under the control of separate programming devices. Close temporal contiguity between one response and the subsequent reinforcement for another can strengthen the first. For example, under Conc VI EXT, extinction responding maintains because extinction responses are frequently followed by reinforcement for a subsequent VI response; introducing a COD, and thereby temporally separating extinction responses from VI reinforcers, reduces or eliminates extinction responding (Catania & Cutts, 1963). If the delivery of a reinforcer for a current response immediately following a precurrent response is a primary variable responsible for the maintenance of the precurrent operant, then one would expect that adding the COD would reduce, if not eliminate, precurrent responding.

Subjects

The participants were S2 and S3 from Experiment 1B.

Procedure and Results

All conditions were identical to previous sessions except for the parametric manipulations described below for each subject and summarized in Tables 7 and 8.

S2.

Insert Table 7 and Figure 16 here

In Session 41, a 1-s COD was imposed upon the PPC condition such that the reinforcement probability for current responding within 1 s (Di) of a precurrent response was zero (Pi), and then the probability increased to .08 (Pc) for 14 s (Dc). Table 7 and Figure 16 show no changes in any of the dependent variables, although obtained reinforcers declined slightly.

Although continued exposure to a 1-s COD might have eventually altered precurrent responding, S2 was willing to participate in only a few more sessions. If a COD effect was to be demonstrated, it appeared that a longer COD might be necessary. Thus, a 2-s COD was introduced for Sessions 42-45 (2-s COD phase), i.e., Di was increased to 2 s. Table 7 and Figure 16 reveal lower levels of precurrent responding and the PiPc CP during the first 2-s COD session, which become more pronounced during the latter two 2-s COD sessions. The means of the last two PPC III sessions (Sessions 39-40) were compared with those of the

TABLE 7

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC and COD Sessions for S2

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
PPC II (Pn=.02; Pc=.06; Dc=15s)					
26	302	8126	.71(.15)	121	419
27	260	8456	.64(.15)	119	370
28	217	8876	.68(.12)	104	396
29	201	8086	.53(.11)	91	339
30	106	8442	.42(.06)	55	306
31	153	7778	.57(.11)	83	362
32	127	7767	.61(.12)	81	332
33	123	7815	.64(.13)	95	322
34	27	8474	.23(.03)	22	271
PPC III (Pn=.02; Pc=.08; Dc=15s)					
35	120	8789	.48(.08)	62	415
36	93	8590	.42(.07)	57	396
37	241	8316	.64(.15)	117	491
38	165	7833	.66(.13)	91	467
39	72	7707	.50(.07)	46	429
40	126	7707	.61(.10)	69	411
1-S COD (Pn=.02; Pi=0; Pc=.08; Di=1s; Dc=14s)					
41	136	7860	.57(.10)	69	343
2-S COD (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=13s)					
42	63	7543	.32(.05)	34	277
43	69	7424	.37(.06)	39	306
44	36	7713	.27(.04)	26	305
45	33	7642	.17(.03)	20	218
(Pn=.02; Pc=.06; Dc=15s)					
46	18	7877	.11(.02)	10	222
PPC IV (Pn=.02; Pc=.08; Dc=15s)					
47	182	8372	.65(.12)	89	518
48	132	8585	.71(.12)	76	549

[a]Number in parentheses under 2-s COD phase indicates Pi CP; for comparison purposes, number in parentheses under other phases indicates the proportion of current responses emitted within 2 s of a precurrent response.

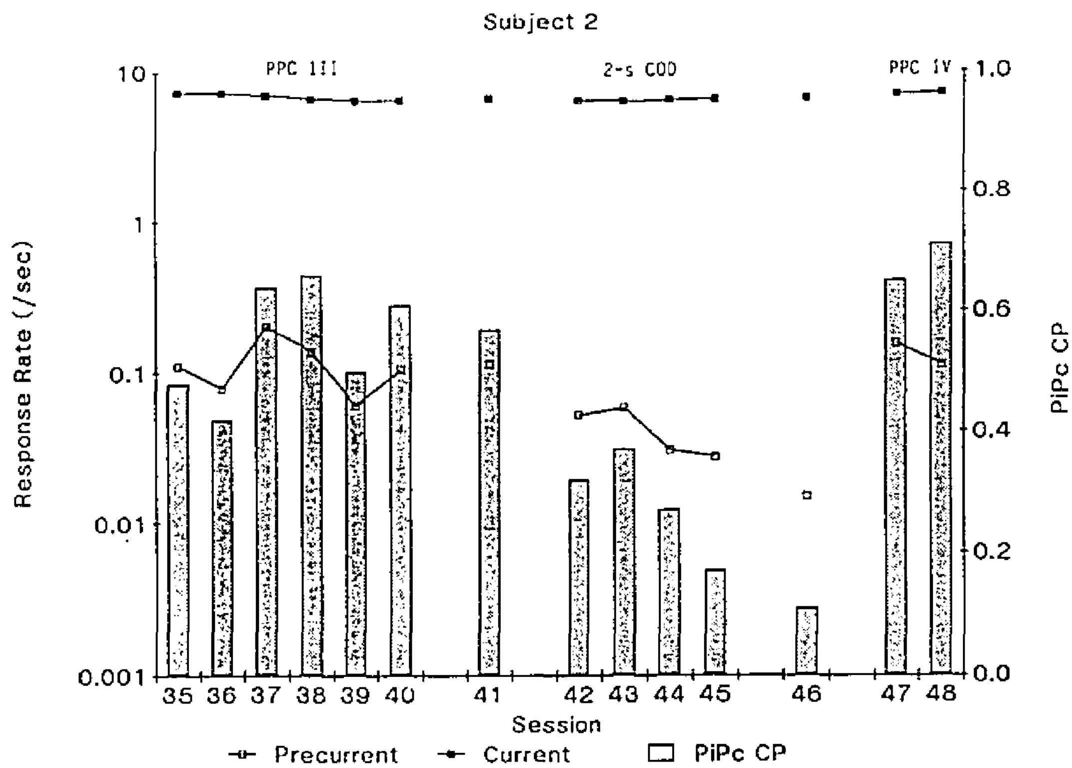


Figure 16. Precurrent and current responses rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC III, 2-s COD, and PPC IV phases for S2.

last two sessions of the 2-s COD phase (Sessions 44-45). Reductions were observed in precurrent responding (from .08 to .03 responses/s) and the PiPc CP (from .55 to .22). Current responding remained stable across the two conditions (6.42 and 6.40 responses/s). Additional calculation revealed that over the last two PPC III sessions, 35.7% (50/140) of current response runs were greater than 135 responses; over the last two 2-s COD sessions, this figure increased to 60.4% (29/48).

An attempt to recover higher levels of precurrent responding by eliminating the COD and reducing Pc to .06 was unsuccessful in Session 46. (These parameters represented an attempt to increase precurrent responding under a condition in which although the probability of reinforcement for current responses within 15 s of a precurrent response would be lower than under the 2-s COD condition, it would now be possible to obtain reinforcers quickly following a precurrent response, i.e., within 2 s.) Again, because of time limitations, a quick procedural change was deemed necessary and the original PPC III parameters were reintroduced for Sessions 47-48 (PPC IV phase). Table 7 and Figure 16 show that under the PPC IV phase, precurrent responding and the PiPc CP increased to levels comparable to those observed during PPC III sessions. Current responding increased slightly across 2-s COD-PPC IV phases. More reinforcers were delivered in each of the two PPC IV sessions than in any PPC III session.

S3.

Insert Table 8 here

In Session 23, the conditions were arranged such that the reinforcement probability for current responding within 2 s (Di) of a precurrent response was zero (Pi), and then the probability increased from .01 (Pn) to .1 (Pc) for 13 s (Dc). Note that during the prior phase (PPC II phase), Pc was set at .08. Unlike the COD procedure for S2, Pc was increased from the prior PPC phase to compensate for the loss of reinforcement during the first two seconds (Di) of the 15-s period following precurrent responding (i.e., Di and Dc combined).

Table 7 shows that although precurrent responding decreased slightly in the first COD session (Session 23), in the next and last COD session, its level was indistinguishable from the final two PPC II sessions (Sessions 21-22). Fewer reinforcers were obtained during the COD sessions.

Discussion

For S2, the results of superimposing a 2-s COD onto a precurrent contingency which maintained precurrent responding and then subsequently withdrawing that COD suggest that the COD was responsible for reducing

TABLE 8

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC and COD Sessions for S3

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
PPC II (Pn=.01; Pc=.08; Dc=15s)					
18	148	4722	.58(.17)	139	234
19		APPARATUS FAILURE			
20[b]	781	4824	.91(.60)	699	352
21	368	4957	.69(.31)	368	292
22	329	5801	.55(.21)	322	322
2-S COD (Pn=.01; Pi=0; Pc=.10; Di=2s; Dc=13s)					
23	252	4809	.64(.23)	235	205
24	368	4412	.80(.33)	356	234

[a]Number in parentheses under 2-s COD phase indicates *Pi* CP; for comparison purposes, number in parentheses under other phases indicates the proportion of current responses emitted within 2 s of a precurrent response.
[b]Prior to Session 20, S3 was told not to move the mouse.

precurrent responding and the PiPc CP to low levels. This effect was not replicated with S3. Note, however, that the nature of the COD condition was different for each subject, as was each subject's experimental history prior to the COD phase.

One could argue that the changes observed with the 2-s COD present for S2 resulted because by reducing Pi to zero for 2 s (Di), the overall probability of reinforcement for current responding within 15 s (Di plus Dc) of a precurrent response would be less than under the PPC III phase when the reinforcement probability is .08 for the same 2-s period. Additional calculation reveals that the reduction was minimal: during the last three PPC III sessions, the obtained probability of reinforcement for current responses within 15 s of a precurrent response was .08; during the last three 2-s COD sessions, this figure dropped only very slightly to .077, a value greater than that obtained for the final PPC III session (.073). Thus, it is unlikely that an overall decrease in the reinforcement probability for current responding within 15 s of a current response--inherent in the COD procedure for S2--can account for the changes observed under the 2-s COD condition.

Considering S2's data further, it is interesting to note that the COD reduced precurrent responding even though many more reinforcers would have been obtained had precurrent responding maintained. For example, if during the final 2-s COD session (Session 45) the level and pattern of precurrent responding had maintained comparable to that observed in the final PPC III session (Session 40), it is estimated that S2 would have earned 375 reinforcers rather than the 218 that she did acquire. An implication is that reinforcement for current responding immediately following (i.e., within 2 s of) a precurrent response was largely responsible for the maintenance of precurrent responding under the PPC III phase for S2.

Some verbal behavior of S2 is interesting to note. At the end of one PPC III session, she volunteered the following information about her performance. She said she knew that pressing only the one button earned her money, but she sometimes pressed the other button because she was bored. Evidently, "boredom" was not a factor when the COD was present. Her statement suggests the absence of any rule concerning the consequences of pressing the precurrent button.

S2 was interviewed following completion of her participation, which ended after Experiment 1D. When asked what the experiment was about, she commented that by pressing with the "right rhythm" on one button (i.e., the current key) she could earn the most money. The "right rhythm" for her translated into "the faster the better". When asked if pressing the other button did anything, she said it did for a couple of sessions (probably the

Conditioning sessions) but then it appeared to do nothing. When asked why she pressed it, she replied that sometimes it appeared as if it helped her to get in the right rhythm on the other button. She also commented that she sometimes thought of pressing it more often but she wasn't willing to risk losing the money that she could obtain by pressing the other button (i.e., current key). She was surprised to learn that pressing the one button (i.e., the precurrent key) affected the reinforcement probability of pressing the other (i.e., the current key) and how sensitive her behavior had been to a subtle change in contingencies (i.e., the introduction of the COD).

EXPERIMENT 2

The purpose of Experiment 2 was twofold. First, S1 was the first subject in the present paradigm ever to have been run under a reversal-replication design to demonstrate that precurrent responding was indeed being maintained by its effect of raising the probability of reinforcement for current responding (in contrast to the between-subject replications of Taylor, 1980). Specifically, Experiment 1C tested whether or not a precurrent operant had developed by removing and then reintroducing the precurrent contingency. The data obtained for S1 were inconclusive in this regard. Experiments 2A and 2B were designed to examine both the reliability and generality of the results obtained with S1.

A second purpose of Experiment 2 concerned studying how a COD might affect the maintenance of a precurrent operant. S2 and S3 were the first subjects in the present paradigm ever to have been exposed to a precurrent contingency that included a COD. The COD reduced precurrent responding (and consequently, reinforcement frequency) for S2, but not S3. Experiment 2C was designed to further analyze the effects of a COD on an established precurrent operant, while Experiment 2D examined whether a precurrent operant could develop with a COD in effect.

The results of Experiment 1 dictated three procedural changes in Experiment 2. First, S3's data suggested that excessive mouse movement may have blocked the development of the precurrent operant. In Taylor's (1980) study, the response manipulandum contained only two telegraph keys, and thus two conspicuous response alternatives. The response manipulandum (i.e., the computer mouse) in the present study also contained two buttons to press; however, in addition, it was possible to move the mouse, and this could be considered a third response alternative. For some subjects, moving the mouse may be a high frequency behavior due to a special reinforcement history in the context of working with computers. The discrepant results between Experiment 1 and Taylor (1980) may be a function of this extra response alternative, especially considering that a large effect on precurrent responding was noted after S3 was told not to move the mouse. Thus, steps were taken to minimize the likelihood of mouse movement in Experiment 2 in an attempt to hasten the development of the precurrent operant.

The anecdctal data with S2 suggest that orderly changes in precurrent responding were observed despite her apparent lack of "awareness" of the consequences of precurrent responding. To more systematically document this phenomenon, in Experiment 2 a form was provided to subjects at the end of each session and they were asked to write about what occurred during that session. This methcd of tracking on-going verbal behavior throughout the experiment seemed preferable to a post-experiment interview which, because of the multiple sessions required in single-subject methodology, might be conducted weeks or even months after the various changes in conditions. A session-by-session completion of the form permitted the assessment of whether changes in post-session verbal behavior accompanied changes in contingencies and/or changes in within-session non-verbal behavior. Also, the reports could draw attention to features of the experiment controlling responding that were not considered in the design of the present paradigm and which could be changed to improve experimental control. (See General Procedure for additional discussion of the post-session verbal reports.)

The third procedural change involved instructing subjects to earn as much money as possible. This instruction was not included in either Taylor (1980) or Experiment 1. In both cases, efficiency, as measured by the <u>PiPc</u> CP, did not approach maximal levels even with repeated exposure to the precurrent contingency. At one point in Experiment 1, S1 commented, "What does it matter how much money I earn?" This is the subject who fell asleep during one session and who ceased precurrent responding altogether during her final two sessions of participation. Perhaps this new instruction would function as an establishing operation (cf., Michael, 1982) for "low motivated" subjects, increasing the reinforcing value of the total points (and ultimately the money) acquired and strengthening/maintaining behavior which in the past had produced the points most effectively.

EXPERIMENT 2A

Subjects

The subjects (S4 and S5) were a female and male student, respectively, enrolled in a behavioral psychology course at the University of Victoria.

Apparatus

The apparatus was identical to that employed in Experiment 1 except for one change to minimize mouse movement. The mouse was taped to a 12 by 24 cm piece of cardboard. The mouse/cardboard unit was moveable so that subjects could adjust the response manipulandum for maximum comfort, but now movement over the desk involved considerably more friction.

Procedure

The written instructions presented to each subject to read prior to Session 1 were as follows:

> It is possible to earn money by manipulating the computer mouse. Do not press the covered button on the computer mouse. Do not move the mouse. The amount of money you have earned at any given time will be displayed on the computer monitor. When the screen prints "END OF SESSION", wait for the experimenter to return and write down the amount of money you have earned. Today there will be one session, approximately a 10 minute break, and then another session. Following today's second session you will be paid the total

amount earned during both sessions. During a session, do not leave your seat without first informing me. I will be within hearing distance in the other room. If you have a watch, please leave it with me and it will be returned to you following today's two sessions. THE OBJECTIVE IS TO EARN AS MUCH MONEY AS YOU CAN.

The instructions were identical to Experiment 1 except for the additional mands to not move the mouse and to earn as much money as possible.

At the end of each session, the subject was presented with a printed form asking, "Briefly describe what you think was happening during this session". The subject was instructed to write his/her comments on this form.

Both subjects began the experiment with no precurrent contingency (APC phase); specifically, both Pn and Pc were set at .02, and Dc was set at 15 s. When precurrent responding was consistently infrequent across sessions, the precurrent contingency was introduced (PPC phase), the only change from the APC phase being that Pc was raised to .08. Thus, a precurrent response functioned to quadruple the reinforcement probability for current responding from .02 to .08 for 15 s under the PPC phase. The precurrent contingency was subsequently removed for S5 (APC II phase).

Results

S4. The top half of Figure 17 presents the cumulative records for the first APC session (Session 1).

Insert Figure 17 here

Figure 17 reveals that precurrent responding occurred at a fairly steady rate for the first 3.5 min, but then ceased altogether for the remainder of the session. Very few reinforcers were delivered during the initial 3.5 min. Current responding was continuous throughout the session, and while fluctuations in rate occurred, by the final quarter of the session a sustained high stable rate is observed.

Insert Tables 9 and 10 and Figure 18 here

Figure 18 and Table 9 show a decreasing trend across APC sessions for precurrent responding and the PiPc CP to very low levels by Session 3. Current responding increased across the three APC sessions as did the number of reinforcers obtained. Table 10 reveals a focus in verbal behavior in APC sessions about an apparent contingency between mouse movement and reinforcement.

No precurrent responses were emitted during the first two PPC sessions and therefore no contact was made with the precurrent contingency (see Table 9). A considerable drop in current responding is observed during Session 5. The bottom half of Figure 17 presents the cumulative records

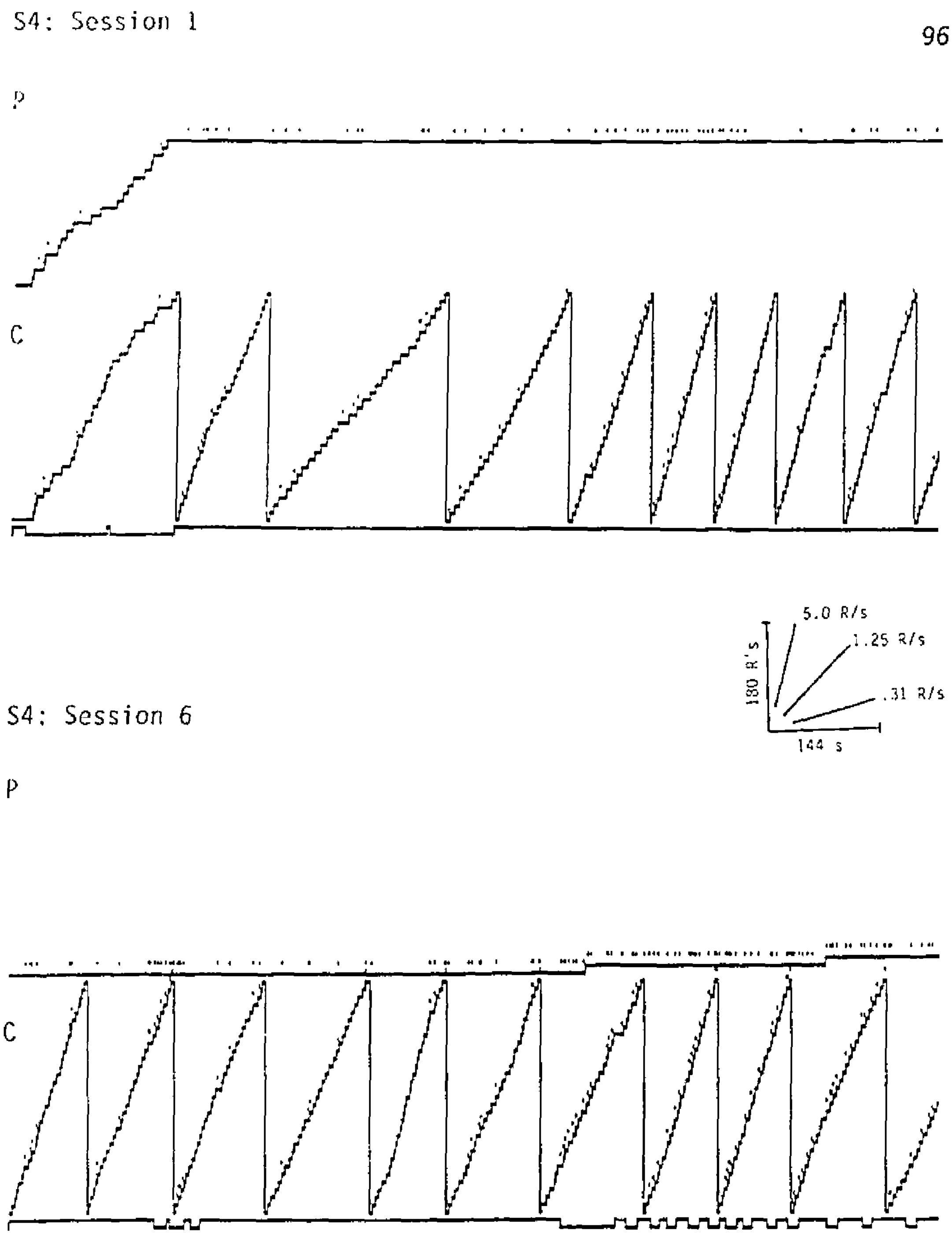


Figure 17. Cumulative records of precurrent (P) and current (C) responding for S4 during Session 1 (top) and Session 6 (bottom).

TABLE 9

<u>Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across APC and PPC Sessions for S4</u>

SESSION	PRECURRENT	CURRENT	*PiPc* CP	CO's	SR's
APC (*Pn*=02; *Pc*=.02; *Dc*=15s)					
1	234	3459	.10	28	55
2	130	4959	.04	15	102
3	64	5409	.03	6	125
PPC (*Pn*=.02; *Pc*=.08; *Dc*=15s)					
4	0	5028	.00	0	101
5	0	3546	.00	0	73
6	26	3895	.26	26	134
7	45	4770	.49	42	250
8	39	4928	.46	38	219

TABLE 10

Post-session Verbal Reports Across APC and PPC Sessions for S4

SESSION	COMMENTS
APC (Pn=02; Pc=.02; Dc=15s)	
1	I was being reinforced for moving the little mouse to the right of the board.
2	I was being reinforced for moving the mouse up and down the side of the board.
3	It seemed to me that if I slowly moved the mouse down the right side of the board, stopping and pressing, I would be reinforced.
PPC (Pn=.02; Pc=.08; Dc=15s)	
4	Still keeping to the right side of the board, but not reinforced as much as previous times.
5	Getting harder. Still staying on the right hand side of the board. Looks like variable ratio SR (??). Not getting reinforced as often, but there are places on the board (right hand side) that is reinforced more often than others.
6	Keeping the mouse in one place, I found that if I pressed the left hand button once, then back to the right hand one, I received a lot more response (went up a lot quicker).
7	Without moving the mouse too much (up and down a couple of cm) and pressing the left hand key every once in a while, I was reinforced quite often, sometimes jumping up .050 in a couple of seconds.
8	Same pretty well as last time, though I did not get reinforced quite as often (probably had to be more specific). Also did not seem to have the emphasis on pressing the left key as much last time.

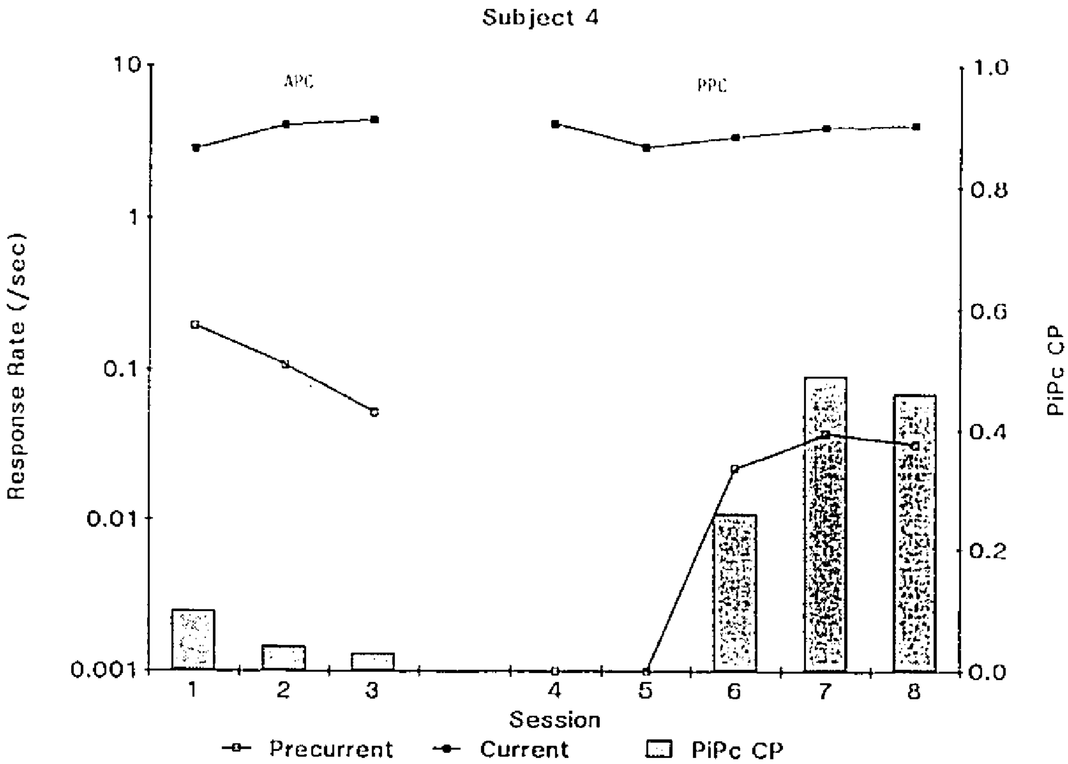


Figure 18. Precurrent and current responses rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the APC and PPC phases for S4.

for Session 6 when the precurrent contingency was first contacted. There is a short period about 3 min into the session during which some precurrent responses were emitted and a noticeably higher frequency of reinforcer delivery is observed during this time. Then, precurrent responding did not occur for over 7.5 min, after which precurrent responses were emitted more consistently (detectable in the state line), more current responses were emitted under PiPc, and reinforcers were delivered more frequently. Current responding continued at a sustained high stable rate throughout the session, although some minor fluctuations are observed.

Table 9 and Figure 18 reveal that the changes that occurred during the last 7.5 min of Session 6 maintained across Sessions 7 and 8. Note that while the PiPc CP and the number of reinforcers acquired were higher in Sessions 6-8 than in any previous session, precurrent responding was actually higher in APC sessions. The fact remains, however, that precurrent responding declined to zero levels across APC sessions, but once the precurrent contingency was contacted, it maintained throughout the PPC phase, a result consistent with Taylor (1980).

The reason for fewer precurrent responses but the considerably higher PiPc CP in the final two PPC sessions (Sessions 7-8) relative to APC sessions (Sessions 1-3) can be illustrated by showing representative cumulative records. The top and bottom halves of Figure 19 present the cumulative records for Sessions 3 and 8, respectively.

Insert Figure 19 here

These records show that all precurrent responses in Session 3 were emitted at the very beginning of the session (an identical pattern was observed in Session 2, and, as seen in Figure 16, also in Session 1). In contrast, precurrent responding maintained at a steady but slow rate throughout Session 8 (as was the case in Session 7). Thus, the within session pattern of precurrent responding was altered once the precurrent contingency was contacted which resulted in substantially higher levels of the <u>PiPc</u> CP (and reinforcers obtained). Appendix C4 is also revealing: while the mean precurrent response run varied between 8-10 responses in Session 1-3, in Sessions 6-9 only one precurrent response per CO occurred.

Table 10 reveals that S4 mentioned pressing the buttons for the first time in Session 6. The statement "I received a lot more response" is unclear. If "response" were to read "reinforcer" or to refer to the machine's response, then her description would be consistent with the precurrent contingency. Her verbal behavior in the subsequent two PPC sessions (Sessions 7-8) is consistent with the precurrent contingency, although she notes a

S4: Session 3

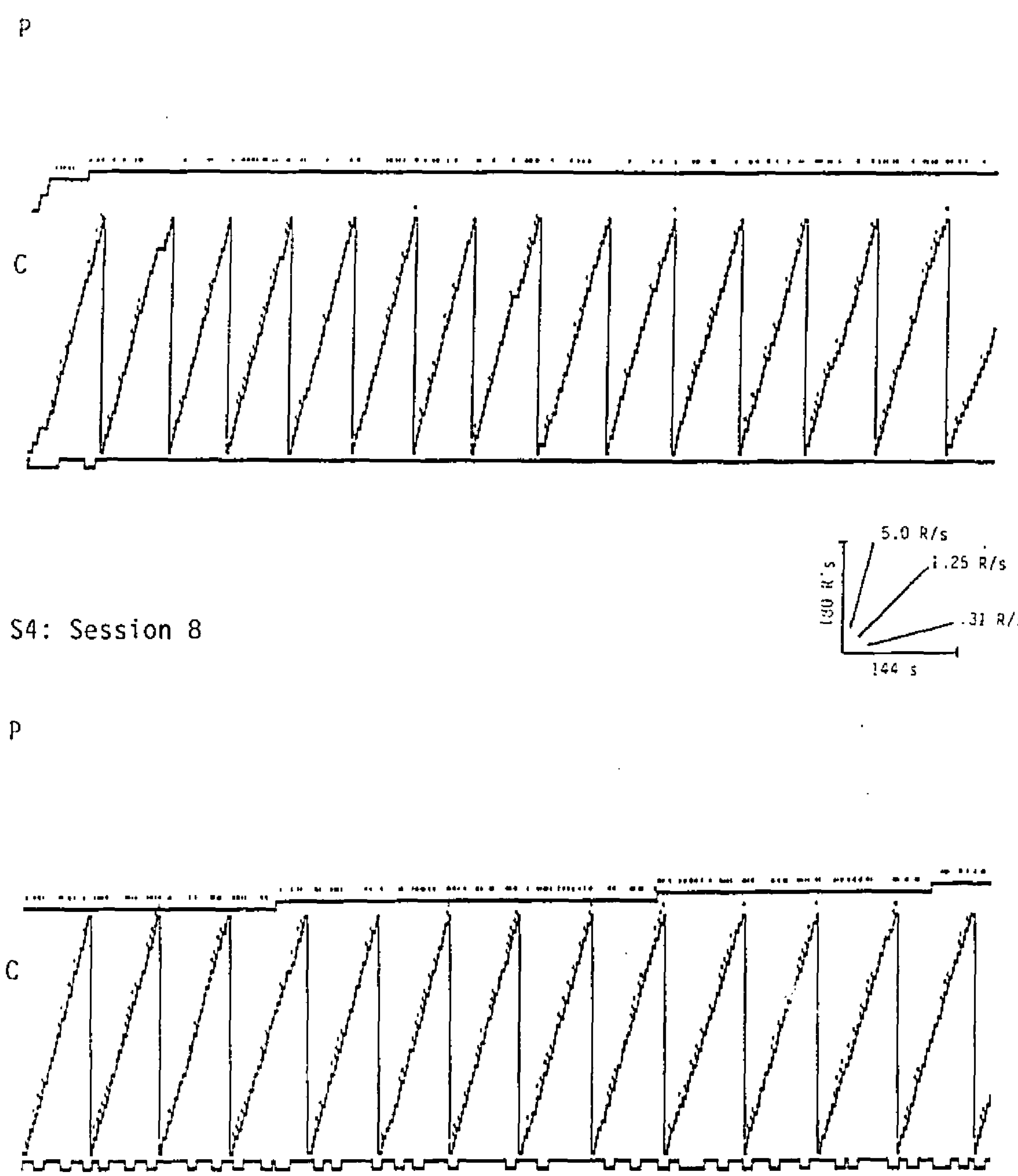


Figure 19. Cumulative records of precurrent (P) and current (C) responding for S4 during Session 3 (top) and Session 8 (bottom).

change in the "emphasis on pressing the left [precurrent] key" across the two sessions.

S5. The top half of Figure 20 presents the cumulative records for the first APC I session (Session 1).

Insert Figure 20 here

Figure 20 reveals that low rate responding occurred for the first 110 s of the session, and then there was a high stable rate of current responding which sustained for the rest of the session. Current responding was occasionally interrupted with bursts of precurrent responses but these interruptions became less frequent as the session progressed and virtually no precurrent responses were emitted over the last half of the session.

Insert Tables 11 and 12 and Figure 21 here

Table 11 and Figure 21 show that by the last APC I session (Session 3), precurrent responding and the PiPc CP declined to near zero levels. Current responding increased across the three APC I sessions. S5 made no mention of pressing the precurrent button in any APC session (note that "button" was always used in the singular form), and by Session 3 he quite accurately described the contingency (see Table 12).

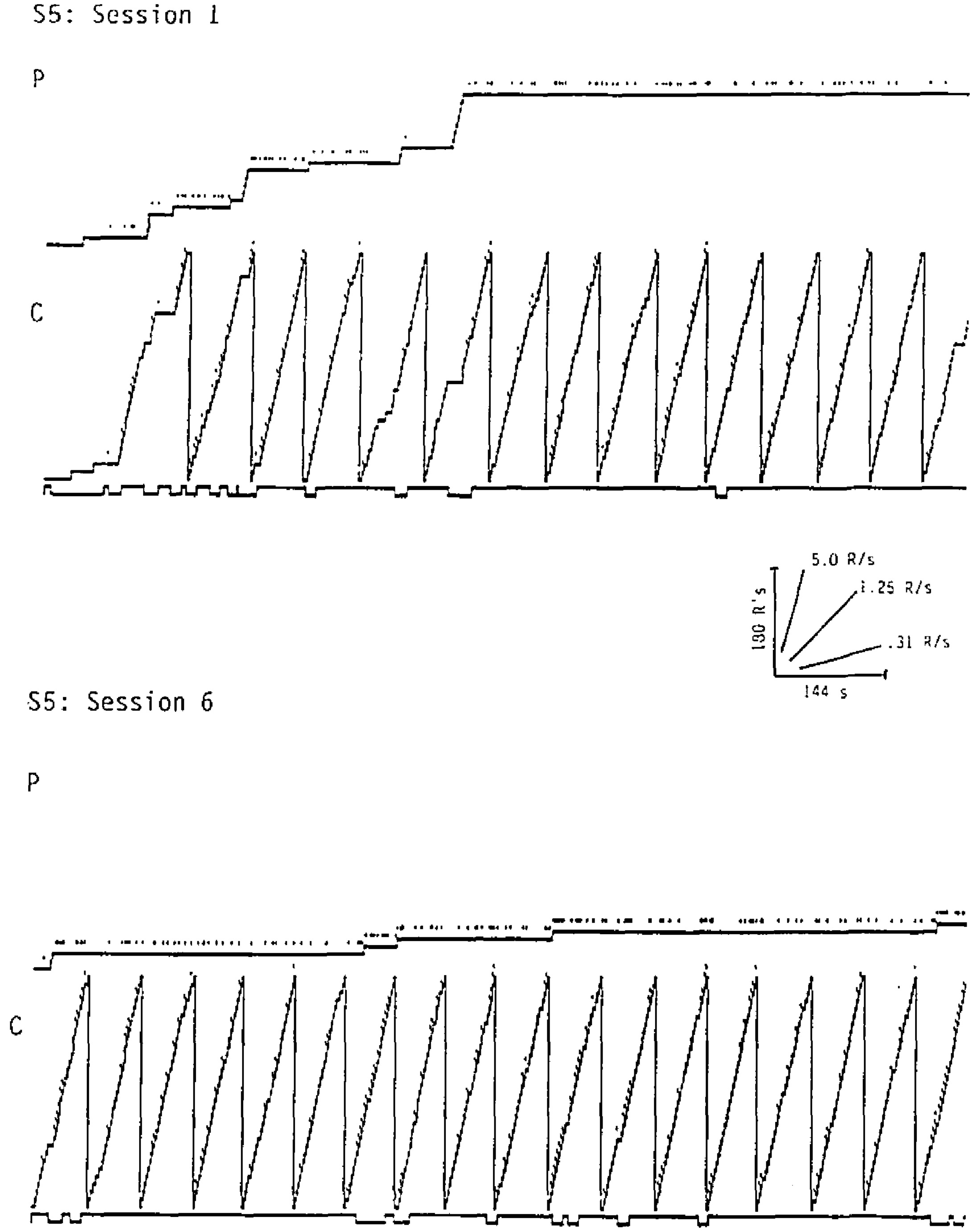


Figure 20. Cumulative records of precurrent (P) and current (C) responding for S5 during Session 1 (top) and Session 6 (bottom).

TABLE 11

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across APC and PPC Sessions for S5

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
APC I (Pn=02; Pc=.02; Dc=15s)					
1	248	5462	.15	27	109
2	247	6086	.16	49	134
3	20	6891	.01	1	145
PPC (Pn=.02; Pc=.08; Dc=15s)					
4	0	6939	.00	0	129
5	0	6933	.00	0	139
6	80	6683	.17	20	206
7	163	6860	.34	34	286
8	174	6892	.50	50	334
9	158	7148	.65	64	423
10	207	6964	.67	59	426
11	285	7007	.77	77	482
12	382	6732	.71	89	391
APC II (Pn=02; Pc=.02; Dc=15s)					
13	352	6608	.47	52	118
14	391	6494	.46	50	127
15	225	6699	.46	41	147
16	254	6623	.42	37	122

TABLE 12

Post-session Verbal Reports Across APC and PPC Sessions for S5

SESSION	COMMENTS
APC I (Pn=02; Pc=.02; Dc=15s)	
1	I think that some behavior was wanted by the experimenter, possibly pushing the right hand button as much as possible, and that money was supposed to reward me and increase the amount that I pressed the button. At points, I found myself thinking that there had to be more, that I was being watched, and that the movements or behaviors I was making not involving the mouse were what was important. After a while, I gave that thought up, though.
2	From what I could tell, I was still only getting reinforced for pressing the right button as much as I could. I think, maybe, that you were seeing if, after quick money increase, I would increase the amount of times I hit the button.
3	We're not supposed to use terms...but I think that the reinforcement is on a VR schedule. My responses are basically continual and the money increases vary from 1 response to about 100.
PPC (Pn=.02; Pc=.08; Dc=15s)	
4	The same as all the other sessions. I got less money this time...I don't know why. Maybe I was getting tired or bored and thus, didn't press the button as much.
5	As in the last four sessions, I think that the more I pressed the right button the more money I was given. I don't know if you care, but it's awfully boring in there.
6	Same thing. Made more money, don't know why.
7	Well I made more in this one than in the first two together, sessions, that is. I think that rate of reinforcement increases if I press the left button and then press the right one as much as possible. It seems like a variable ratio with a decrease in range of number of responses required by me when I press the left. This only seems to last for about 30 seconds or so though, then I have to press the left button again...Then again, I could be totally off the beaten track!
8	Seemed the same as Session 7. I have to admit,

TABLE 12 (continued)

SESSION	COMMENTS
	I'm not near as bored as I was before. May be it's because I'm getting more money, maybe because I think I've caught on to something, whether I'm right or wrong, I don't know.
9	I think it was the same as the last two or however long it's been going on. It's become more of a game for me. The higher I get, the more..."proud" I feel. I suppose that's making me press faster and with more endurance. I'm not quite sure if I have to press the left button more than once to get an increase in money. It seems like only once is sufficient. Then again, who knows? Well...I suppose you do.
10	Same thing as #9, didn't notice any differences.
11	Same as the others, I try different combinations but it doesn't seem to have any real effect. I don't know, I'm too tired to think anyways.
12	Less money, seemed to reinforce less often, not pleasing. Just kidding, I don't know if anything was different. Maybe I was just too tired still?
APC II (Pn=02; Pc=.02; Dc=15s)	
13	I don't know what's happening, but it's frustrating; it's hard going from over $2.00 in one session to just over 50 cents. I tried a lot of different combinations, all to no avail. Oh well, guess I'll just go with the flow.
14	I somehow get the feeling I'm going through extinction--all I know is that it's not fun anymore—not a challenge...Although I can't figure out what really is happening. It's frustrating. Oh well.
15	I don't know! Maybe you're trying to break the contingency between left and right buttons, maybe you're starting all over again. It kind of feels like the first sessions now. Once again it's kind of frustrating. I hate not knowing what's going on...you know?
16	I don't know what's happening! That's all there is to it.

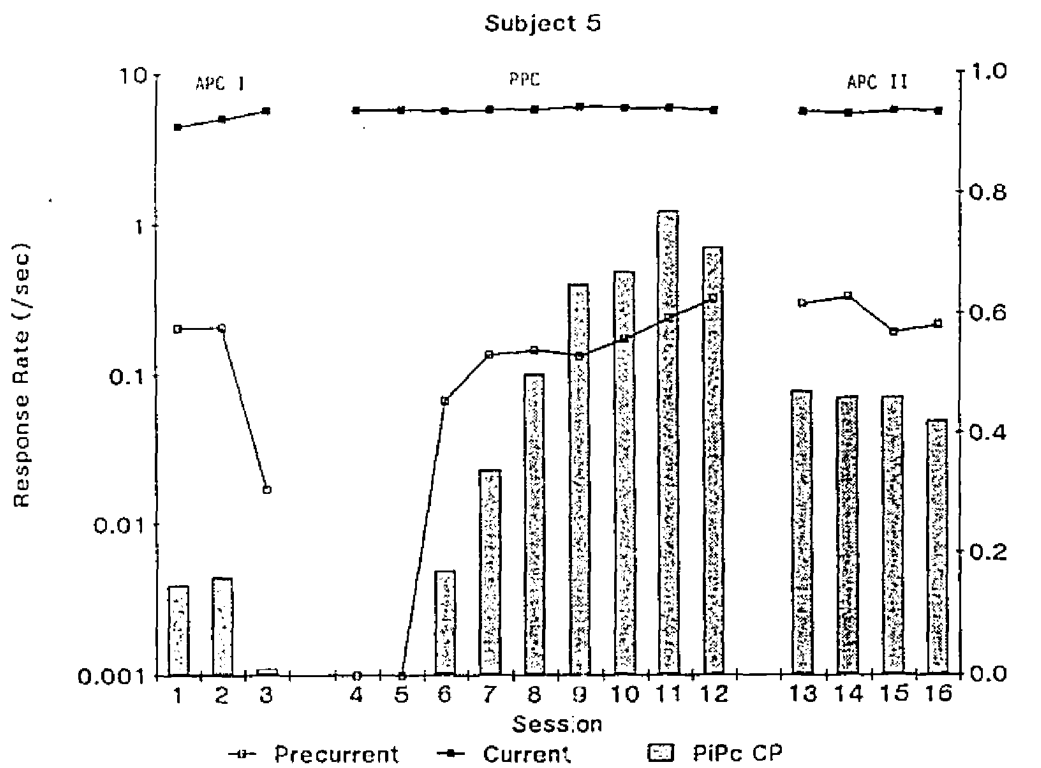


Figure 21. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the APC I, PPC, and APC II phases for S5.

The precurrent contingency was scheduled for Sessions 4-12 (PPC phase). No precurrent responses were emitted during the first two PPC sessions (Sessions 4-5), and therefore no contact was made with the precurrent contingency. The bottom half of Figure 20 presents the cumulative records for Session 6 when the precurrent contingency was first contacted. The sustained high stable rate of current responding was occasionally interrupted by very small bursts of precurrent responding throughout the session. The cumulative record shows distinguishable periods of higher rate reinforcer delivery following precurrent responding.

Table 11 shows that the number of reinforcers acquired by S5 was higher in Session 6 than in any previous session, while precurrent responding and the PiPc CP were enhanced relative to the previous three sessions. S5 comments that he does not know why more reinforcers were acquired in Session 6 (see Table 12).

Figure 22 presents the cumulative records for S5 during Session 7 when a noticeable increase in the rate of precurrent responding was observed.

Insert Figure 22 here

Figure 22 shows that over the first 7.5 min of the session there was only one small burst of precurrent

S5: Session 7

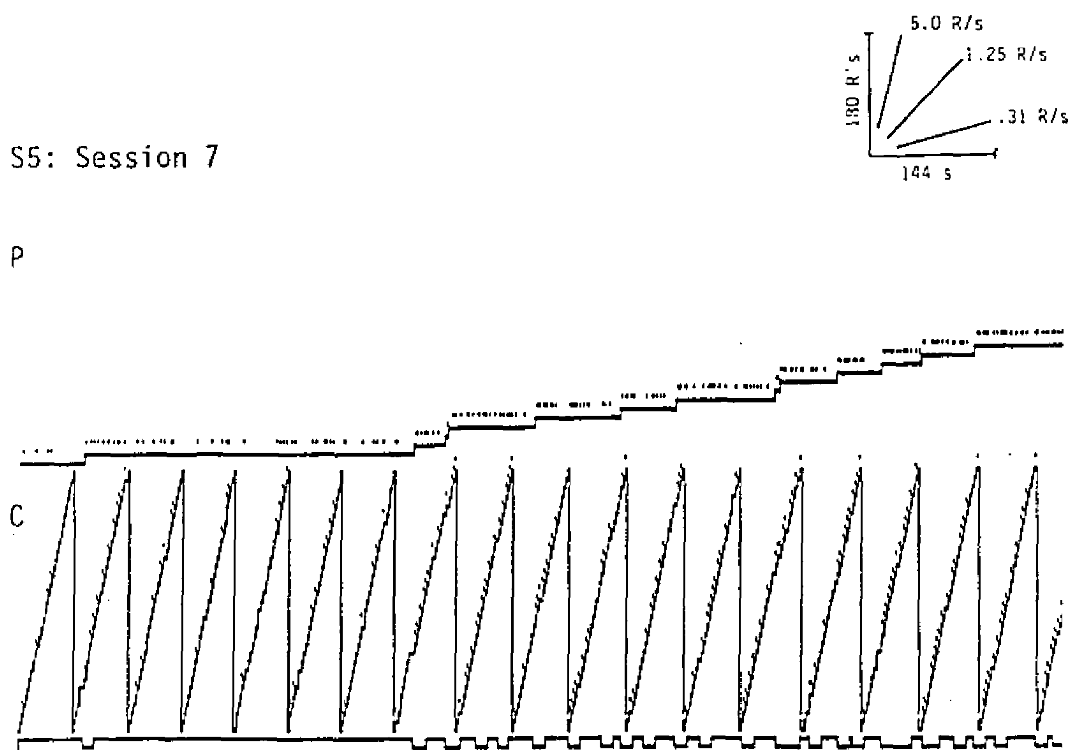


Figure 22. Cumulative records of precurrent (P) and current (C) responding for S5 during Session 7.

responding, after which precurrent responding occurred more consistently and frequently as did reinforcer delivery.

Table 11 and Figure 21 show an increasing trend in precurrent responding over the last four PPC sessions (Sessions 9-12). The PiPc CP and reinforcers obtained steadily increased across PPC sessions (with the exception of Session 12).

Table 12 reveals that S5 gave a fairly accurate description of the precurrent contingency for Session 7, the session in which the substantial change in precurrent responding occurred. His comment that the effect lasts about 30 s coincides with his performance observed in Figure 22: following precurrent responding, high rate current responding continues for a period of time past Dc (and thus into Pn) before more precurrent responses are emitted (see state line). Similar verbal behavior is observed in subsequent PPC sessions (Sessions 8-12), although the within session performance changed, as seen in Table 11 and Figure 21 (i.e., the PiPc CP steadily increased) and Appendix C5 (i.e., the mean current response run steadily decreased).

The precurrent contingency was withdrawn for Sessions 13-16 (APC II phase). The top and bottom halves of Figure 23 present the cumulative records for the last PPC session (Session 12) and the first APC II session (Session 13), respectively.

Insert Figure 23 here

The cumulative records reveal a subtle change in responding across the two sessions, most noticeable in the state line. Whereas periods under Pn were relatively brief during Session 12, longer periods are observed in Session 13, coinciding with longer current response runs (see also Appendix C5). Additional calculation reveals that in Session 12 only 1.1% (1/90) of current response runs were greater than 270 responses; in Session 13, this figure increased to 13.2% (7/53). This change is reflected in the drop in the PiPc CP across Sessions 12 and 13, as seen in Table 11 and Figure 21.

Comparing the means of the last two sessions of the PPC (Session 11-12) and APC II (Sessions 15-16) phases, reductions are observed in precurrent responding (from .28 to .20 responses/s), and especially the PiPc CP (from .74 to .44) and CO's (from 84 to 39).

S5's comments during APC II sessions reveal a definite change in verbal behavior. His comments about "extinction" in Session 14, and "break[ing] the contingency between left and right buttons" in Session 15 suggest awareness of the ineffectiveness of precurrent responding. He compared Session 15 to the first few sessions (APC I phase) when identical contingencies were in effect.

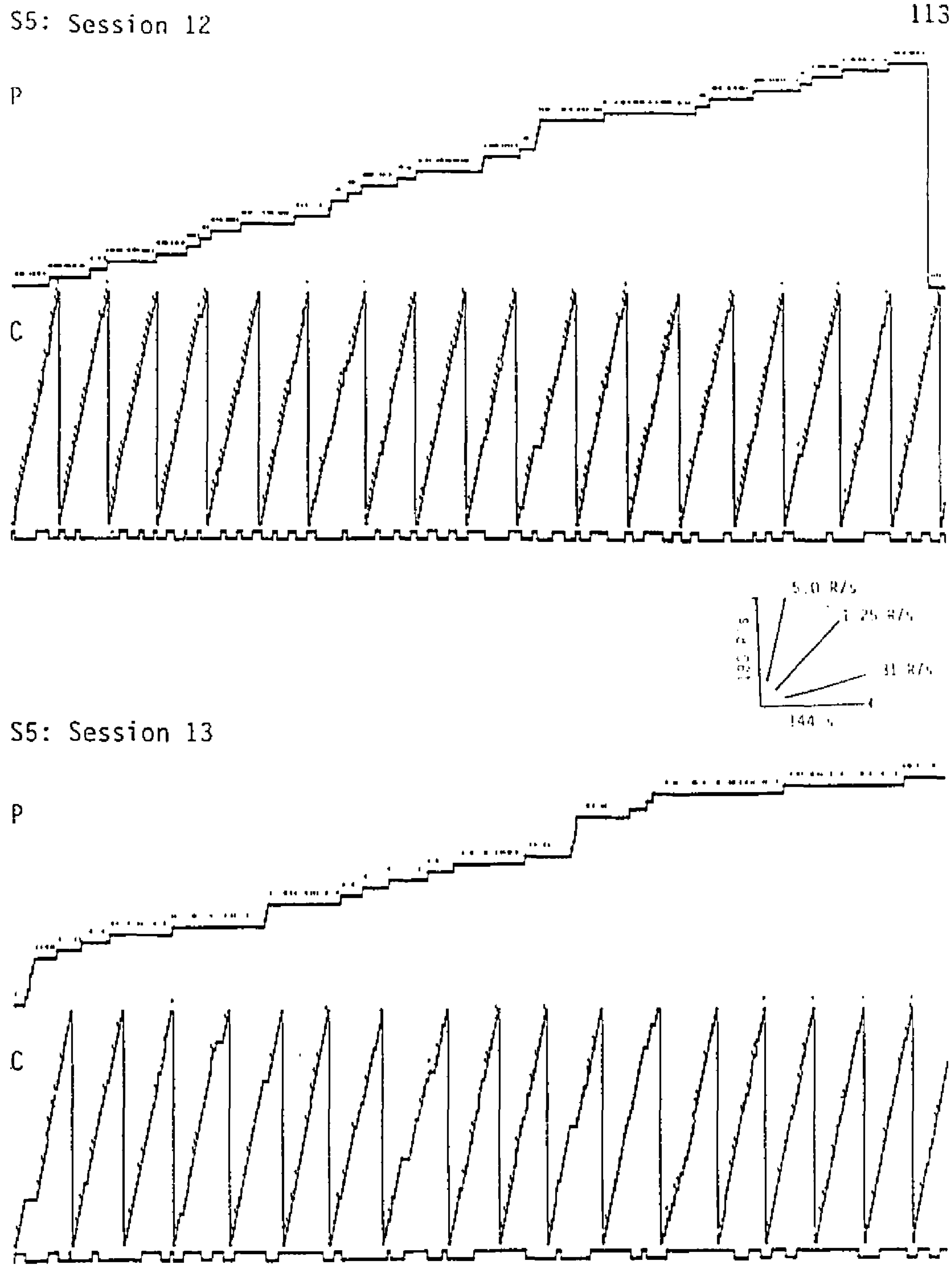


Figure 23. Cumulative records of precurrent (P) and current (C) responding for S5 during Session 12 (top) and Session 13 (bottom).

Discussion

Both S4 and S5 discontinued their participation in the experiment before a planned ABAB design was complete. The APC data for both subjects are in general agreement with Taylor (1980) and Experiment 1A: under an initial condition during which precurrent responding had no scheduled consequence, precurrent responding dropped to near zero levels after two sessions. Current responding continued throughout this condition at a sustained high stable rate. Unlike Experiment 1B, however, and more in line with Taylor (1980), for both S4 and S5, precurrent responding and the PiPc CP were enhanced when a precurrent response increased the reinforcement probability for current responding from .02 to .08 for 15 s during the PPC phase. S5 stands out from all other subjects, however, in that these changes occurred gradually, i.e., after repeated contacts with the precurrent contingency (see Figures 20 and 22).

When S5 was returned to APC condition, there was only a slight decrease in precurrent responding. However, more pronounced reductions were seen in the PiPc CP and CO's, an indication that the reversal produced a change in the pattern of precurrent and current responses to one that would have earned far fewer reinforcers had the precurrent contingency remained in effect.

The verbal behavior of S4 and S5 suggest that both subjects came to accurately describe the precurrent contingency during the PPC phase in the sense that both mentioned that higher rates of reinforcement were obtained by first pressing the precurrent button and then the current button. It is interesting to note that in Session 6, when S5 first contacted the precurrent contingency, there were 20 CO's (i.e., repeated contact with the precurrent contingency) and far more reinforcers earned than in any previous session; however, S5 commented that the conditions were the same as before and he didn't know why more reinforcers were obtained. In the subsequent session (when the notable change in precurrent responding occurred), he gave a fairly accurate description of the precurrent contingency, but he also indicated that the effect lasted 30 s (rather than 15 s) and did not revise this description for the remaining sessions of the PPC phase. Note that this was not consistent with his within session performances: if he was to respond as if Dc was 30 s throughout the PPC phase, then one would not expect the PiPc CP to increase across PPC sessions and certainly not to the 74% level obtained over the final two PPC sessions (Sessions 11-12).

EXPERIMENT 2B

An experiment using single-subject methodology with humans runs the risk of subjects terminating their participation before a sufficient number of sessions are run for a complete analysis, as was the case with S4 and S5. Experiment 2B attempted to develop the precurrent operant more quickly by exposing subjects to the precurrent contingency (PPC condition) from the very first session. If precurrent responding maintained across these initial PPC sessions and a subject were to leave the experiment prior to a reversal (APC condition), there would still be reason to believe that maintenance was due to the precurrent contingency. The data for S1, S2, S4, and S5, as well as for four of five subjects in Taylor (1980), all indicate that precurrent responding does not maintain when the precurrent contingency is absent in the initial condition.

Subjects

The subjects (S6, S7, and S8) were three female students enrolled in an undergraduate behavioral psychology course at the University of Victoria.

Procedure

All conditions were identical to Experiment 2A except these three subjects began the experiment under the PPC condition. At least one reversal-replication was planned for each subject.

Results

S6. The top half of Figure 24 presents the cumulative records for Session 1.

Insert Figure 24 here

It is clear from this record that precurrent responding maintained throughout the session. This is in marked contrast to subjects beginning the experiment under the APC phase (e.g., compare to Figures 17 and 20). Current responding maintained at a high stable rate throughout the session. Most (92%) current responses in the last 12 min, and all in the final 4 min, were emitted under PiPc (see state line).

Insert Tables 13 and 14

Table 13 shows that precurrent responding maintained throughout the PPC phase (Sessions 1-4), although it declined across sessions. The PiPc CP was more variable across PPC sessions, with lower levels observed in Sessions 3-4 relative to Sessions 1-2.

It is possible the precurrent responding may have decreased further with continued exposure to the PPC phase. The bottom half of Figure 24 presents the cumulative records for the final PPC session (Session 4).

S6: Session 1

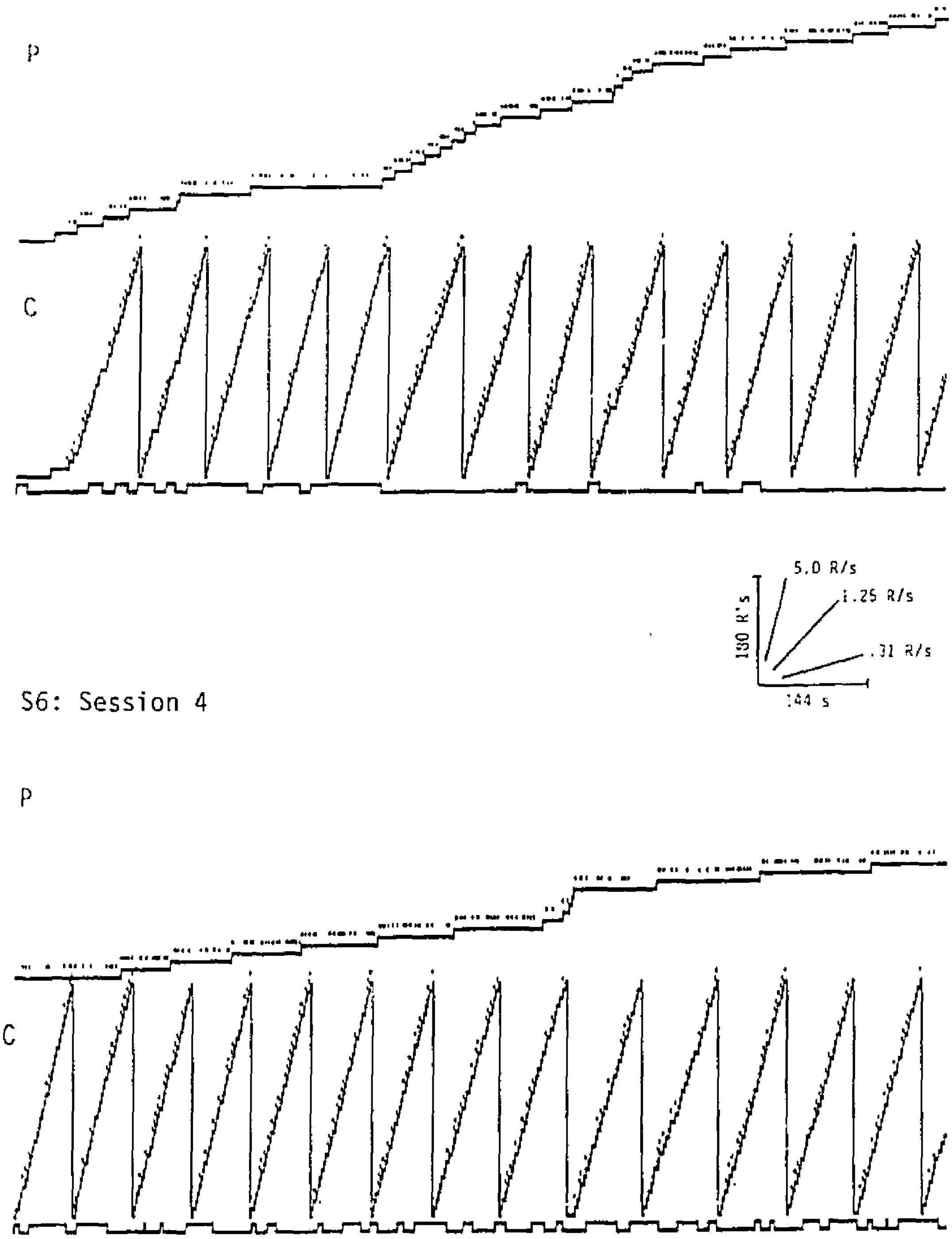


Figure 24. Cumulative records of precurrent (P) and current (C) responding for S6 during Session 1 (top) and Session 4 (bottom).

TABLE 13

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC Sessions for S6

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
PPC (Pn=02; Pc=.08; Dc=15s)					
1	352	4992	.69	154	303
2	274	5160	.83	134	340
3	202	5156	.33	40	194
4	178	5337	.59	100	297

TABLE 14

Post-session Verbal Reports Across PPC Sessions for S6

SESSION	COMMENTS
PPC (Pn=02; Pc=.08; Dc=15s)	
1	I was being reinforced with .5 cents after a certain number of button pressing with the button on the right side. Pushing the left button was not reinforced. After a while it seemed like that if I pushed the button on the left (once or twice) and then continue pushing the right I was reinforced more often than just pushing the right button exclusively.
2	Reinforcement was for only pressing the right button. Although it still seemed like one or two presses of the left button increased the reinforcement. I'm not sure if it was the amount of time (interval) that was being reinforced but I thought it was the rate of response so I pressed the right button quite continuously. I think reinforcement was variable.
3	I think I was being reinforced with .5 cents on a variable interval or variable ratio schedule of reinforcement for pressing only the right button on the mouse.
4	Again I think I was being reinforced on a variable ratio or variable interval schedule but I think the average ratio or interval was less this time.

Precurrent responding clearly maintained throughout this session. An additional calculation reveals that the PiPc CP was similar during the first half (61%) and the latter half (57%) of the session. Thus, the within session data of the final 20 min show no trend toward a reduction in precurrent responding or the PiPc CP.

The verbal behavior of S6 in Table 14 indicates that she provided an accurate description of the precurrent contingency in Sessions 1 and 2. S6 did not mention the precurrent contingency in Sessions 3 and 4. The word "only" in her comment in Session 3 about being reinforced "for pressing only the right button" suggests a focus away from the precurrent contingency. S6 terminated her participation in the experiment following Session 4.

S7. The top and bottom halves of Figure 25 show the cumulative records for the first two PPC I sessions (Sessions 1 and 2), respectively.

Insert Figure 25 here

Figure 25 shows that, like S6, relatively high rate precurrent responding maintained across Session 1 (in contrast to subjects exposed to the APC phase in Session 1); unlike S6, stable high rate current responding did not develop until later in Session 2, at which time the precurrent response rate is reduced slightly. The records

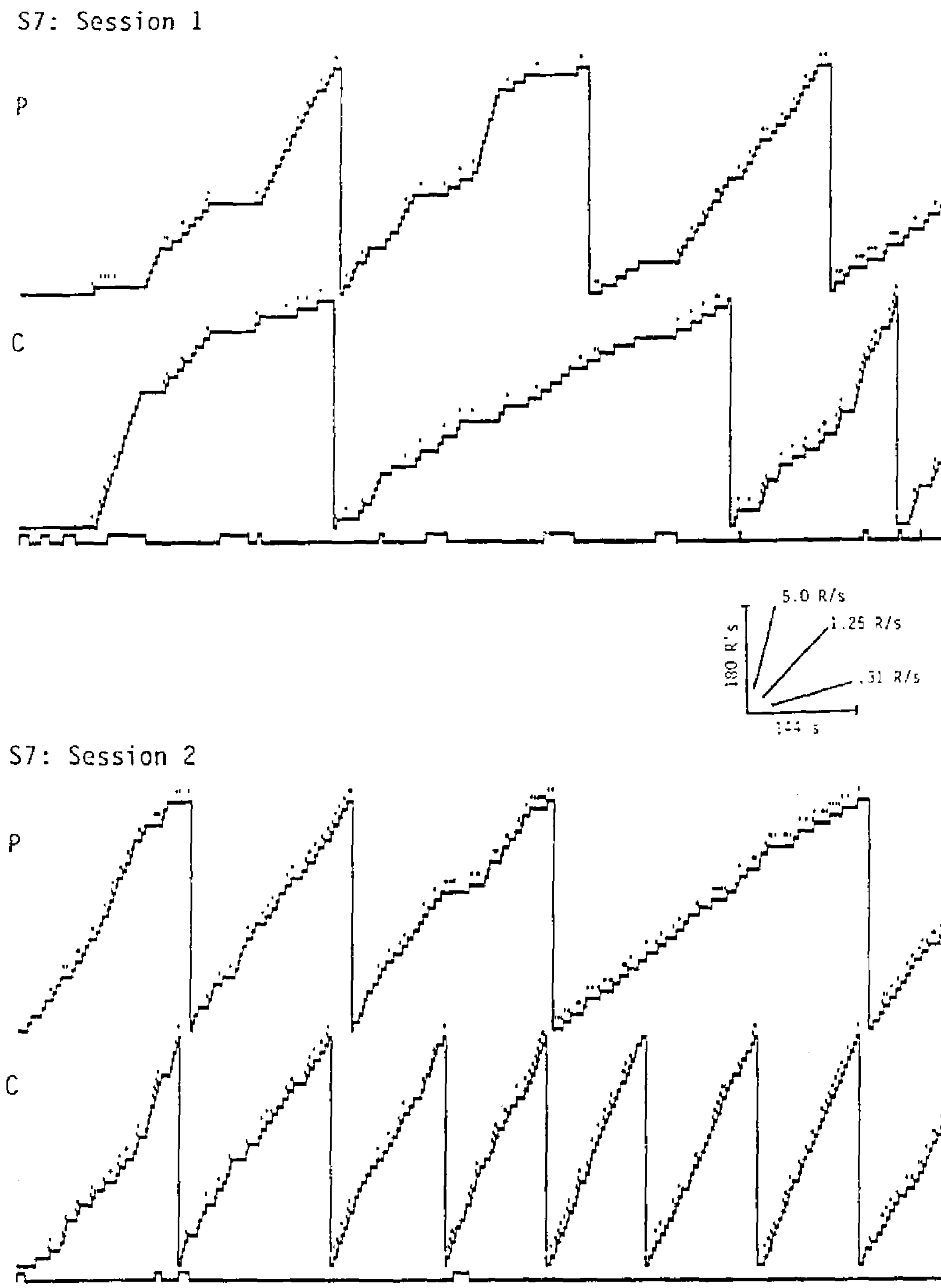


Figure 25. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 1 (top) and Session 2 (bottom).

for both sessions, especially Session 2, reveal that the large majority of current responses were emitted under PiPc.

Insert Tables 15 and 16 and Figure 26 here

Table 15 and Figure 26 reveal that precurrent responding maintained across Sessions 1-7 (PPC I phase), although the levels were considerably lower over the last five sessions; alternatively, current responding was considerably higher over the last five sessions. Although the PiPc CP was highest in Session 2, more reinforcers were obtained in Sessions 3-7 because of the substantially greater current response rate.

S7 commented that reinforcement may depend on combinations of presses on the two keys in Session 1, but for remaining sessions of the PPC I phase, if a response was mentioned in connection with reinforcement, it was the current response (see Table 16). In some PPC I sessions, she mentioned that reinforcers came in "bursts", but she does not indicate that her (precurrent) behavior controlled these bursts in any way.

The top and bottom halves of Figure 27 present the cumulative records for the last session of the PPC I phase (Session 7) and the first session of APC I phase (Session 8), respectively.

TABLE 15

<u>Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC and APC Sessions for S7</u>

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
PPC I (Pn=02; Pc=.08; Dc=15s)					
1	1269	1216	.77	161	84
2	1641	2828	.95	305	199
3	440	5225	.50	96	268
4	629	5633	.72	283	353
5[a]	411	5513	.52	109	264
6	333	5127	.30	40	205
7	666	5445	.51	65	264
APC I (Pn=02; Pc=.02; Dc=15s)					
8	527	5123	.30	48	100
9	101	5906	.10	15	124
10	4	5953	.02	2	116
PPC II (Pn=02; Pc=.08; Dc=15s)					
11	718	5795	.54	57	282
12	710	5899	.55	92	300
13	850	4840	.70	96	314
14	499	5663	.49	61	287
APC II (Pn=02; Pc=.02; Dc=15s)					
15	72	5856	.07	10	108
16	0	6573	.00	0	130
PPC III (Pn=02; Pc=.08; Dc=15s)					
17	7	6142	.03	2	132
18	0	6344	.00	0	121
19	260	6336	.30	46	225
20	817	5998	.81	135	402
21	1066	5241	.91	192	381

[a]The raw data following the initial 430 s of Session 5 were lost, although the exact numbers of precurrent and current responses, and reinforcers for the entire session were retained. The PiPc CP applies only to this initial period. The number of CO's is projected based on the available data which indicates 39 CO's in the first 429.2 s of the session.

TABLE 16

Post-session Verbal Reports Across PPC and APC Sessions for S7

SESSION	COMMENTS
PPC I (Pn=02; Pc=.08; Dc=15s)	
1	I think that I (the subject) was being reinforced for a certain combination of the proper presses of the keys. It seemed to work on both a time interval and a ratio of response kind of schedule. I don't know if that's possible but it's what I thought.
2	Seemed like there was more of a pattern developed. Definitely one of the keys (the right one) gives the reinforcement. The money also seemed to come in sort of "bursts", like bunches of 3 or 4.
3	Sometimes its seemed like I received money for the number of times I pressed the button. Other times it seemed completely random, like the computer gave me the money whenever (based on time not responses) it "felt" like it.
4	Here it seemed like the more responses I gave, the more money I received, and this "pattern" was interspersed with periods where no matter how many times the button was pressed, I would not receive money for them. I simply had to wait through an unspecified interval before I could be eligible to receive more money.
5	When some money was given, if I pressed the button many times right after, quite a few "bits" of money followed directly after. Then there would be spaces where no amount of button pressing would deliver any money.
6	Seemed like lower rates of responding were more apt to get steady-like reinforcements. Other than that, I just don't know.
7	It seemed like a pattern was developing; a pattern of when the money is given out. As in, it depended on intervals, not on the number of button presses.
APC I (Pn=02; Pc=.02; Dc=15s)	
8	Well, the computer was being way stingier. And again, it seemed like money was given at intervals, rather than by no. of responses.

TABLE 16 (continued)

SESSION	COMMENTS
9	I wasn't sure what was happening, thus I resorted to pressing the button constantly, at a relatively steady rate (I tried), because this would deliver as much money as I could get regardless of the schedule it's being delivered on.
10	The session seemed the same as #9, except money was even a bit more "difficult" to earn. It was slower in coming.
PPC II (Pn=02; Pc=.08; Dc=15s)	
11	During this session it seemed that there were quite definite periods where the reinforcement (money) could be received and quite definite periods where it could not. Like the money came along in "chunks" or bursts.
12	Seemed to be the same as in Session 11, except that the "definite periods" were shorter in time.
13	Seemed to be the same as in the previous session. Money was available at various chunks of time, and at others it wasn't.
14	Here, being given money seemed like it might depend somewhat on the rate of lever pressing.
APC II (Pn=02; Pc=.02; Dc=15s)	
15	The computer would give out money whenever it felt like it. As in, randomly. As in any time it wanted. As in, number of button presses was not the important thing here.
16	The same as Session 15. Sure seemed that way.
PPC III (Pn=02; Pc=.08; Dc=15s)	
17	Same as previous session? I'm not really sure.
18	I can't figure out when the money will be given so I just try to press the button at a steady(?) and unstopping rate, so as to "cover" all chances of getting money.
19	When money was not quickly forthcoming, it seemed to "help" to press the other button for a brief amount of time to get the computer to give more money.
20	Money seemed to come in bursts again, but just as in Session 19, pressing the other button seemed to help in getting the computer to give more money.

TABLE 16 (continued)

SESSION	COMMENTS
21	Reinforcement seems aided by pressing the other button, however it may be that pressing the other button is really another way of marking time. Like, it's something to do while you not get any forthcoming reinforcement.

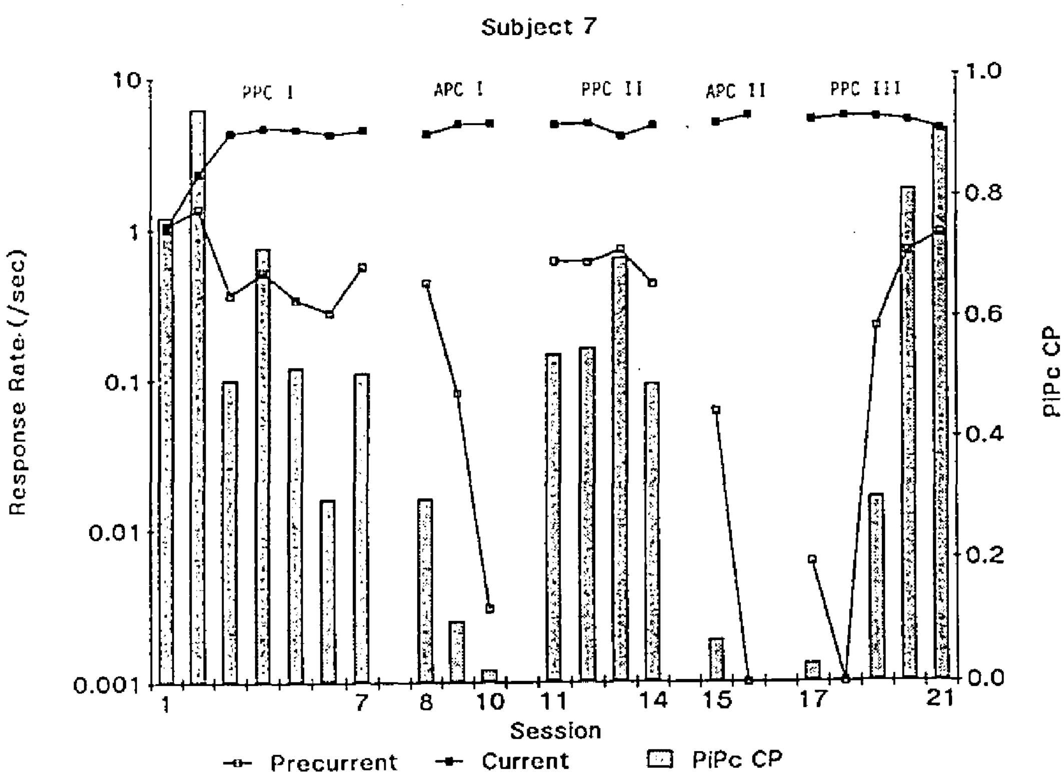


Figure 26. Precurrent and current responses rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC I, APC I, PPC II, APC II, and PPC III phases for S7.

Insert Figure 27 here

While precurrent responding was infrequent during the first 500 s of Session 7, a stable rate of precurrent responding comparable to previous PPC sessions occurred thereafter. When the precurrent contingency was removed in Session 8, this pattern is broken; long periods without precurrent responding are observed throughout the session and consequently considerably more current responses are emitted under Pn during these periods. Additional calculation reveals that in Session 7 only 6.2% (4/64) of current response runs were greater than 225 responses; in Session 8 this figure increased to 16.7% (8/45).

The top half of Figure 28 presents cumulative records for the second session of the APC I phase (Session 9), which reveals a further reduction in precurrent responding to near zero levels.

Insert Figure 28 here

Table 15 and Figure 26 show substantial reductions in precurrent responding and the PiPc CP across APC I sessions. Current responding occurred at its highest levels yet in Sessions 9 and 10. Table 16 reveals that S7 mentioned the change in reinforcer density during APC I

S7: Session 7

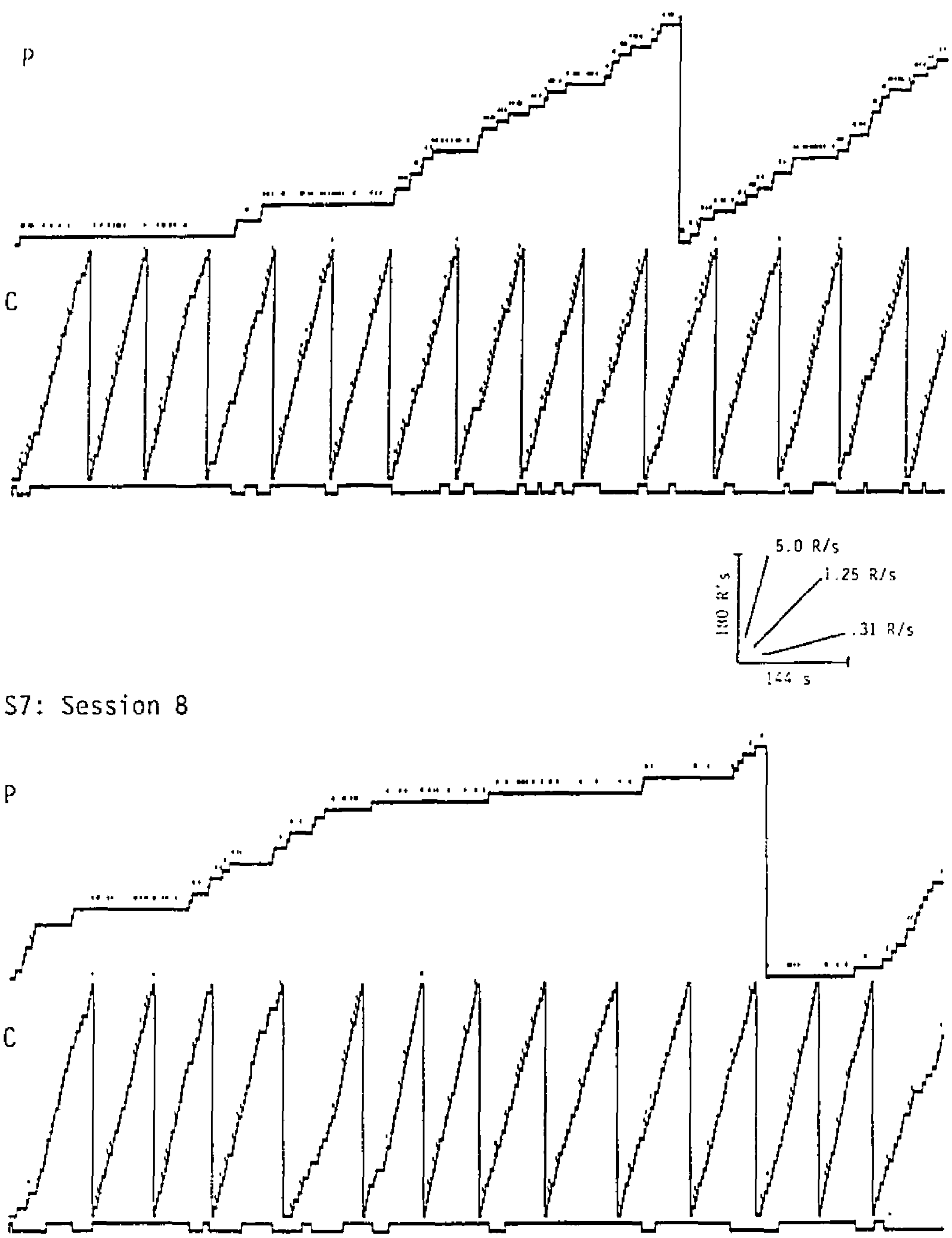


Figure 27. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 7 (top) and Session 8 (bottom).

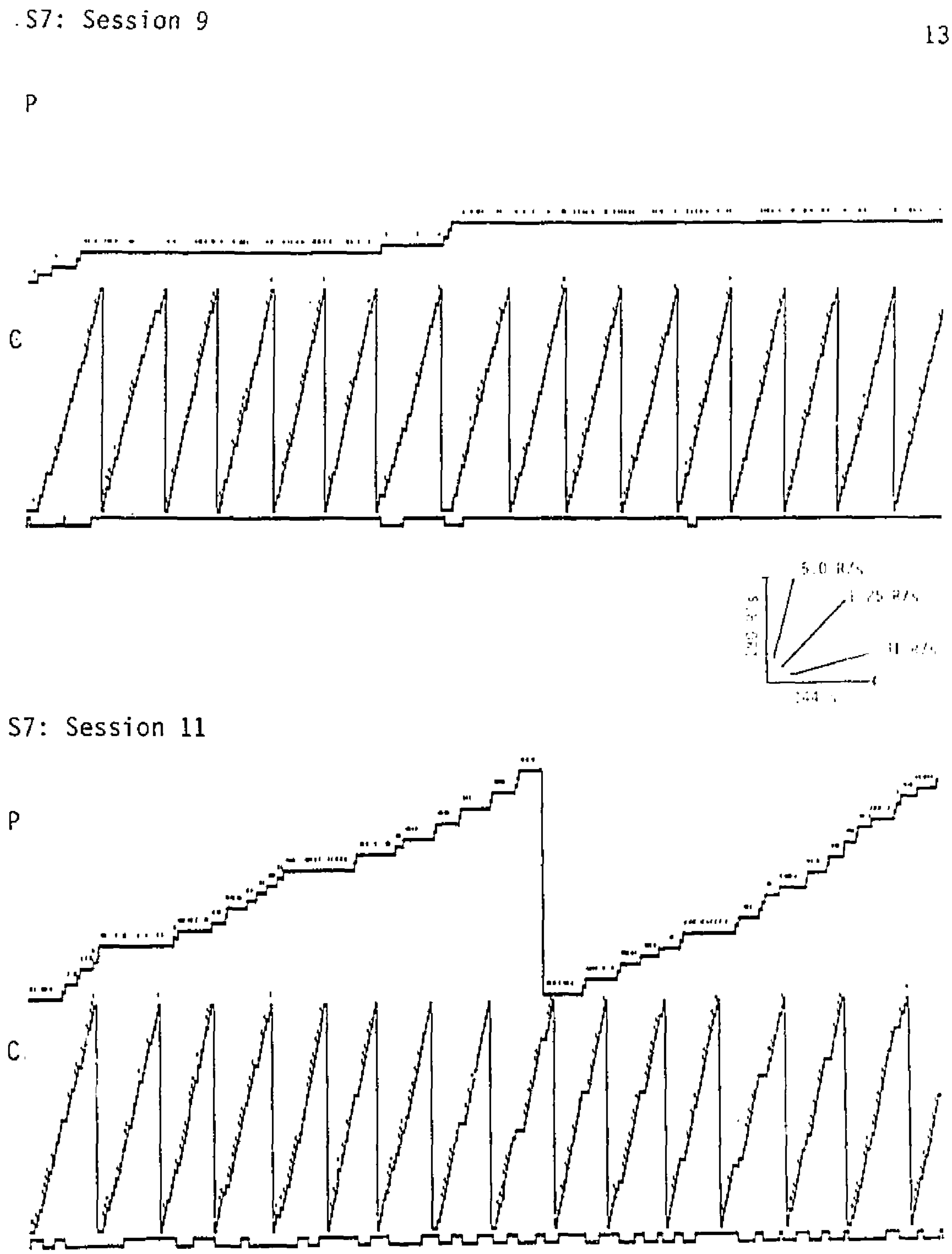


Figure 28. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 9 (top) and Session 11 (bottom).

sessions, but she did not speculate as to any changes in contingencies regarding pressing the precurrent button.

The PPC condition was reinstated for Sessions 11-14 (PPC II phase). The bottom half of Figure 28 presents the cumulative records for the first PPC II session (Session 11). Precurrent responding occurred early and maintained throughout the session at a rate comparable to PPC I sessions (cf., top half of Figure 27).

Table 15 shows that precurrent responding and the PiPc CP increased substantially during the first PPC II session and these elevated levels maintained throughout PPC II sessions comparable to PPC I sessions. Current responding declined during Session 13, but returned to a more characteristic rate during Session 14. Table 16 shows that in the PPC II phase, as in the PPC I phase, S7 identified periods ("chunks") of dense reinforcement but no mention is made of her (precurrent) behavior being responsible for these periods.

The APC condition was reinstated for Sessions 15-16 (APC II phase). Figure 29 presents the cumulative records for the last PPC II session (Session 14) and the first APC II session (Session 15).

Insert Figure 29 here

These records show that while precurrent responding

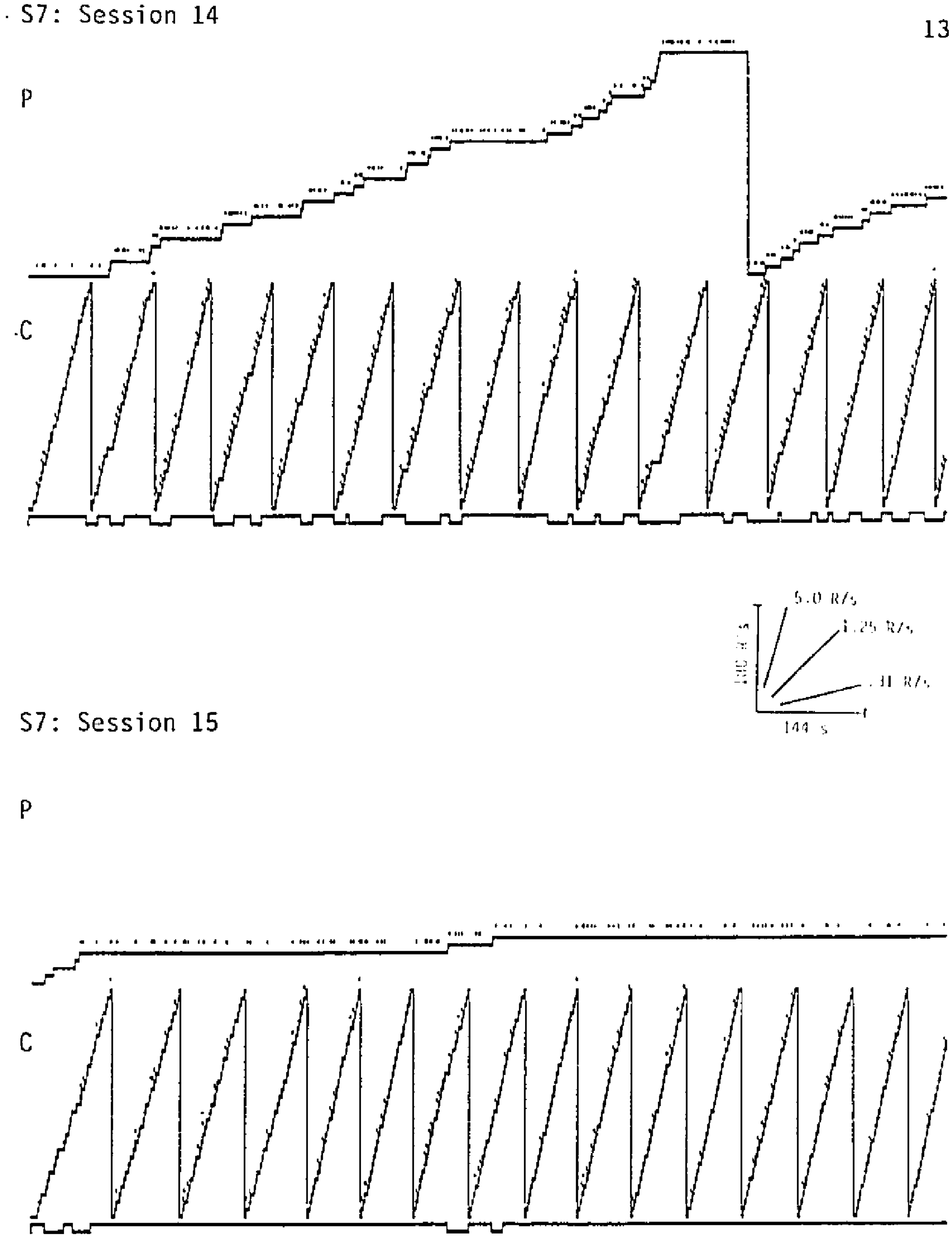


Figure 29. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 14 (top) and Session 15 (bottom).

maintained throughout Session 14, and continued into the very beginning of Session 15, very little precurrent responding was observed thereafter. Thus, precurrent responding extinguished more quickly during the first APC II session relative to the more gradual decline in precurrent responding across the first two sessions of the APC I phase (see bottom of Figure 27 and top of Figure 28).

Table 15 and Figure 26 reveal the dramatic effect of removing the precurrent contingency in Sessions 15-16: precurrent responding was rare during Session 15 and did not occur at all during Session 16. Current responding occurred at its highest level at any time during the experiment in Session 16. S7's comments in Table 16 note the change in reinforcement density, but no mention is made of precurrent responding despite the significant and rapid changes in this behavior across PPC II and APC II phases.

The PPC condition was introduced for a third time during Sessions 17-21 (PPC III phase). Only seven precurrent responses and two CO's occurred during Sessions 17-18 and thus contact with the precurrent contingency was infrequent. Figure 30 presents the cumulative records for Sessions 19 and 20.

Insert Figure 30 here

The top of Figure 30 shows that contact with the

S7: Session 19

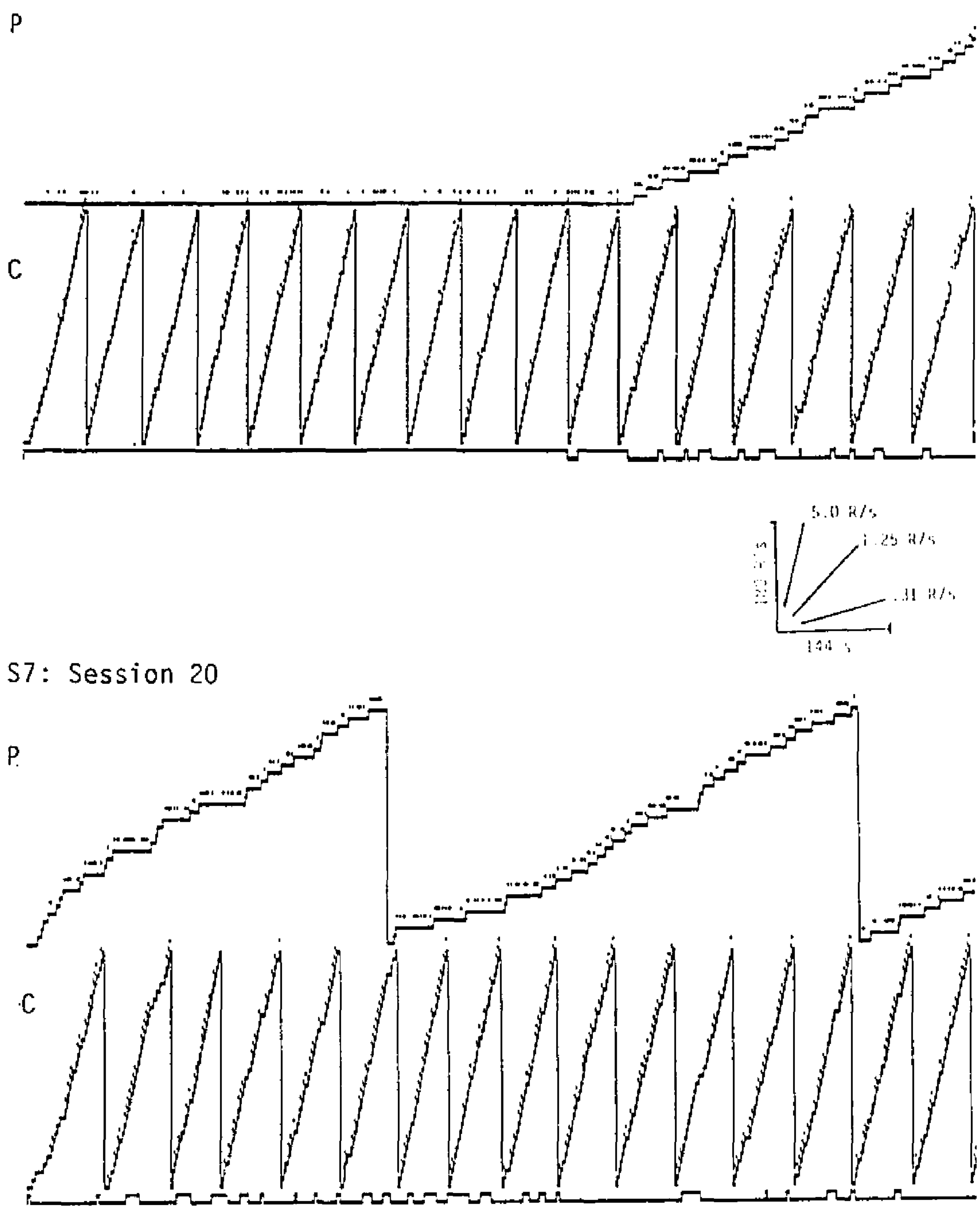


Figure 30. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 19 (top) and Session 20 (bottom).

precurrent contingency in Session 19 first occurred about 12 min into the session; then, current responding continued well past Dc (for over a minute into Pn); and finally the characteristic pattern of precurrent responding is seen for the remainder of the session, producing a large proportion of current responses emitted under PiPc (90% over the final 4 min) and a major increase in reinforcer density. Current responding remained unaffected. These changes continued into Session 20 (see bottom of Figure 30).

Table 15 and Figure 26 show that following Session 19, precurrent responding and the PiPc CP maintained at high levels for the remainder of the PPC III phase, increasing across Session 20-21. The number of reinforcers acquired in Sessions 20 and 21 were greater than in any prior session.

Table 16 reveals that S7 mentioned the precurrent contingency for the very first time in Session 19 and again in Session 20 (i.e., "it seemed to 'help' to press the other button for a brief period of time to get the computer to give more money"). However, in Session 21 she qualified her previous statements by suggesting that precurrent responding is "something to do while you not get any forthcoming reinforcement". No reference was made in Sessions 19-21 to the fact that she had ever contacted a similar contingency previously in the experiment.

S8. The top half of Figure 31 presents the cumulative records for the first session of exposure to the PPC condition (Session 1).

Insert Figure 31 here

Figure 31 shows that unlike S6 and S7, precurrent responding was infrequent from the beginning and progressively longer periods of time were spent, and thus progressively more current responses were emitted, under Pn. No precurrent responses occurred during the final 6 min of the session. Like both S6 and S7, a high stable rate of current responding developed.

Insert Tables 17 and 18 and Figure 32 here

Sessions 1-6 will be referred to as the PPC Ia phase. Table 17 and Figure 32 show that precurrent responding did not maintain across these sessions. CO's were infrequent. Current responding increased and then remained relatively stable across Sessions 3-6. S8's comments in PPC Ia sessions reveal a focus on the relationship between current responding and reinforcement (see Table 18). There was no comment about the precurrent response other than to exclude it from the reinforcement contingency (see Session 5).

Experiment 1D showed that the lack of reinforcement for current responding within 2 s of a CO can affect the

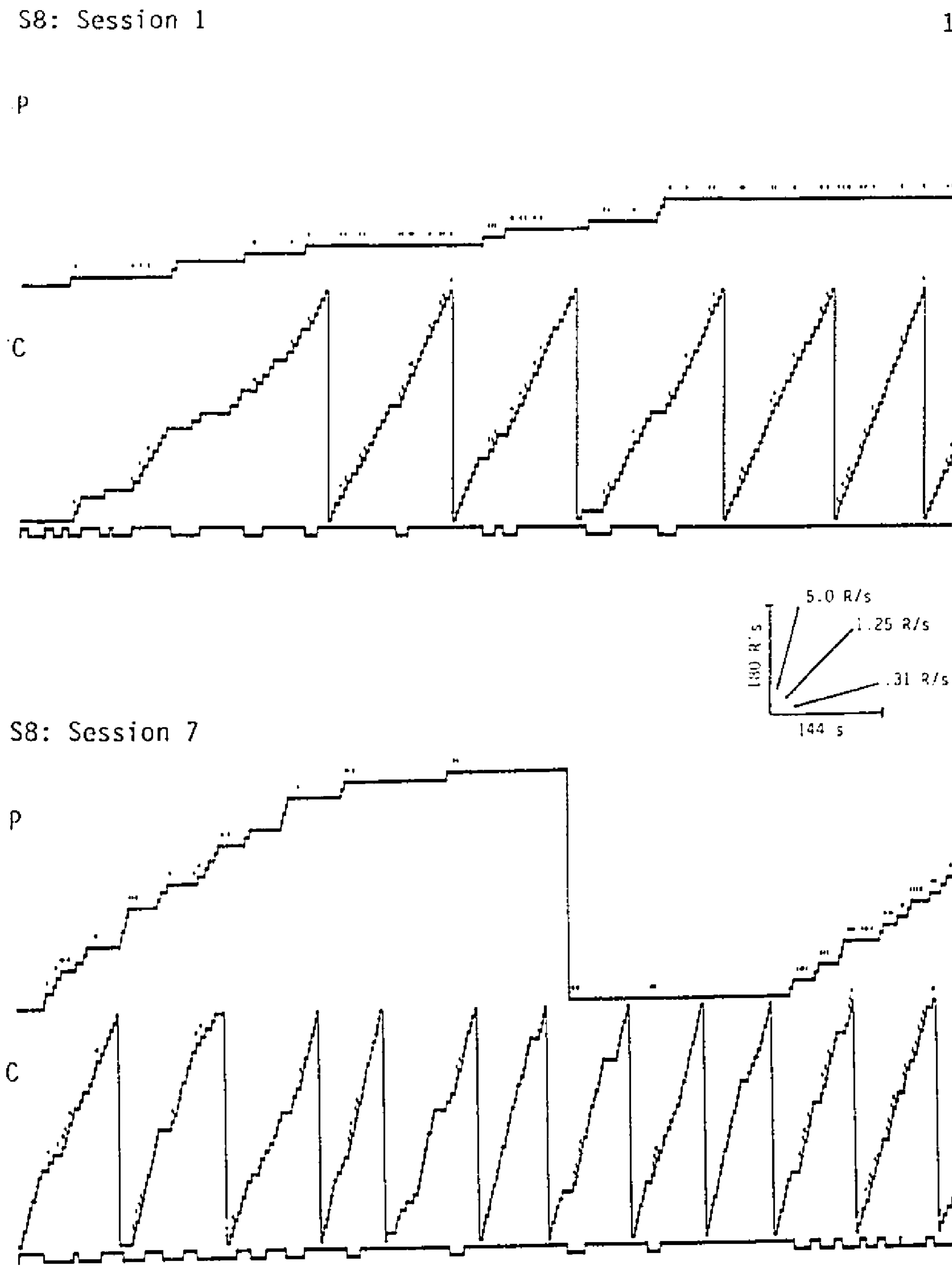


Figure 31. Cumulative records of precurrent (P) and current (C) responding for S8 during Session 1 (top) and Session 7 (bottom).

TABLE 17

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC, Booster, and APC Sessions for S8

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
PPC Ia (Pn=02; Pc=.08; Dc=15s)					
1	137	2334	.12	16	61
2	184	3854	.03	6	84
3	40	5317	.03	4	123
4	19	5544	.01	1	106
5	0	5826	.00	0	104
6	4	5469	.01	1	109
Conditioning (Pn=0; Pc=.08; Dc=15s)					
7	559	4147	.31	31	91
PPC Ib (Pn=02; Pc=.08; Dc=15s)					
8	819	4690	.46	34	259
9	872	4773	.62	58	279
10	827	5442	.60	45	317
11	649	5600	.50	41	306
12	593	5766	.44	34	260
APC I (Pn=02; Pc=.02; Dc=15s)					
13	441	6068	.31	28	130
14	112	5834	.07	6	109
15	51	5822	.04	4	109
PPC II (Pn=02; Pc=.08; Dc=15s)					
16	451	5341	.36	28	235
17	545	5487	.44	36	255
18	564	5357	.45	34	260
19	520	5516	.42	34	251

TABLE 18

Post-session Verbal Reports Across PPC, Booster, and APC Sessions for S8

SESSION	COMMENTS
PPC Ia (Pn=02; Pc=.08; Dc=15s)	
1	I really haven't a clue, but it seemed that I could only get money on the screen by pressing the right side button. But it didn't matter how many times I pressed it. Sometimes 3 sometimes 100!
2	I still don't know, some sort of VR schedule for me pressing the right hand button so many times. Not as many times as before though.
3	I didn't think I was doing anything different than the other 2 sessions, still pressing the right hand button, perhaps a bit faster. I must be doing something right, for I'm getting reinforced more often!
4	Something wasn't as good as before, although I don't know what it was...I did exactly the same thing, but it didn't go up as much or as fast. This is frustrating--maybe I have to respond faster or something.
5	It now seems that when I press the right hand button (not the left) at at a certain speed (either fast or slow) for the same pace for a number of presses, then I get money. It doesn't seem to matter if it's fast or slow, only that it's the same speed for a period of time.
6	I guess it doesn't matter what speed I press the buttons. I don't know what I'm doing to make it go higher, but it does the more I concentrate on getting the button pressing fast and at the same speed.
Conditioning (Pn=0; Pc=.08; Dc=15s)	
7	At the beginning, it would give me money 2 or 3 times in a row and then not again for about a minute (I was always pressing the right hand button) then later on, I would press the left button a few times and then the right button and would get more money that way...by going back and forth, but I would never get money for pressing the left button, only when I returned to the right.

TABLE 18 (continued)

SESSION	COMMENTS
PPC Ib (Pn=02; Pc=.08; Dc=15s)	
8	Whatever I did, I must have done it right! I kept pressing the right button until it seemed to stop giving money, then I pressed the left for a little while, then when I'd go back to the right, I'd get money. It was pretty steady the whole time--it didn't seem to matter how fast I would press the buttons.
9	As before, I would keep pressing the right hand button until I stopped getting money; then I'd press the left hand button for a few times, then go back to the right hand button and I'd get money then. Sometimes I think it depends on where I was pressing the right hand button, at the top or at the bottom. It seemed pretty steady.
10	It went quite slowly at the beginning, but got faster at the end. I didn't have to push the left button quite so much this time, but I had to alternate between the top and the bottom of the right button. The faster I pushed it, the more money I got at the end.
11	About every 5 responses (only on the right hand button) got money, sometimes after 2, sometimes after 10. If it took more than about 20 times, I'd press the left button and then go back to the right. Right away (or 5 times later), I'd get money.
12	The money at the beginning of the session came very slowly. This was especially frustrating because I thought I was doing everything the same as before...I couldn't figure out what I was doing wrong. After a while it started to be the same though (about every 5 times) although I didn't have to push the left hand button as much.
APC I (Pn=02; Pc=.02; Dc=15s)	
13	I had no idea what I was doing to earn money. Everything I had tried before didn't seem to work, or was irregular. It didn't matter if I pressed the left button; or the top, or bottom of the right button; how hard I pressed, etc. Once in a while I'd get money for doing one of these things, but it was never regular. I'm not sure exactly what I did to get the money I got!

TABLE 18 (continued)

SESSION	COMMENTS
14	This reminds me of the very first few sessions when it (the money) just seemed to be delivered variably to the number of times I'd push the right hand button. I just kept pushing it, and occasionally I'd get reinforced. (Although at the very <u>end</u>, if I didn't push the button down all the way, I got more money).
15	It seemed longer than 20 minutes today, but I guess that's just because I didn't earn very much money. The method that worked best for me was to press the top of the right-hand button, but not depress it all the way. It made no difference how fast I'd press it.
<u>PPC II</u> (<u>Pn</u>=02; <u>Pc</u>=.08; <u>Dc</u>=15s)	
16	I guess I did something right that time. I went back to what I did before (pressing the left-hand button, then switching to the right) and it seemed to have an effect on giving more money. I didn't press the right-hand button in any particular way, just <u>after</u> the left hand button.
17	I kept pressing the right button (rather quickly) and when it stopped giving money (usually they came in 5's), I'd press the left button and go back to the right. It would always be fairly steady until just before a quarter way, and then it would stop (i.e., .245 it would take forever to get to .250; or .995 to 1.000; .745 -> .750 etc.)
18	I did the same thing as last time (push the right, then left, then right again) only I didn't push the buttons as fast (so I thought). This time the money came slowly, then a really fast period happened, then back to slow, back to fast. I tried to duplicate what I was doing during the periods where I got a lot of money fast, but I didn't know what it was I did!
19	The money seemed to come in clusters, (2 or 3 at a time), or fairly steady (1 every 5 clicks or so), or not at all. It would give money in a bunch, wait 10 seconds, perhaps another little bunch, wait, and then steady for about 5 or six 1/2 pennies. All of this didn't seem to depend on anything except that I pressed the right button. (neither fast or slow, or if I had pressed the left button first)

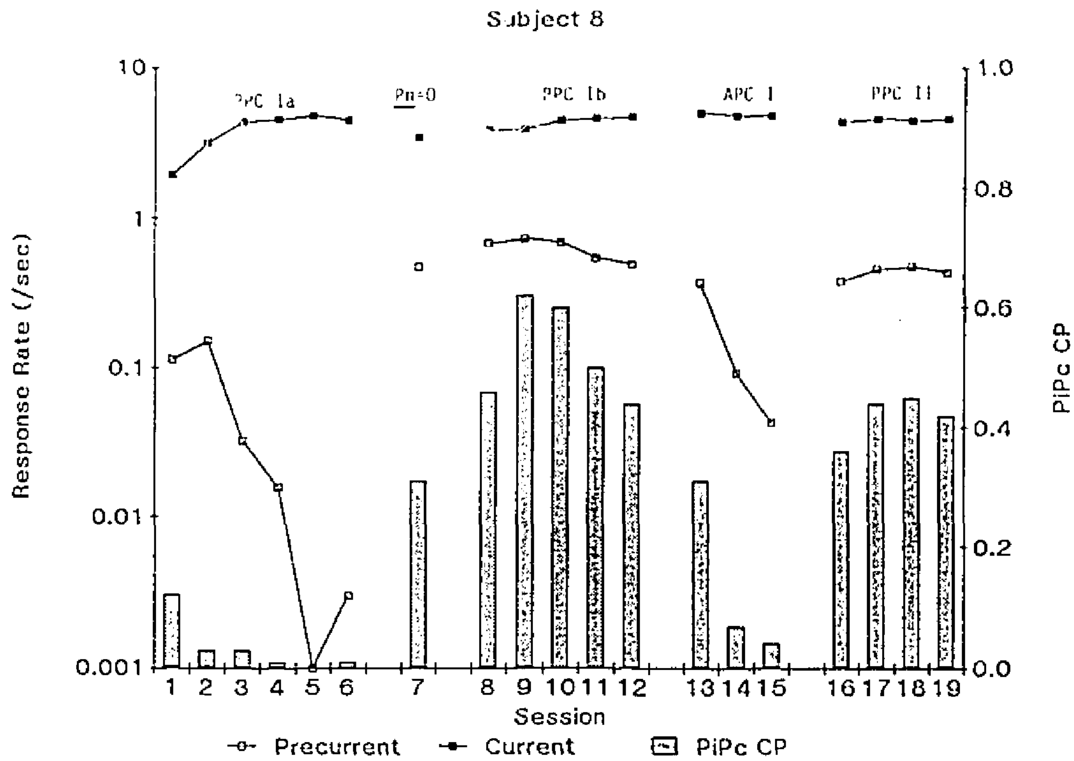


Figure 32. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC Ia, Pn=0, PPC Ib, APC I, and PPC II phases for S8.

maintenance of precurrent responding under the PPC condition. A fine-grained analysis of current responses emitted within 2 s of a CO revealed: in Session 1, 15 current responses occurred, only one of which was reinforced; in Session 2, 13 current responses occurred, none of which were reinforced; and in Session 3, 16 current responses occurred, again none of which were reinforced. Overall, when current responding did occur within 2 s of a CO in Sessions 1-3, the obtained reinforcement probability was only .023.

In Session 7 (a "Conditioning" session), Pn was reduced to zero. Thus, current responding could not be reinforced unless a precurrent response had occurred at least once within the past 15 s. The bottom of Figure 31 presents the cumulative records for this session. It can be seen that precurrent responding occurred early in the session, as did current responding and reinforcement, but then some long periods of time without precurrent responding are observed and thus reinforcement was infrequent. Then, during the final 3.5 min precurrent responding increased, there were no long periods without precurrent responding, and reinforcement became more frequent and constant. Slight pauses in current responding are observed throughout the session, notably when bursts of precurrent responses were emitted.

Table 17 and Figure 32 show the enhanced levels of precurrent responding and the PiPc CP in Session 7. Relative to the previous four sessions, current responding was less frequent, and despite the increase in the PiPc CP, fewer reinforcers were obtained. Table 18 reveals that S8's comments about the contingency in Session 7 were fairly accurate. It is interesting to note that she mentions that she received reinforcement for current responding at the beginning of the session in the absence of any prior precurrent responding, which of course was an impossibility.

The original PPC parameters were returned in Sessions 8-12 (PPC Ib phase). Table 17 and Figure 32 show that precurrent responding and the PiPc CP maintained at relatively high levels throughout these sessions. Current responding increased across PPC Ib sessions to levels comparable to those observed over the final four sessions of the PPC Ia phase. For each PPC Ib session in Table 18, S8's descriptions are consistent with the precurrent contingency.

The APC condition was scheduled for Sessions 13-15 (APC I phase). Figure 33 presents the cumulative records for the last PPC Ib session (Session 12) and the subsequent first session of the APC I phase (Session 13).

Insert Figure 33 here

S8: Session 12

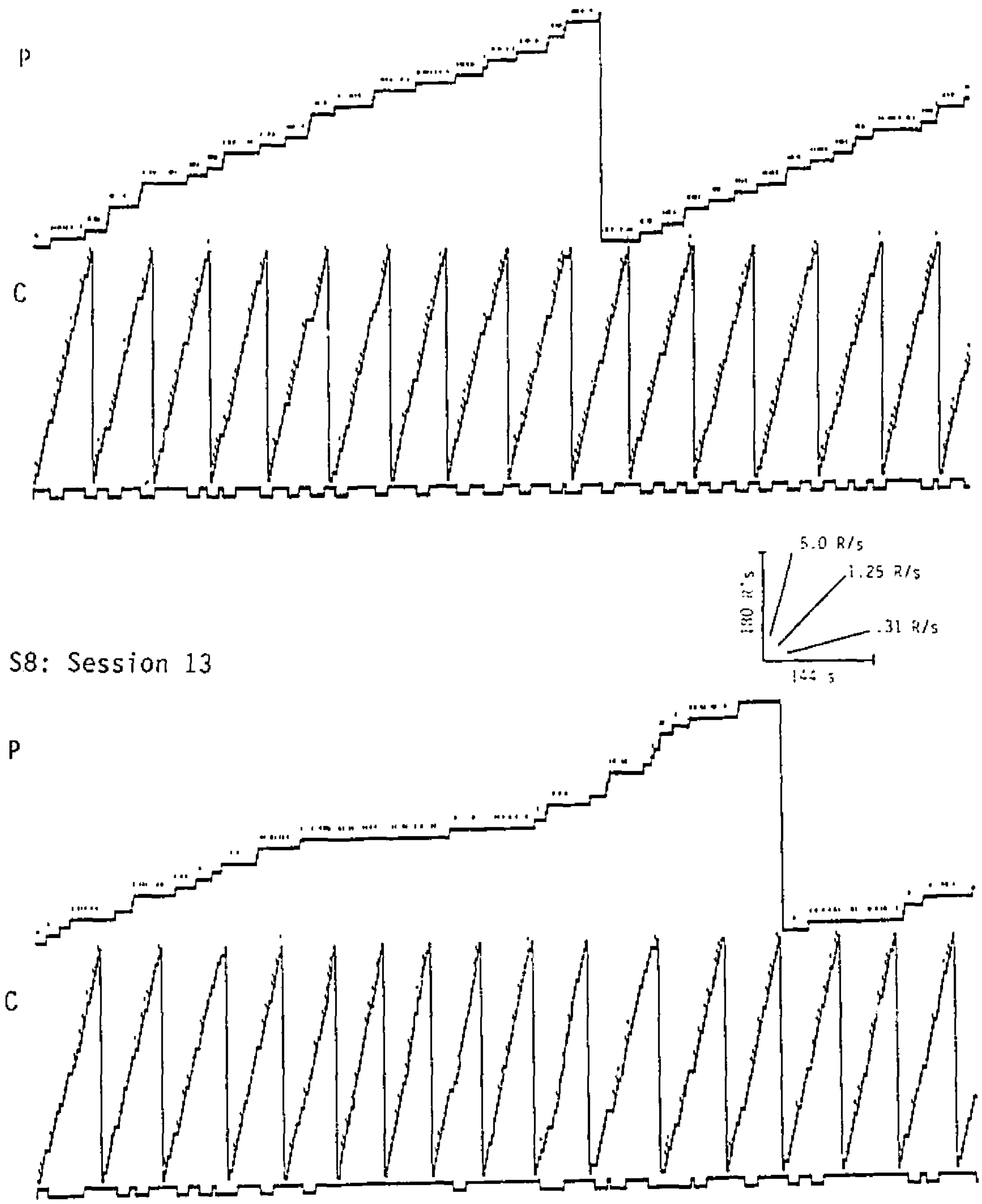


Figure 33. Cumulative records of precurrent (P) and current (C) responding for S8 during Session 12 (top) and Session 13 (bottom).

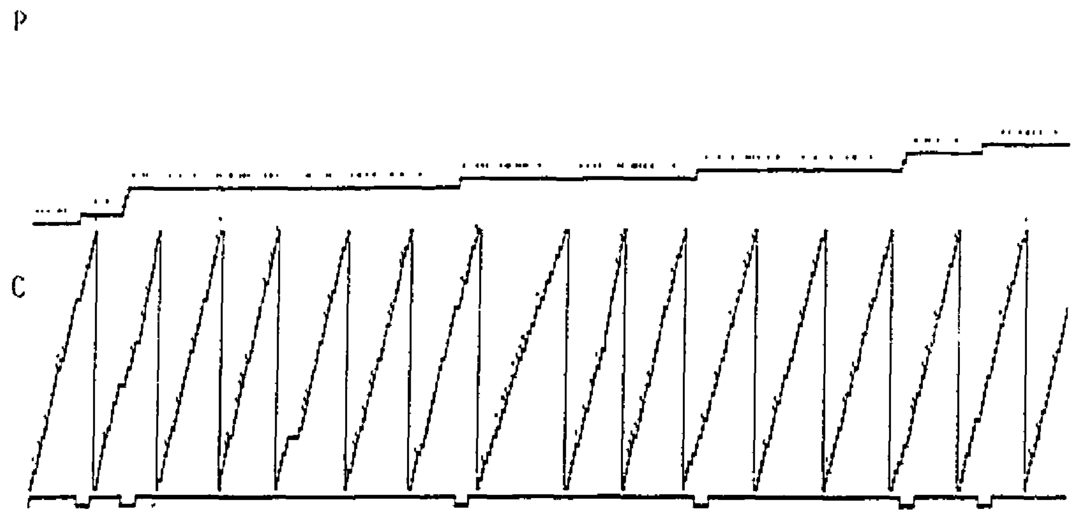
Figure 33 indicates that pauses between precurrent response bursts were relatively constant throughout Session 12; with the removal of the precurrent contingency in Session 13, the gradient of precurrent responding is less consistent, long periods of time without precurrent responding are observed (that were not seen in any PPC Ib session), and many more current responses were emitted under Pn. Additional calculation reveals that in Session 12, 22.9% (8/35) current response runs were greater than 225 responses; in Session 13, this figure increased to 37.9% (11/29). The top of Figure 34 presents the cumulative records for the next APC session (Session 14), in which the relative infrequency of precurrent responding is clearly evident.

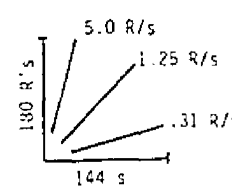
Insert Figure 34 here

Table 17 and Figure 32 show a decline in precurrent responding and the PiPc CP across APC I sessions. S8's comments in Table 18 for APC I sessions indicate an accurate description of the change in contingencies. She states in Session 13, e.g., that everything she tried in earlier sessions, including pressing the precurrent button, no longer lead to "regular" reinforcement.

The precurrent contingency was reintroduced in Sessions 16-19 (PPC II phase). The bottom half of Figure 34

S8: Session 14





S8: Session 16

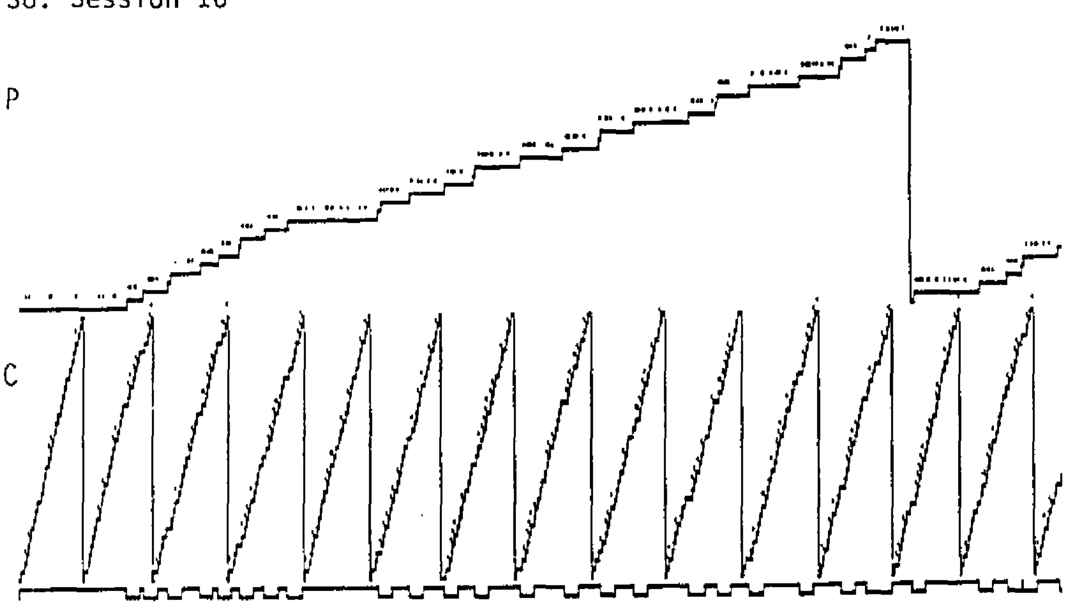


Figure 34. Cumulative records of precurrent (P) and current (C) responding for S8 during Session 14 (top) and Session 16 (bottom).

presents the cumulative records for Session 16. This figure shows that precurrent responses did not occur at the very beginning of the session, but then were emitted consistently in a pattern similar to the last session of the PPC Ib phase (see top half of Figure 33). Table 17 and Figure 32 show that under the PPC II phase precurrent responding and the PiPc CP returned to levels comparable to the PPC Ib phase. Current responding decreased slightly from the prior APC I phase.

S8's comments for PPC II sessions were similar to her verbal behavior in the prior PPC condition (PPC Ib phase), again indicating an accurate description of the precurrent contingency (see Table 18). However, in Session 19, with the contingencies exactly the same as in the previous three PPC II sessions, she notes that pattern of reinforcement "didn't seem to depend on anything except that I pressed the right [current] button (neither fast nor slow, or if I had pressed the left [precurrent] button first" (emphasis mine). Figure 35 presents the cumulative records for this session.

Insert Figure 35 here

The cumulative record for Session 19 looks remarkably similar to that for Session 16 (see bottom of Figure 34) both of which are representative of PPC II responding.

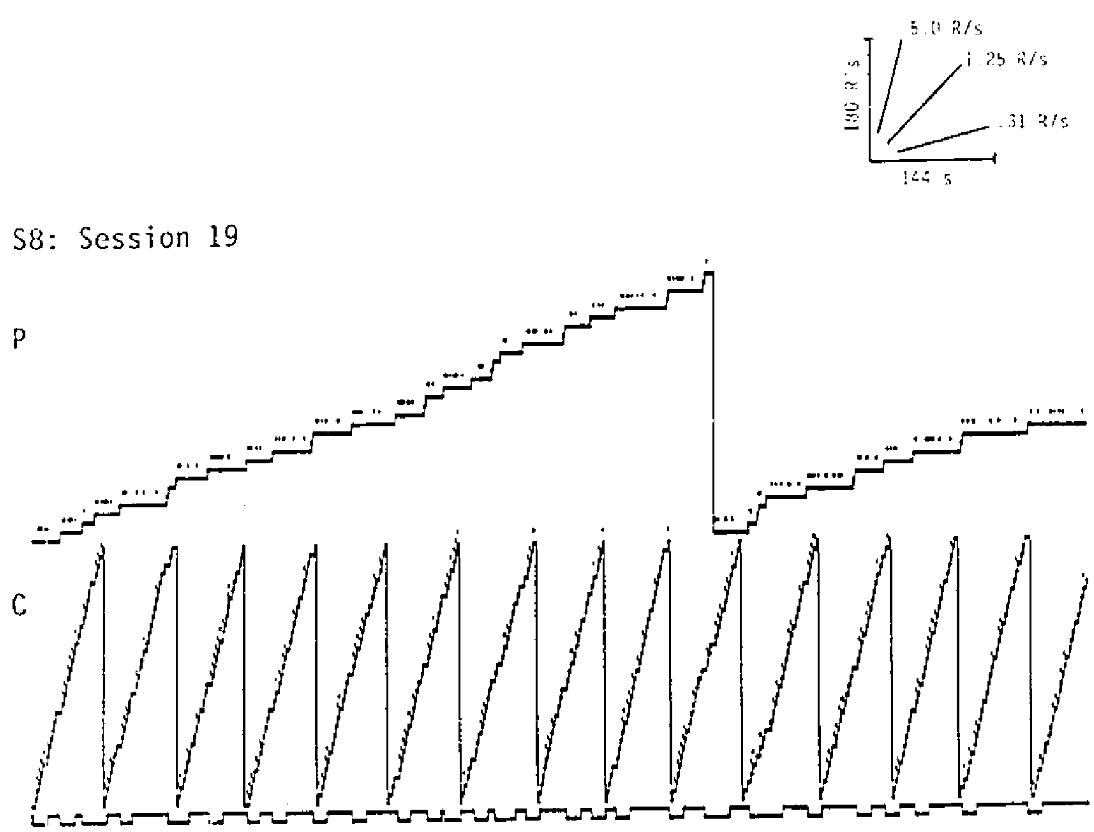


Figure 35. Cumulative records of precurrent (P) and current (C) responding for S8 during Session 19.

Thus, a change in precurrent responding did not accompany a change from an accurate to an inaccurate description of the precurrent contingency.

Discussion

High levels of precurrent responding and the PiPc CP maintained for the three subjects in Experiment 2B when precurrent responding functioned to increase the reinforcement probability for current responding from .02 to .08 for 15 s. When the precurrent contingency was removed for S7 and S8, these levels were significantly reduced. Reintroducing the precurrent contingency enhanced precurrent responding and the PiPc CP once again for these two subjects, and, for S7, a subsequent removal and reintroduction of the precurrent contingency produced a decrease and then increase for these measures, respectively. These between- and within-subject replications suggest that the precurrent contingency was responsible for the high levels of precurrent responding and the PiPc CP.

The data for S6 also suggest that high levels of precurrent responding and the PiPc CP maintained due to the precurrent contingency. Consider the data of S1, S2, S4, and S5. When precurrent responding had no scheduled effect in the initial condition for these subjects, its rate fell quickly to near zero within Session 1 and near zero rates were observed across all subsequent APC sessions. In marked contrast, with the precurrent contingency in effect for S6, high levels of precurrent responding (and the PiPc CP) maintained throughout Session 1 and across the three subsequent PPC sessions. Although slight reductions were observed in these measures across PPC sessions for S6, no within-session decrease was evident during the final PPC session.

Unlike S6 and S7, precurrent responding did not maintain during the initial PPC condition for S8. It is interesting to note from Table 17 that in Session 1 precurrent responding was less frequent and the number of CO's were far fewer than for any other subject in Experiments 1 and 2 (excluding S3 whose initial five minutes of data are unavailable), including subjects run under the APC condition during Session 1, i.e., S1, S2, S4, and S5. S8's deviant tendency for low rate precurrent responding (and CO's) even at the start of the experiment resulted in very few contacts with the precurrent contingency in Session 1 as well as all subsequent PPC Ia sessions. Furthermore, as already noted, these infrequent contacts resulted in practically no immediate payoff: in the first three sessions the reinforcement probability for the 44 current responses that occurred within 2 s of a precurrent response was only .023, a negligible increase from the Pn value of .02. In Experiment 1B, precurrent responding did not maintain under a similar Delay condition for S3; and, in Experiment 1D it was shown that reinforcement for current responding in a 2-s period following a precurrent response can play an important role in the maintenance of precurrent responding. Perhaps insufficient contact with the precurrent contingency and/or lack of immediate reinforcement for current responding following a precurrent response disrupted the development of the precurrent operant in the PPC Ia phase for S8.

Reducing Pn to zero for one session enhanced precurrent responding and the PiPc CP for S8 and these enhanced levels maintained despite returning Pn to .02. This result differs from S3 in Experiment 1B for whom it was found that precurrent responding returned to near zero levels when Pn was raised from zero to .01.

As observed in Experiment 1B, the PiPc CP, the efficiency measure, did not improve across successive PPC sessions and did not approach optimal levels (i.e., 100%) for the three subjects in Experiment 2B--for an exception see Sessions 20-21 for S7. In fact, for S6, the PiPc CP levels were lower during later PPC sessions. It is interesting to note that for S8 this measure was consistently below 50% during the PPC II phase even though she gave descriptions that closely approximated the precurrent contingency in three out of the four sessions.

The verbal behavior of the three subjects suggests that subjects could accurately describe the precurrent contingency. However, it appears that such descriptions are not necessary for the precurrent contingency to control precurrent responding. For example, S7 did not mention the precurrent contingency until Session 19; prior to that time an ABAB sequence of PPC and APC conditions provided strong evidence that precurrent responding was maintained due to the precurrent contingency. Furthermore, the verbal behavior of all three subjects changed at various points under the PPC condition away from an accurate description of the precurrent contingency with no accompanying change in precurrent responding.

EXPERIMENT 2C

The purpose of Experiment 2C was to further examine the effects of imposing a 2-s COD onto a precurrent contingency that maintains precurrent responding. As stated in Experiment 1D, this manipulation allows for an assessment of the degree to which maintenance is due to reinforcers closely following (i.e., within 2 s of) a precurrent response.

Under the PPC condition, the probability of reinforcement for current responding within 15 s of a precurrent response (*Di* plus *Dc*, where *Di* = 0 and *Dc* = 15 s) is .08 (*Pc*). In a COD condition, *Di* is set at the value of the COD and *Pi* equals zero. If the value of *Di* plus *Dc* is equated across the PPC and COD conditions, then in the COD condition the *Dc* value must be reduced to the same degree that the *Di* value is increased. Thus, with a 2-s COD, *Di* and *Dc* are set at 2 s and 13 s, respectively. To equate the probability of reinforcement under *Di* plus *Dc* (i.e., within 15 s of a precurrent response) across the two conditions, *Pc* must be set at a higher value in the COD condition to compensate for the unavailability of reinforcement under *Di* (i.e., within 2 s of a precurrent response). This was the COD procedure implemented for S7.

Another way to impose the COD entails keeping the *Dc* and *Pc* values constant across the PPC and COD conditions while raising *Di* from zero to the COD value. This was the

COD procedure implemented for S8. Using this method produces a problem with comparing the PiPc CP between the PPC and COD conditions, however, because the value of Di plus Dc is unequal under the two conditions. With a 2-s COD and Dc set at 15 s, the period of time that a precurrent response affects the current response reinforcement probability would be 17 s under the 2-s COD condition relative to 15 s under the PPC condition. For consistency of analysis between S8 and other subjects exposed to a COD, the proportion of current responses emitted within 15 s (15-s CP) and 2 s (2-s CP) of a precurrent response was calculated for S8 even though the value of Di plus Dc was greater than 15 s and Di did not always equal 2 s under the various COD phases.

Subjects

The two subjects were S7 and S8 from Experiment 2B. Experiment 2B provided strong evidence that precurrent responding was being maintained by the precurrent contingency for both of these subjects.

Procedure and Results

All conditions were identical to Experiments 2A and 2B except for the changes in parameters outlined in Tables 19 and 21 and described below.

S7. Following the PPC III phase (Sessions 17-21), in Sessions 22-25, a 2-s COD was imposed onto the precurrent contingency such that the probability of reinforcement for current responding within 2 s (Di) of a precurrent response was zero (Pi) and then was raised to .09 (Pc) for 13 s (Dc); these sessions will be referred to as the 2-s COD phase. The COD was removed during Sessions 26-28 (PPC IV phase).

Insert Tables 19 and 20 and Figure 36 here

Table 19 and Figure 36 reveal that the COD produced no effect on the precurrent response rate. However, the extremely high levels of the PiPc CP observed during the final two PPC III sessions (Sessions 20-21), dropped with the introduction of the COD and continued to do so across all subsequent 2-s COD sessions. This trend, however, was reversed with the removal of the COD. A different trend is observed for Pi CP and CO's: both declined across the PPC III and the 2-s COD phases but there was little if any reversal with the removal of the COD.

An effect of the COD can be seen by examining the cumulative records for the last session of the PPC III phase (Session 21), the 2-s COD phase (Session 25), and the PPC IV phase (Session 28), as presented below in Figures 37 and 38.

TABLE 19

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across PPC and COD Sessions for S7

SESSION	PRECURRENT	CURRENT	PiPc CP[a]	CO's	SR's
PPC III (Pn=02; Pc=.08; Dc=15s)					
17	7	6142	.03(.00)	2	132
18	0	6344	.00(.00)	0	121
19	260	6336	.30(.07)	46	225
20	817	5998	.81(.21)	135	402
21	1066	5241	.91(.31)	193	381
2-S COD (Pn=.02; Pi=0; Pc=.09; Di=2s; Dc=13s)					
22	998	5572	.77(.18)	111	334
23	654	6283	.66(.12)	70	362
24	651	6326	.62(.10)	59	371
25	765	6055	.60(.12)	67	327
PPC IV (Pn=02; Pc=.08; Dc=15s)					
26	894	5741	.70(.13)	74	355
27	635	6036	.77(.13)	76	391
28	771	5838	.78(.14)	76	361

[a]Number in parentheses under 2-s COD phase indicates Pi CP; for comparison purposes, number in parentheses under other phases indicates the proportion of current responses emitted within 2 s of a precurrent response.

TABLE 20

Post-session Verbal Reports Across PPC and COD Sessions for S7

SESSION	COMMENTS
PPC III (Pn=02; Pc=.08; Dc=15s)	
17	Same as previous session? I'm not really sure.
18	I can't figure out when the money will be given so I just try to press the button at a steady(?) and unstopping rate, so as to "cover" all chances of getting money.
19	When money was not quickly forthcoming, it seemed to "help" to press the other button for a brief amount of time to get the computer to give more money.
20	Money seemed to come in bursts again, but just as in Session 19, pressing the other button seemed to help in getting the computer to give more money.
21	Reinforcement seems aided by pressing the other button, however it may be that pressing the other button is really another way of marking time. Like, it's something to do while you not get any forthcoming reinforcement.
2-S COD (Pn=.02; Pi=0; Pc=.09; Di=2s; Dc=13s)	
22	Same as #21.
23	Same as previous session.
24	Once again, same as before.
25	I think pressing the "other" button is definitely a way of marking time (or biding your time) until the next reinforcement would possibly be available.
PPC IV (Pn=02; Pc=.08; Dc=15s)	
26	Same as 25.
27	I'd be inclined to say that this one was like the last 5 or 6 sessions. Although I must admit that my attention was not 100% fixed on the computer.
28	Same. All of these sessions I've been wondering or trying to figure out what the schedule of reinforcement was. I just don't know.

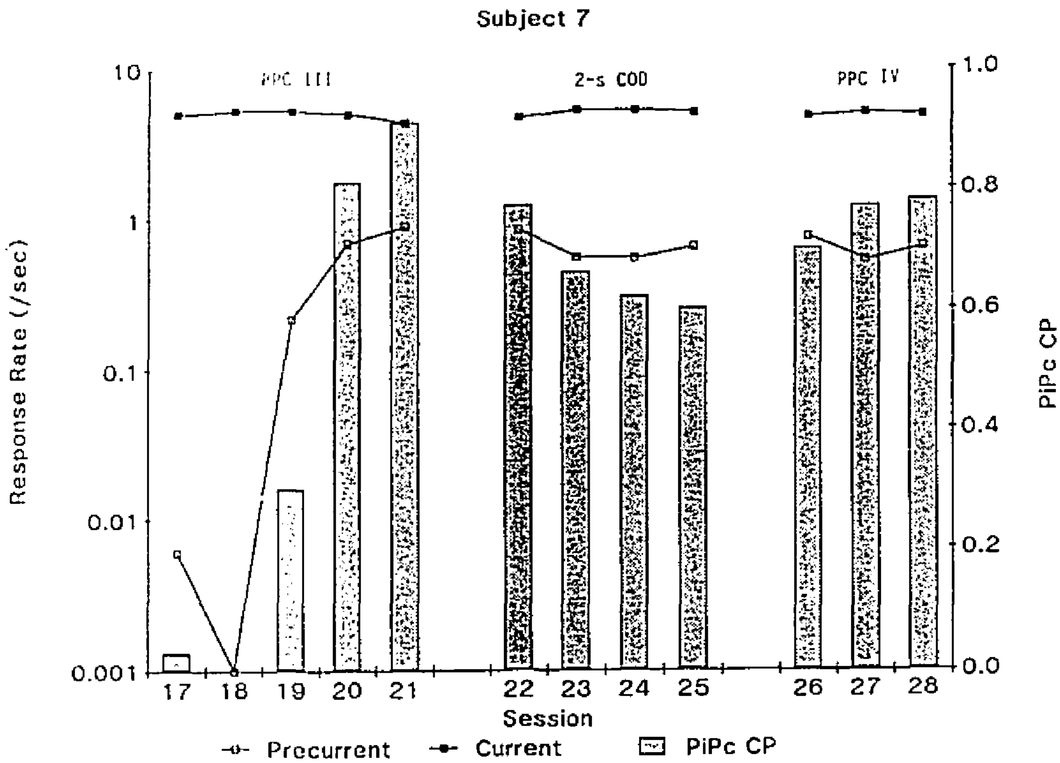


Figure 36. Precurrent and current responses rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC III, 2-s COD, and PPC IV phases for S7.

Insert Figures 37 and 38

In Session 21, precurrent responding occurred at a sufficiently high rate that almost all current responses were emitted under PiPc; in Session 25, the rate is less constant and some long pauses are noted, producing extended periods of time of current responding under Pn; in Session 28, precurrent responding once again occurred at a sufficiently high rate that almost all current responses were emitted under PiPc. Additional calculation is consistent with these observations: in the Session 21, only 1% (2/193) of current response runs were greater than 175 responses; in Session 25, this figure increased to 13.4% (8/60); and in Session 28, this figure decreased to 3.9% (3/76). Thus, long current response runs (and thus long periods without precurrent responding) were more likely during the final 2-s COD session than during the final session of either the PPC III or the PPC IV phase.

Table 20 shows that S7 described the contingencies in Session 21 (last PPC III session), Sessions 22-25 (2-s COD), and Sessions 26-28 (PPC IV), as all the same.

S8. Following the PPC II phase (Sessions 16-19), in Sessions 20-23, a 2-s COD was imposed onto the precurrent contingency such that the probability of reinforcement for current responding within 2 s (Di) of a precurrent response

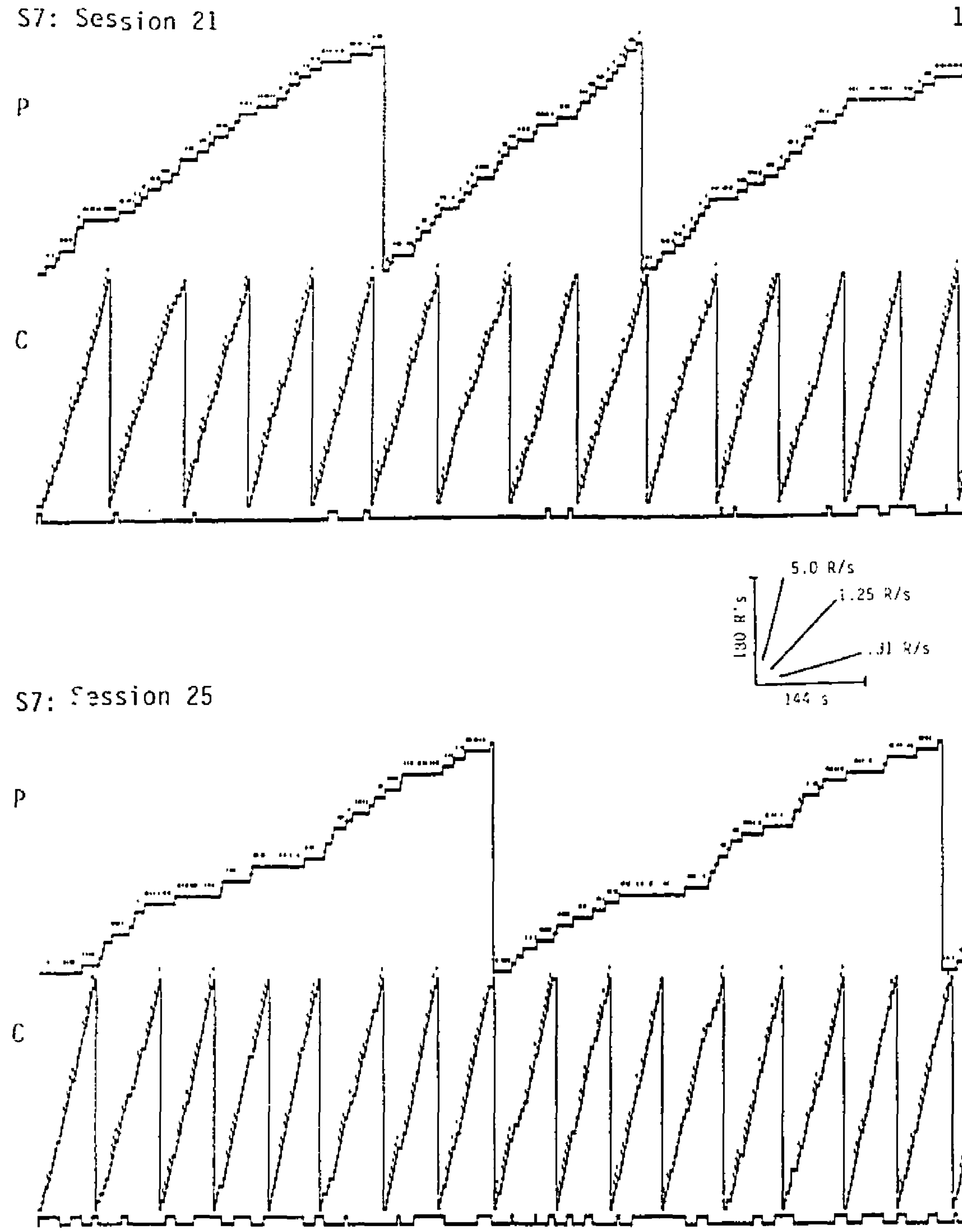


Figure 37. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 21 (top) and Session 25 (bottom).

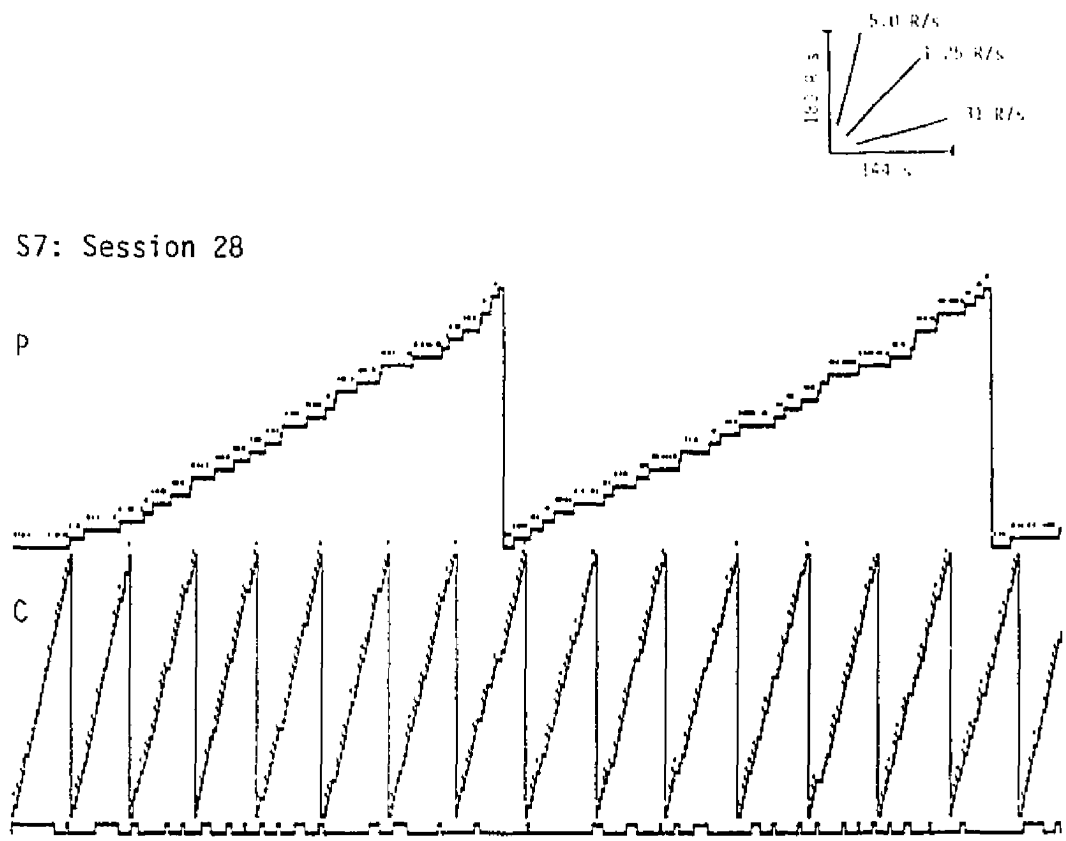


Figure 38. Cumulative records of precurrent (P) and current (C) responding for S7 during Session 28.

was zero (Pi) and then was raised to .08 (Pc) for 15 s (Dc); these sessions will be referred to as the 2-s COD I phase. The COD was subsequently removed during Sessions 24-26 (PPC III phase).

The top of Figure 39 presents the cumulative records for the first 2-s COD I session (Session 20) and will be compared to the record for the last PPC II session (Session 19; see Figure 35).

Insert Figure 39 here

Precurrent responding maintained across both sessions, but in Session 20 there were extended periods during which no precurrent responses occurred and consequently more current responses were emitted under Pn. (These figures are deceiving in a conservative way: 17 s of change from Pn was produced by a precurrent response in Session 20 relative to 15 s of change in Session 19). Additional calculation reveals that in Session 19, 23.5% (8/34) of current response runs were greater than 225 responses; in Session 20, this figure increased to 65% (13/20).

Insert Tables 21 and 22 and Figure 40 here

Table 21 and Figure 40 reveal that (1) precurrent responding and the 15-s CP were significantly reduced under

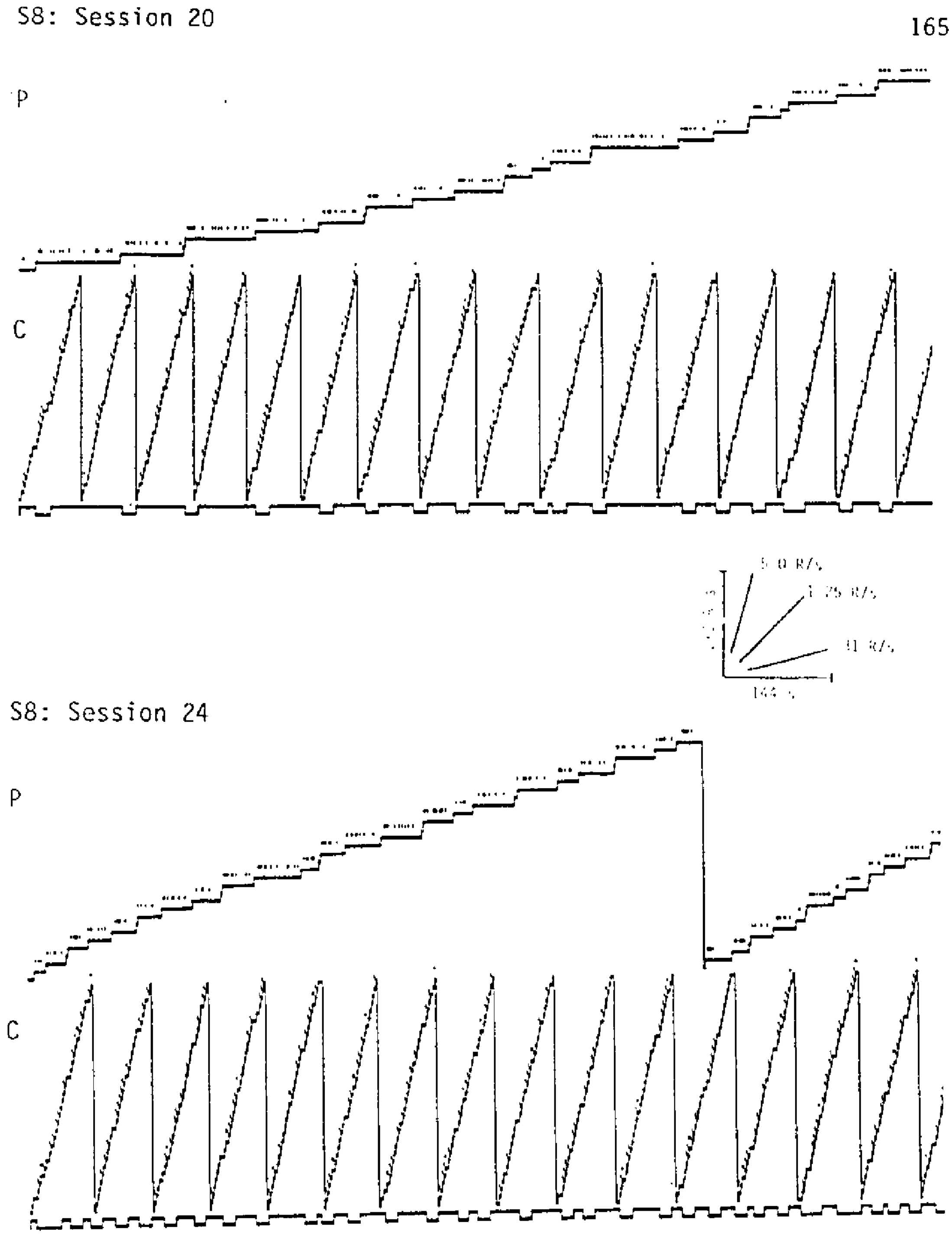


Figure 39. Cumulative records of precurrent (P) and current (C) responding for S8 during Session 20 (top) and Session 24 (bottom).

TABLE 21

Precurrent and Current Responses, 15-s and 2-s CP's, Changeovers (CO's), and Reinforcers (SR's) Across PPC, COD, and APC Sessions for S8

SESSION	PRECURRENT	CURRENT	CP 15 s	CP 2 s	CO's	SR's
PPC II (Pn=02; Pc=.08; Dc=15s)						
16	451	5341	.36	.04	28	235
17	545	5487	.44	.06	36	255
18	564	5357	.45	.06	34	260
19	520	5516	.42	.05	33	251
2-S COD I (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)						
20	303	5821	.24	.03	19	208
21[a]	144	5891	.09	.01	9	158
22	154	5866	.11	.01	9	139
23	0	6202	.00	.00	0	128
PPC III (Pn=02; Pc=.08; Dc=15s)						
24	565	5736	.46	.05	35	288
25	511	5617	.41	.05	31	221
26	494	5418	.41	.05	31	235
2-S COD II (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)						
27	462	6007	.39	.05	29	253
28	372	5751	.29	.03	23	225
29	454	5682	.36	.04	28	241
3-S COD II (Pn=.02; Pi=0; Pc=.08; Di=3s; Dc=15s)						
30	478	5564	.37	.04	29	219
4-S COD II (Pn=.02; Pi=0; Pc=.08; Di=4s; Dc=15s)						
31	422	5941	.33	.04	26	199
32	357	5966	.28	.03	22	207
33	368	5987	.30	.04	23	215
APC II (Pn=02; Pc=.02; Dc=15s)						
34	344	5957	.27	.03	21	126
35	336	5893	.27	.03	21	129
36	372	5698	.24	.03	21	98

[a]During Session 21 Dc was accidentally set at 13 s.

TABLE 22

Post-session Verbal Reports Across PPC, COD, and APC Sessions for S8

SESSION	COMMENTS
PPC II (Pn=02; Pc=.08; Dc=15s)	
16	I guess I did something right that time. I went back to what I did before (pressing the left-hand button, then switching to the right) and it seemed to have an effect on giving more money. I didn't press the right-hand button in any particular way, just after the left hand button.
17	I kept pressing the right button (rather quickly) and when it stopped giving money (usually they came in 5's), I'd press the left button and go back to the right. It would always be fairly steady until just before a quarter way, and then it would stop (i.e., .245 it would take forever to get to .250; or .995 to 1.000; .745 -> .750 etc.)
18	I did the same thing as last time (push the right, then left, then right again) only I didn't push the buttons as fast (so I thought). This time the money came slowly, then a really fast period happened, then back to slow, back to fast. I tried to duplicate what I was doing during the periods where I got a lot of money fast, but I didn't know what it was I did!
19	The money seemed to come in clusters, (2 or 3 at a time), or fairly steady (1 every 5 clicks or so), or not at all. It would give money in a bunch, wait 10 seconds, perhaps another little bunch, wait, and then steady for about 5 or six 1/2 pennies. All of this didn't seem to depend on anything except that I pressed the right button. (neither fast or slow, or if I had pressed the left button first)
2-S COD I (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)	
20	I wasn't paying too close attention, but the gaps of no money seemed to be larger this time. Also, when the money came in clusters, it was when I would push the right button down only half way (so it seemed), it came faster this way.

TABLE 22 (continued)

SESSION	COMMENTS
21	I couldn't press the button either too fast or too slow to get money...it had to be just right. This is like being a blind batter...I have no idea what I'm swinging at, and I sure didn't get very many hits!
22	At the beginning of the session, I tried to push only the right button at a steady rate. This didn't seem to get me anywhere, so I tried anything and everything that I've used before (i.e., fast, then slow, then fast, pressing it all the way down, 1/2 way down, pressing the other button first)--it worked a little better but not much.
23	I was determined not to touch the left-hand button this time to see what would happen. So I only pushed the right-hand button, fast and slow. Silly or not, my superstition worked better than it did without it this time. It took forever this way just to make ten cents!
PPC III (Pn=02; Pc=.08; Dc=15s)	
24	Well, my superstition theory worked...I made almost 3 times as much this time by pressing the left-hand button every once in a while when the right-hand button stopped giving money. All the way through it was pretty steady. (either that, or Dave fixed the machine!)
25	Since I don't know any better, I'm sticking to my right-button, left-button technique. As long as it keeps working, I'll keep using it. I'm still wondering what it is I'm doing to make the money come quickly in groups of 3 or 4, and other times slowly, but steady.
26	Same as before (right, left, right) but I pressed the left button more often, and I pressed the right button faster. Up until about 15 cents, the money came about every 6 presses, after that it was uneven for the rest of the time.

TABLE 22 (continued)

SESSION	COMMENTS
2-S COD II (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)	
27	This time, it seemed like it depended on how I pressed the right button that got me the money (I still pressed the left one intermittently, though). If I pressed it hard, it didn't seem to earn as much as if I pressed it softly (1/2 way) and a bit slower.
28	Most of the way through the experiment, the money came fairly slow, but steady--until about the last five mins...it came in real quick bunches. I didn't think I pressed the buttons any faster, though--it was really weird. I still pressed it (the button) down half way.
29	This time, I just concentrated on pressing the right button, and if it was more than a few seconds since the last cent was given, then I pressed the left button, then back to the right. This kept working, so I kept doing it. I didn't worry about how or where I pressed the right button (top or bottom, fast or slow).
3-S COD II (Pn=.02; Pi=0; Pc=.08; Di=3s; Dc=15s)	
30	The way the money was delivered, and the way I pressed the buttons seemed totally unrelated. (Maybe it was!) First, at the beginning, it (the money) came in bunches, rather quickly--then it came very slow in the middle, and again quick at the end. I pressed a bit faster at the end, but I though the beginning and the middle were the same.
4-S COD II (Pn=.02; Pi=0; Pc=.08; Di=4s; Dc=15s)	
31	The money came so slowly at the beginning...I think it was because I wasn't pressing fast enough. Then it seemed to come in sets--the first set I'd have to push the button down hard, and another set I'd have to push it very lightly, almost half the way down only. At the end, I got more money if I pushed it fast--then it came pretty steady.
32	I tried to push the right button the same all the way through (same pressure, same rate), as well as alternating with the left button. It worked pretty well...the money came steadily, not fast, but pretty even the whole way through.

TABLE 22 (continued)

SESSION	COMMENTS
33	As far as I know, I haven't changed the way I've been pressing the buttons (with the exception that I press a little bit faster at the end); but the money came really, really slow at the beginning, and super-fast at the end. I don't think it was only because I was pressing the button faster, it couldn't have been, for during the session I would press fast and nothing would happen.
APC II (Pr=02; Pc=.02; Dc=15s)	
34	This time it didn't seem to make a difference how fast I pressed, but really how soft or hard I pressed. It seemed to alternate between the two. Overall, though, it was really slow...this session it took forever to get any money!
35	I don't know what I was doing wrong, but the money sure came slow this session. I did everything I had been doing before, but none of it (or very little of it) seemed to earn anything this time. Perhaps I wasn't pressing the button hard enough.
36	This was really frustrating! What worked in the past isn't working now (or working at a very slow rate)...I'm all out of ideas. I tried pressing harder, faster, alternating more between the right and let buttons--none of it worked consistently like before. I don't know what else to try. Some sessions it works--this session it didn't.

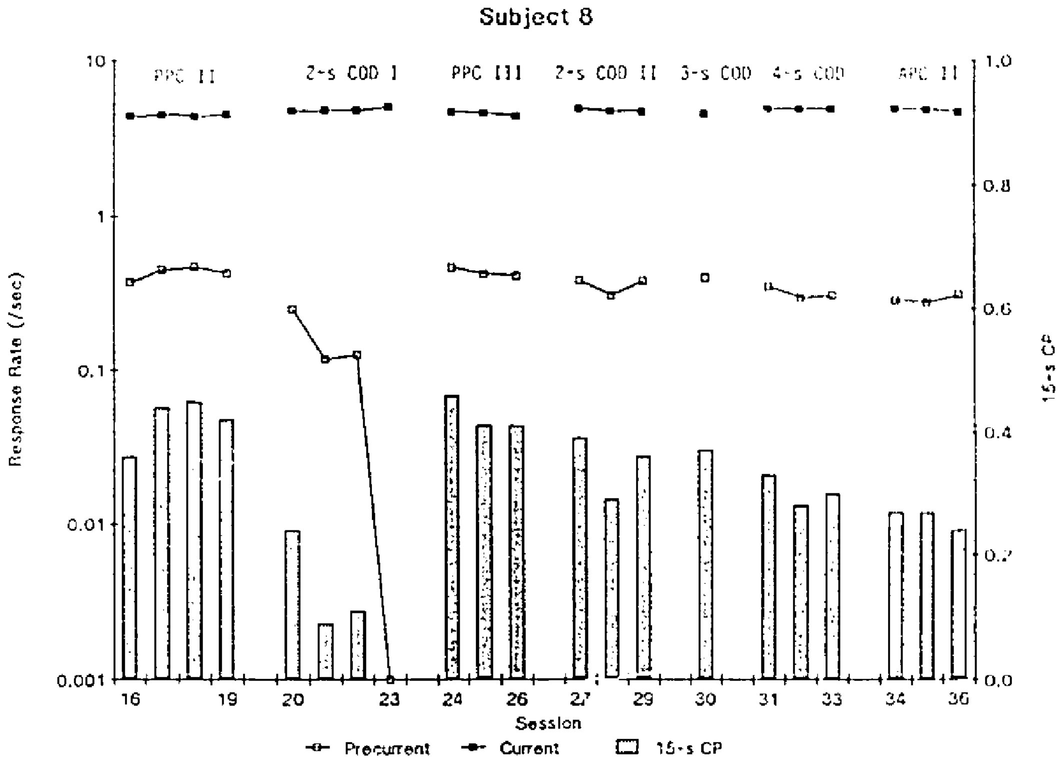


Figure 40. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the PPC II, 2-s COD I, PPC III, 2-s COD II, 3-s COD, 4-s COD, and PC II phases for S8.

the 2-s COD I phase to the point that no precurrent responses were emitted in Session 23, (2) progressively fewer reinforcers were obtained across 2-s COD I sessions, and (3) current responding increased slightly across the two phases.

The bottom of Figure 39 presents the cumulative records for the first PPC III session after the COD was removed (Session 24). The pattern of responding resembled very closely that observed for the last session prior to the imposition of the COD (Session 19; see Figure 35).

Table 21 and Figure 40 show that precurrent and current responding, the 15-s CP, and obtained reinforcers all returned and remained at pre-COD levels under the PPC III phase.

Table 22 reveals that verbal behavior about the precurrent contingency, unlike the first three PPC II sessions (Session 16-18), was lacking during the first three 2-s COD I sessions (Sessions 20-22), the emphasis being on current responding and reinforcement. However, the focus switched in the next and last 2-s COD I session (Session 23): she reported engaging in a form of hypothesis testing concerning the effects of precurrent responding: "I was determined not to touch the left-hand [precurrent] to see what would happen". She described the result: "It took forever this way to make ten cents!" Consistent with this observation, in the next session (Session 24), she noted that she earned almost three times as much money than in the previous session (actually it was 2.25 times as much) by pressing the precurrent button when reinforcement was not forthcoming for pressing the current button. She stated that she used a similar strategy in Sessions 25-26 but still expressed uncertainty about "what it is I'm doing to make the money come more quickly". It is interesting to note that she reported pressing the precurrent button more often in Session 26 (the last PPC III session) when in actuality she pressed it less often than in either of the two prior sessions.

For Sessions 27-29 (2-s COD II phase), the 2-s COD was reintroduced as in Sessions 20-23. Table 21 and Figure 40 show that this time only very slight reductions occurred for precurrent responding and the 15-s CP during 2-s COD sessions. An additional calculation reveals that, like S7, the proportion of long current response runs was greater under the 2-s COD phase: in the last PPC III session (Session 26), 37.5% (12/32) of current response runs were greater than 175 responses; in the last 2-s COD II session, this figure rose to 51.7% (15/29).

In Session 27 the focus of S8's verbal behavior changed to "how" she pressed the current button, but by Session 29 she was once again describing a relationship consistent with the precurrent contingency (see Table 22).

The COD was lengthened to 3 s in Session 30 (3-s COD) and 4 s in Sessions 31-33 (4-s COD). Table 21 and Figure 40 reveal little change from the prior 2-s COD II phase. However, additional calculation reveals that the proportion of long current response runs became even greater during these sessions: e.g., in the final 4-s COD session (Session 33), 66.7% (16/24) of current response runs exceeded 175 responses.

Table 22 reveals changes in verbal behavior for the 3-s and 4-s COD sessions: in Session 30, she states "The way the money was delivered, and the way I pressed the buttons seemed totally unrelated"; and, in Session 31, her verbal behavior once again focused on how she pressed the current button. Although she mentioned pressing the precurrent button in Session 32, overall there appears to be less emphasis on the precurrent contingency in her reports in the 3-s and 4-s COD sessions than in the prior 2-s COD II sessions.

S8 had agreed to continue her participation for only a few more sessions. Thus, rather than return to the PPC condition to examine whether the minor changes under the 4-s COD phase would return to pre-COD levels, it was deemed more important to determine whether precurrent responding was in fact being maintained under the various COD phases because it enhanced the reinforcement probability for current responding. Therefore, in Sessions 34-36 (APC II phase) the precurrent contingency was removed. Table 21 and Figure 40 show that relative to the prior 4-s COD phase there was little change. In the last two APC II sessions (Sessions 35-36), S8's verbal behavior suggests that she noticed the change in contingency because "what worked in the past isn't working now", including "alternating more between the left and right buttons" (see Table 22).

Discussion

In Experiment 2B it was shown that high levels of precurrent responding and the PiPc CP were maintained by the precurrent contingency for both S7 and S8. In this experiment, a 2-s COD was imposed onto the precurrent contingency such that reinforcement was unavailable for current responding within 2 s of a precurrent response.

For S7, the precurrent response rate was generally unaffected by the 2-s COD. However, a closer examination of the data revealed that when the COD was present, there was a larger proportion of long current response runs (and thus long periods of time with no precurrent responses) and consequently fewer current responses were emitted under PiPc.

For S8, the 2-s COD produced large reductions in precurrent responding and the 15-s CP. While these effects were reversed when the COD was withdrawn, reintroducing the 2-s COD, and subsequently lengthening it to 3 s and then 4 s, produced less obvious effects on these measures. However, as with S7, a greater proportion of long current response runs were observed during sessions when a COD was present, especially in the 4-s COD phase.

Removing the precurrent contingency following the 4-s COD phase for S8 did not extinguish precurrent responding as observed in the APC I phase in Experiment 2B.

For S7, verbal behavior did not change across PPC and COD phases. For S8, there appears to be less of a focus on the precurrent contingency during sessions when a COD was present. For example, in all but one of the seven PPC sessions (Session 19), her initial comment focused exclusively on the contingency involving pressing the precurrent button; in only two of the 11 COD sessions was exclusive focus given to the precurrent contingency. Her verbal behavior did noticeably change when the precurrent contingency was removed in the final phase, along the lines of "nothing worked consistently like before".

A post-experiment interview was conducted with S7 following Experiment 2C, three months after she terminated her participation. When she was asked about the purpose of the experiment, she did not mention her behavior on the precurrent button. When asked if pressing the precurrent button had any effect on the money she acquired, she replied no but then qualified her reply by saying that it was a way to pass time while no reinforcement was scheduled for pressing the other (current) button. When the experiment was explained and she was shown a graph illustrating the orderly changes in precurrent responding across the PPC and APC conditions, she expressed surprise.

A post-experiment interview was conducted with S8 about a month following the last session of her participation. She said there was one session in which she purposely did not press the other [precurrent] button to see how it affected the amount of money she earned in that session. She said she discovered that she earned less money by not pressing the other [precurrent] button in that session and from that point forward always made sure she pressed it during every session. The session she refers to was probably Session 23 (see her comments in Session 23 in Table 22), and true to her word, little change in precurrent responding was noted for the remainder of the experiment. Like S7, when shown graphs of her data S8 was surprised to see orderly changes in her behavior.

EXPERIMENT 2D

The results of Experiment 1D and Experiment 2C suggest that when a COD is imposed upon the precurrent contingency, the result can be reductions in precurrent responding and the PiPc CP, and/or increases in the proportion of long current response runs. Experiment 2D addressed the following question: Can a precurrent operant develop when a subject is initially exposed to the PPC condition with a 2-s COD in effect?

Subject

The subject (S9) was a female enrolled in a behavioral psychology course at the University of Victoria.

Procedure and Results

For Sessions 1-4 (2-s COD phase), a precurrent response decreased the probability of reinforcement for current responding from .02 (Pn) to zero (Pi) for 2 s (Di) and then raised it to .08 (Pc) for 15 s (Dc). For Sessions 5-8 (APC phase), precurrent responding had no scheduled consequence. All other conditions were the same as in previous sections of Experiment 2.

The top half of Figure 41 presents the cumulative records for the first 2-s COD session (Session 1).

Insert Figure 41 here

Figure 41 shows that a step-like gradient of precurrent

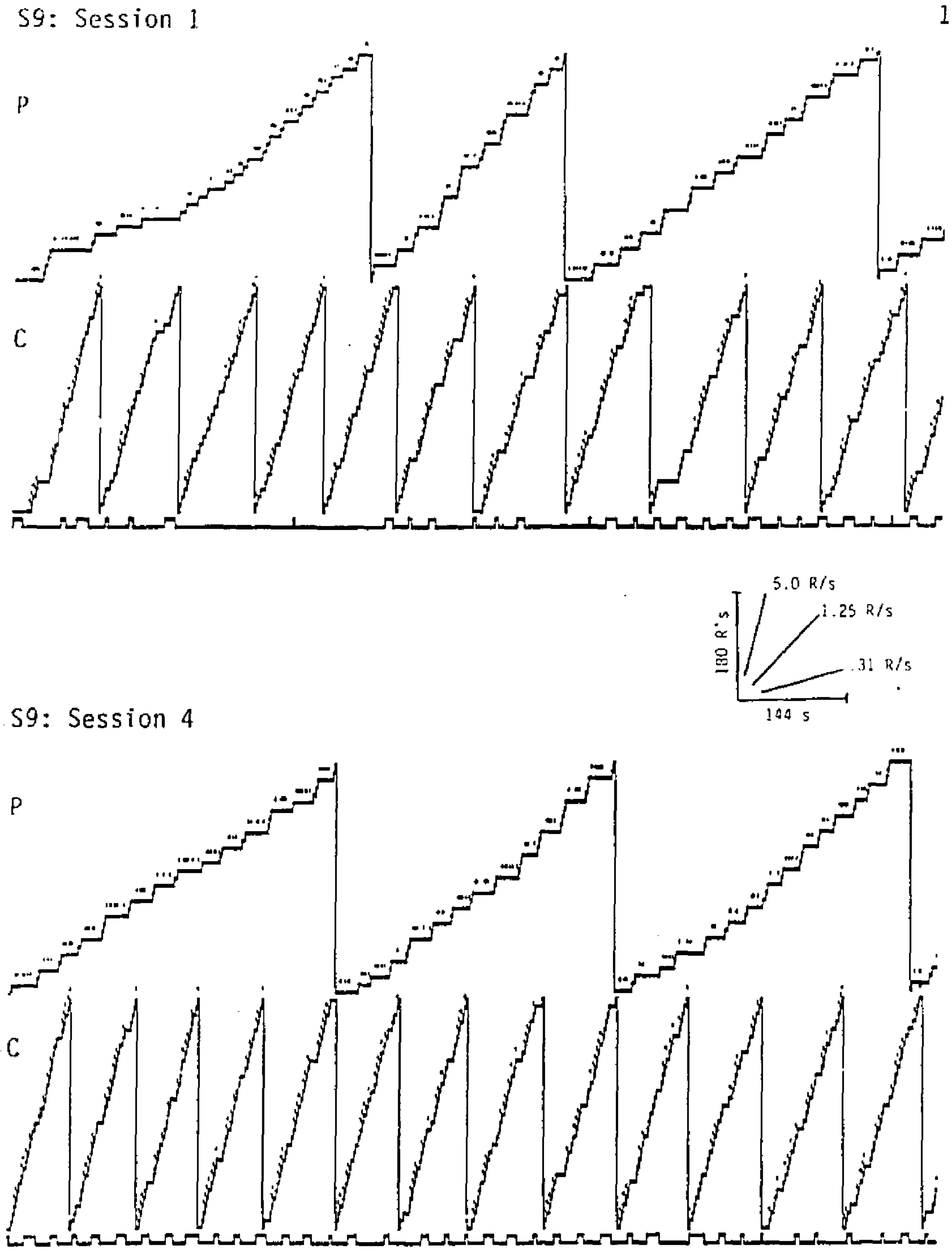


Figure 41. Cumulative records of precurrent (P) and current (C) responding for S9 during Session 1 (top) and Session 4 (bottom).

responding and high stable rate current responding developed early and continued throughout the session, resulting in a large majority of current responses emitted under PiPc. The bottom half of Figure 41 shows the cumulative record for the last 2-s COD session (Session 4), which reveals the continued stability of the pattern developed in Session 1.

Insert Tables 23 and 24 and Figure 42 here

Table 23 and Figure 42 show that precurrent responding maintained throughout the 2-s COD phase, although some fluctuations are observed. The PiPc CP remained fairly stable throughout this phase. Table 24 reveals that S9's comments for all 2-s COD sessions closely approximated the precurrent contingency, although there is no direct mention of the fact that reinforcement was unavailable immediately following precurrent responding.

The top half of Figure 43 presents the cumulative records for the first APC session (Session 5).

Insert Figure 43 here

The pattern of responding observed throughout the 2-s COD phase (see Figure 41) was altered during Session 5, especially during the first half of the session. Long

TABLE 23

Precurrent and Current Responses, PiPc CP, Changeovers (CO's), and Reinforcers (SR's) Across COD and APC Sessions for S9

SESSION	PRECURRENT	CURRENT	PiPc CP	CO's	SR's
2-S COD (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)					
1	1188	4274	.66(.15)	94	237
2	1139	4968	.70(.10)	46	292
3	709	5236	.65(.12)	60	308
4	1160	4897	.65(.09)	43	277
APC (Pn=Pi=.02; Di=2s; Dc=15s)					
5	885	3986	.39(.06)	27	76
6	1023	3589	.42(.06)	27	75
7	633	5079	.39(.06)	33	107
8	212	5387	.08(.01)	5	119

[a]Numbers in parentheses indicate Pi CP.

TABLE 24

Post-session Verbal Reports Across COD and APC Sessions for S9

SESSION	COMMENTS
2-S COD (Pn=.02; Pi=0; Pc=.08; Di=2s; Dc=15s)	
1	I thought that my response rate was being recorded (i.e., the amount of times I pressed switches on the mouse). I got the "best" results by pressing the left button 25 times and then continually pressing the right button until the increments subsided, then I would do the sequence again.
2	This time I tried to decrease the number of presses on the left hand button (to save time) & found that I still made money pressing it only 5 times & then repeatedly pressing the right button until the increments subsided.
3	I notice that as I steadily press the right hand button, the rate of reinforcement isn't a constant. I think that I am "on" some kind of time schedule rather than response rate. I also tried pressing the left button after each reinforcement (while continually pressing the right button) & found that reinforcements were fewer than pressing left button a few times independently, then continually pressing the right button until reinforcement(s) (rate) slowed down.
4	I didn't try anything new from the first few sessions the other day--pressing the left button 10-30 times, then pressing the right one until reinforcement rate subsides, repeat again. Once, I tried pressing the left button repeatedly until I was reinforced but never was. Reinforcement of pressing right hand button must be contingent upon pressing the left hand button.
APC (Pn=Pi=.02; Di=2s; Dc=15s)	
5	I'm not sure. I tried a few different responses & couldn't figure out how to get a steady rate of reinforcement like the previous sessions. I think I was on a variable interval schedule.
6	Still not sure. Hard to figure out when the reinforcements are few and far between. Still think pressing the left button is SD for pressing right hand button and being reinforced. Didn't think very hard about the experiment today.

TABLE 24 (continued)

SESSION	COMMENTS
7	I think I am on a variable ratio/interval schedule. I think that no matter what I do (i.e., how many presses, how fast, how many times I press the left button) I don't have a lot of control over reinforcements.
8	I didn't need to press the left button to get the occasion for reinforcement of pressing the right button. I just kept pressing the left button continually because I got a fairly steady rate of reinforcement that way.

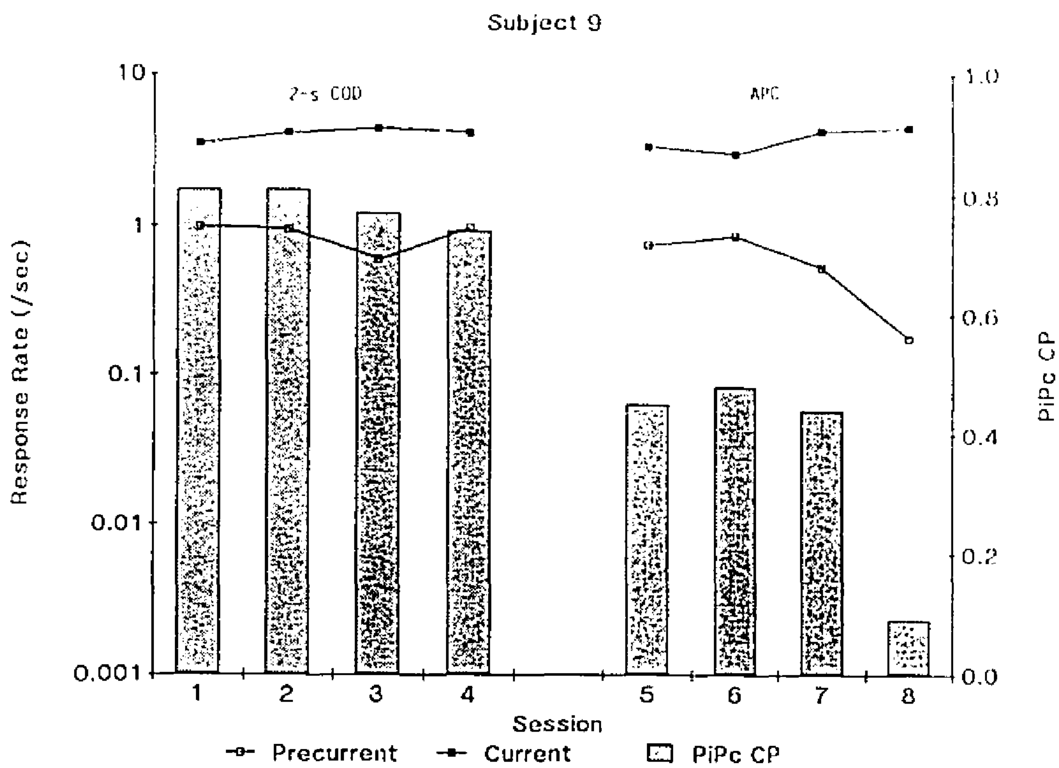


Figure 42. Precurrent and current response rates and the proportion of current responses emitted under the Pi and Pc states combined (PiPc CP) for each session in the 2-s COD and APC phases for S9.

S9: Session 5

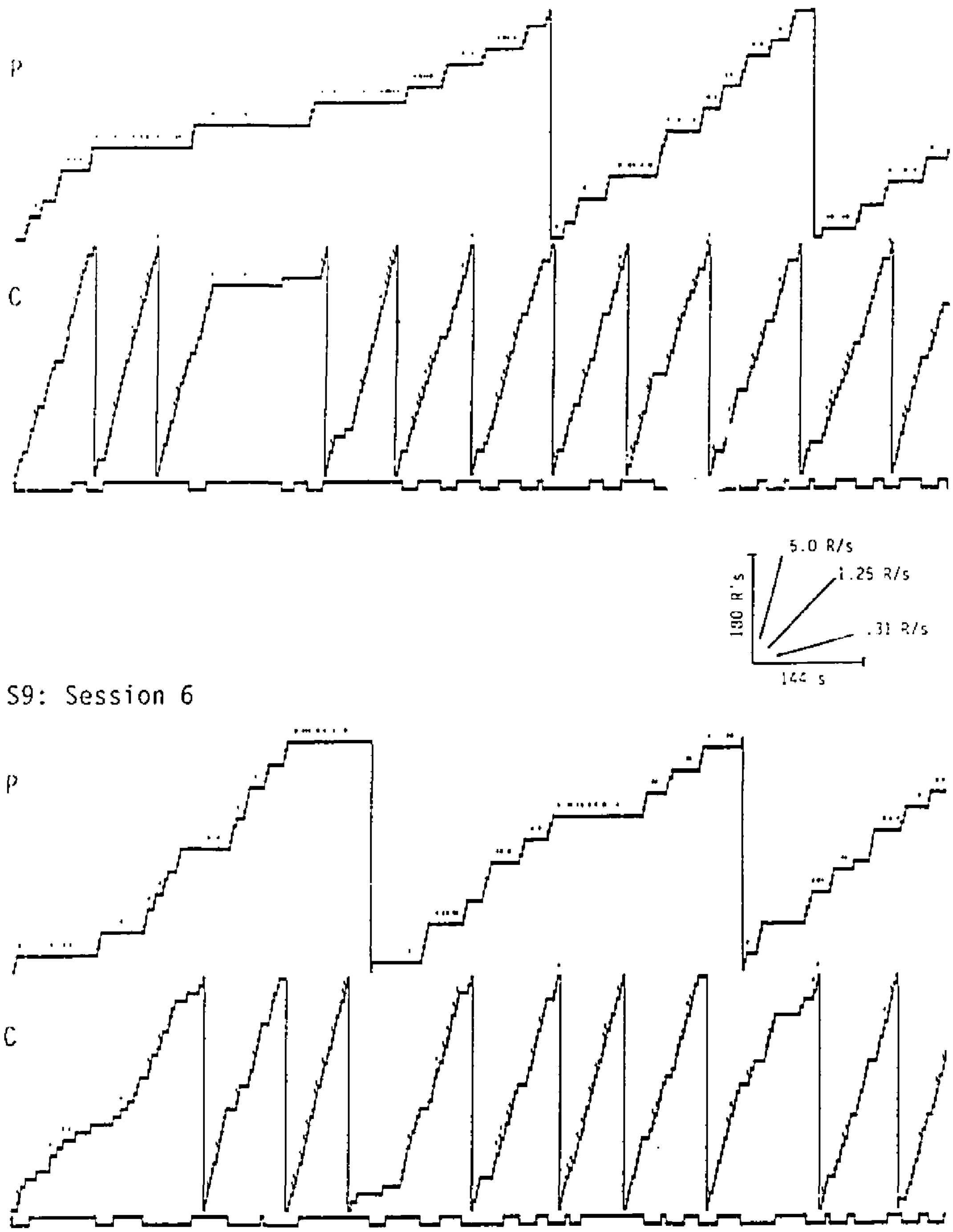


Figure 43. Cumulative records of precurrent (P) and current (C) responding for S9 during Session 5 (top) and Session 6 (bottom).

periods with no precurrent responses are observed, and there is one period of very low rate current responding. Additional calculation reveals that in Session 4, 0% (0 of 44 current response runs were greater than 180 responses; in Session 5, this figure increased to 25.9% (7/27). The bottom half of Figure 43 presents the cumulative records for the next APC session (Session 6), and again unusual fluctuations are noted in precurrent and current responding. It is clear from the cumulative records of Sessions 5-6 that the unstable pattern of responding in those sessions resulted in considerably more current responses emitted under the Pn state.

Figure 44 presents the cumulative records for the next, and final, two APC sessions (Sessions 7-8).

Insert Figure 44 here

In Session 7, long periods without precurrent responding became more frequent as the session progressed and there was a return to high stable rate current responding. While some precurrent responding occurred early in Session 8, no precurrent responses were emitted over the final 12.5 min.

Table 23 and Figure 42 show that the lowest levels of precurrent responding and the PiPc CP occurred during the final two APC sessions (Sessions 7-8), and current

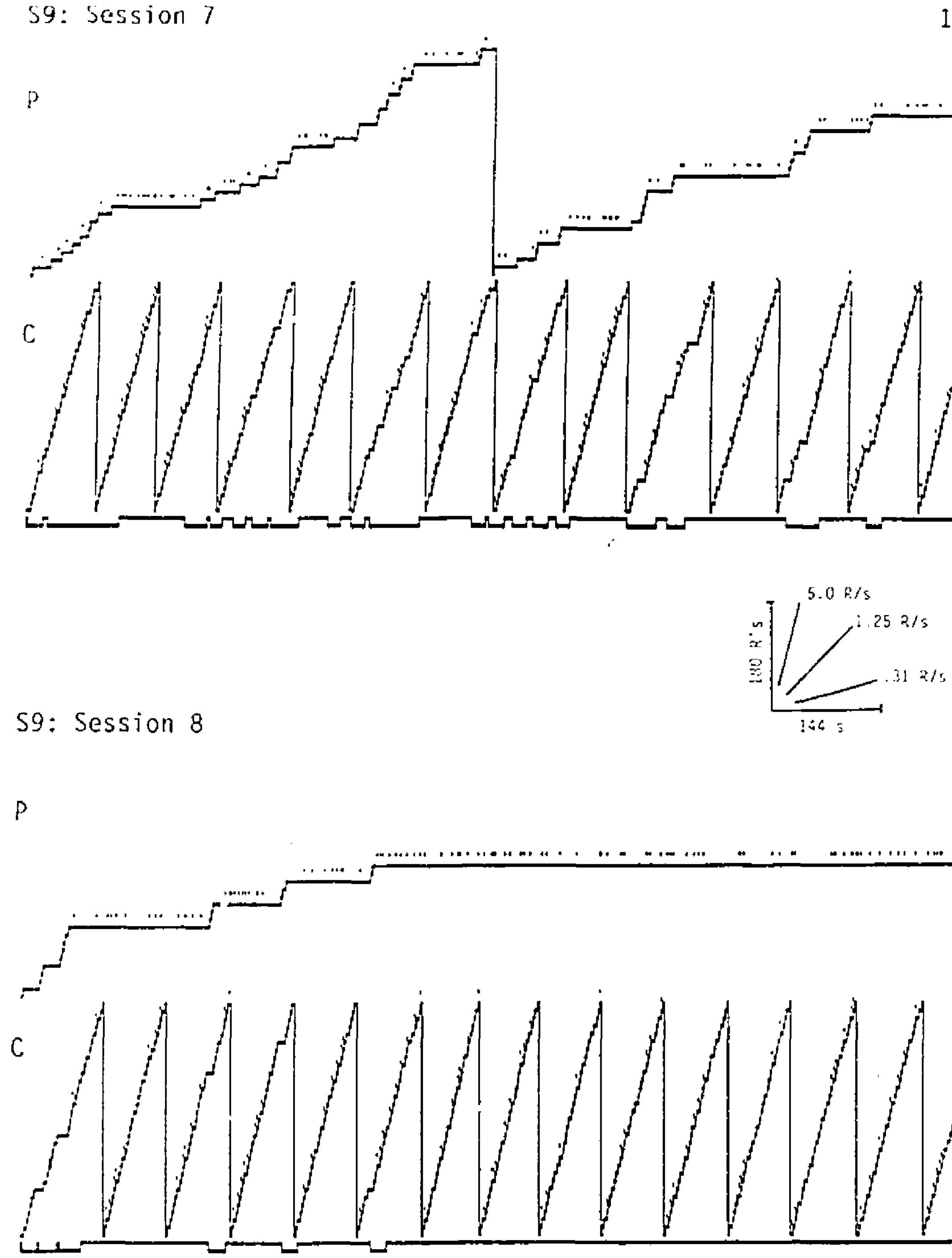


Figure 44. Cumulative records of precurrent (P) and current (C) responding for S9 during Session 7 (top) and Session 8 (bottom).

responding increased to levels more comparable to 2-s COD sessions.

Table 24 shows that S9 did not mention precurrent responding in the first APC session (Session 5), but in the next session she described a relationship indicating that precurrent responding still functioned as it had earlier. By the fourth and final APC session, however, she explicitly acknowledged that left (precurrent) button pressing was no longer part of the reinforcement contingency.

Discussion

The results for S9 indicate that high levels of precurrent responding and the PiPc CP can maintain when a subject is first exposed to the standard precurrent contingency with a 2-s COD. Her descriptions of the precurrent contingency were accurate throughout the 2-s COD phase, although there was no direct mention of the unavailability of reinforcement within 2 s of a precurrent response. She did imply, however, that rapid switching under the 2-s COD phase was less effective in producing reinforcement than her typical mode of responding (see Table 24: Session 3). When the precurrent contingency was removed, stable patterns of precurrent and current responding were altered from the beginning, resulting in longer current response runs and considerably more current responses emitted under Pn. In the last two APC sessions, precurrent responding was progressively less frequent, to the point that no precurrent responses occurred for the final 12.5 min. This change in precurrent responding suggests that the precurrent contingency in the 2-s COD phase was responsible for the high levels of precurrent responding and the PiPc CP. It is interesting to note that in the second APC session S9 speculated that precurrent responding was functioning as it had previously, even though changes from PPC response patterns were clearly evident during the first two APC sessions. Unfortunately, S9 discontinued her participation at this point before a planned return to the 2-s COD condition could be implemented.

GENERAL DISCUSSION

Developing and Maintaining the Precurrent Operant

The standard precurrent contingency employed in the present study was as follows: a precurrent response increased the reinforcement probability for current responding from .02 (or a minor deviation thereof) to .08 for 15 s. The precurrent operant eventually maintained under this contingency for all nine subjects. Generally, given a high rate of precurrent responding, for whatever reasons, precurrent responding continued for as long as the precurrent contingency was in effect. When there was no precurrent contingency, precurrent responding dropped to near zero levels; this occurred when there was no precurrent contingency in the initial phase (S1, S2, S4, S5) and during phases when the precurrent contingency was withdrawn after previously being present (S2, S7, S8, S9). These results suggest that precurrent responding was maintained due to the precurrent contingency in the present experiments.

In two rare cases, precurrent responding persisted when the precurrent contingency was not present: S5, APC II; S8, APC II. (It should be noted, however, that relative to an earlier condition with the precurrent contingency operative, the pattern of precurrent responding for both subjects changed to one that would have be less efficient had the precurrent contingency remained present. Thus, removing the precurrent contingency was not without effect.) Persistence of human operant responding under extinction conditions is not an uncommon finding (cf., Weiner, 1983). To account for the discrepant human-animal performances under extinction conditions, Weiner (1983) has implicated reinforcement histories as a powerful variable:

> Operant data exist which show reinforcement histories can affect the likelihood of response suppression in the face of nonreinforcement under FI (Weiner, 1969a), VI (Weiner, 1965), avoidance/escape contingencies (Weiner, 1969b), and during extinction (Weiner, 1982). Histories of intermittent reinforcement following long periods of nonreinforced responding may be more common with humans than with captive inbred laboratory animals. As a result, nonreinforcement with humans may signify "no reinforcement has as yet been forthcoming" rather than "no reinforcement is possible" or that "responding will not produce reinforcement". In concert with this notion, Weiner (1970) found that nonreinforced human responding during extinction tends to persist when subjects are falsely encouraged to believe that reinforcements are available for procurement. Responding stopped immediately when subjects were told that reinforcements were withdrawn. (p. 523)

Both S5 and S8 had experienced a period of time when precurrent responding produced no scheduled consequence (APC I) followed by a period of extended exposure to the precurrent contingency (S5, PPC I; S8, PPC II) prior to showing persistence of precurrent responding when the precurrent contingency was absent. Thus, a history of intermittent reinforcement for precurrent responding following long periods of nonreinforcement had been established in the laboratory (the reinforcer being an increase in the reinforcement probability for current responding). In the absence of such a history (i.e., during the first exposure to the APC condition), the present data and Taylor (1980) strongly indicate that precurrent responding does not persist.

For four subjects, initial exposure to the precurrent contingency resulted in the development of a precurrent operant; precurrent responding maintained when the precurrent contingency was present in the initial condition (S6, S7) and increased from near zero levels following a history when there was no precurrent contingency (S4, S5). For four other subjects, the development of a precurrent operant did not occur with initial exposure to the precurrent contingency; precurrent responding did not maintain when the precurrent contingency was present in the initial condition (S8), and did not increase from near zero levels following a history when there was no precurrent contingency (S1, S2) or a delayed precurrent contingency (S3).

Perhaps, due to the nature of precurrent responding, conditioning is a more difficult and unreliable process than with current responding. A precurrent response is always one step removed from reinforcement; i.e., it is the current response that produces the reinforcer. The susceptibility of current responses to reinforcing events following their occurrence is well established. For example, Neuringer (1970) delivered response-produced reinforcers for the first three pecking responses of pigeons, followed by response-independent reinforcer delivery (VT 30 s) for the remainder of that session and the next 19 sessions. Three birds averaged 2700 responses each; rates were first relatively high and then decreased to a low level, but in no session did responding cease altogether (unlike control subjects).

Taylor's (1980) precurrent operant data appear consistent with reports such as Neuringer's (1970); i.e., Taylor's results show that precurrent responding increased substantially from near zero levels following the first few contacts with the precurrent contingency. This effect was not replicated with S1 and S2 even though contact occurred with the precurrent contingency in every session after it was introduced. It should be noted that contact was infrequent during these sessions. While this may be an important variable in the conditioning of a precurrent operant, Taylor's (1980) data suggested otherwise. Results comparable to Taylor were obtained when the magnitude of the precurrent contingency was increased: following a single contact with this new contingency, large increases in precurrent responding were observed for both S1 and S2.

The data in Experiment 2A concerning the conditioning of a precurrent operant following an initial phase with the precurrent contingency absent are somewhat more consistent with Taylor (1980). Increases in precurrent responding were observed for both S4 and S5 when the precurrent contingency was introduced. The increase occurred soon after the precurrent contingency was contacted by S4, but for S5 the change was more gradual and occurred after repeated contacts over two sessions. The factor(s) responsible for discrepant results in Experiment 1A (S1 and S2) and Experiment 2A (S4 and S5) are unclear, but there were certain procedural differences: in Experiment 2A subjects were told not to move the mouse and to earn as many points as possible, the magnitude of the precurrent contingency was slightly greater (i.e., Pn was [illegible] at .02 rather than .04), and subjects were exposed to [illegible] sessions without the precurrent contingency prior to introducing it.

For two (S6 and S7) of the three subjects exposed to the precurrent contingency in the initial phase, precurrent responding maintained throughout this phase in contrast to subjects for whom the precurrent contingency was absent in the initial phase (S1, S2, S4, S5). Most subjects entered the experiment with high operant levels of pressing both buttons (S5 and S8 being the exceptions). If the precurrent contingency is present from the beginning, then this "entering repertoire" ensures repeated contact with the precurrent contingency. If the precurrent contingency is absent in the initial phase, precurrent responding drops to near zero levels, and subsequently when the precurrent contingency is introduced, infrequent precurrent responding produces infrequent contact with the precurrent contingency. If frequency of contact is an important variable, then one would expect a more reliable conditioning effect with the precurrent contingency present in the initial phase than when it is absent and then introduced in a subsequent phase.

In what at first glance appears to be contrary to this hypothesis, for S8 precurrent responding did not maintain when the precurrent contingency was present in the initial phase. Recall, however, that she was one of the two subjects with an entering repertoire of low level responding on the precurrent button (as well as the current button). Thus, contacts with the precurrent contingency were infrequent from the beginning, and according to the present hypothesis, one would not expect a precurrent operant to develop. As discussed in Experiment 2B, an additional factor may have hampered the development of a precurrent operant in this initial phase for S8: when contact with the precurrent contingency did occur, the probability of reinforcement for current responding within 2 s of a precurrent response was near zero. The absence of reinforcement within 2 s of a precurrent response was later shown to disrupt the maintenance of the precurrent operant for S8 (to be discussed), suggesting that this variable may also have disrupted conditioning.

Future research could examine the role of frequency of contact with the precurrent contingency. For example, subjects could be instructed to press only the precurrent button whenever a particular stimulus appears on the screen. (An analogous situation might be instructing a child at certain times to preface his requests with "please".) This stimulus could be presented briefly every X min during a session. At all other points in a session subjects would be free to press either button. This arrangement would ensure at least 20/X contacts per session with either the presence or the absence of the precurrent contingency (depending on the condition). If precurrent responding does not occur in the absence of the instructional stimulus with the precurrent contingency present, then the value of X could be reduced to examine the value at which it does. This value would represent "sufficient contact" to condition a precurrent operant for that particular subject.

Two different methods were employed to develop the precurrent operant when the standard precurrent contingency was ineffective in this regard. For S1 and S2, the magnitude of the precurrent contingency was increased; for S3 and S8, Pn was reduced to zero, thus producing a condition under which current responding could not be reinforced unless a precurrent response had occurred within the previous 15 s. Both were successful conditioning procedures. For S1 and S2, the magnitude of the precurrent contingency was gradually reduced to the standard precurrent contingency and the precurrent operant maintained. Future research might examine the effect of gradual versus abrupt changes to the standard precurrent contingency following exposure to a precurrent contingency of large magnitude. For S8, the precurrent operant maintained following an immediate return to the standard precurrent contingency from the Pn = 0 session. This was not the case for S3: raising Pn to .01 following the Pn = 0 session produced an immediate and significant reduction in precurrent responding. Precurrent responding maintained when Pn was set at .01 only after a second exposure to a Pn = 0 session. Overall, the data suggest that while the precurrent contingency was insufficient to induce precurrent responding upon its initial introduction, it was sufficient to maintain precurrent responding once high rate precurrent responding occurred. Perhaps these conditioning procedures enhanced precurrent responding to the point that when subjects were returned to the standard precurrent contingency a sufficient number of contacts occurred to maintain precurrent responding.

Reconditioning of the precurrent operant by removing and then subsequently reintroducing the precurrent contingency was demonstrated once each for S1 and S8, and twice for S7. For S1 and S8, conditioning did not occur upon initial exposure to the standard precurrent contingency; rather, as just described, special conditioning procedures were required. Following maintenance and subsequent extinction, however, exposure to the standard precurrent contingency was a successful conditioning procedure. The apparent relative ease of reconditioning could be studied under the experiment proposed earlier concerning intermittent presentations of an instructional stimulus to press the precurrent button. One might expect reconditioning with fewer required contacts with the precurrent contingency than in an initial conditioning phase. There is some support for this hypothesis with current operants. For example, Bullock & Smith (1953) exposed rats to 10 conditioning-extinction sessions such that in each session 40 reinforced lever presses were followed by 60 min of nonreinforced lever pressing. They discovered that conditioning was more rapid (to a limiting value) with successive conditioning periods.

Noteworthy from S7's data in terms of repeated conditioning is the fact that the removal of the precurrent contingency a second time produced a more immediate reduction in precurrent responding than the first time it was removed. Bullock & Smith (1953) also reported that extinction was more rapid (to a limiting value) with successive extinction periods.

Efficiency

In general, efficiency, as measured by the PiPc CP, did not improve with continued exposure to the precurrent contingency and rarely approached 100%. Taylor (1980) reported similar results. There are at least two possible sources of control for precurrent responding in the present paradigm: (1) the control exerted by the consequence of precurrent responding (i.e., a temporary increase in the probability of reinforcement for current responding) and (2) discriminative control (cf., Lattal, 1981). Discriminative control was minimized in the present study by not including exteroceptive stimuli correlated with the change in reinforcement probabilities. Nevertheless, the different reinforcement schedules themselves could exert discriminative control; to minimize this source, random as opposed to fixed ratio schedules were employed and a low magnitude of change from Pn to Pc was selected. Inefficient responding, in the present sense, may be a function of minimized discriminative control.

Discriminative control was still possible, however. With the precurrent contingency operative, relatively low density reinforcement periods for current responding would be correlated with a precurrent response producing a relatively high density of reinforcement for current responding. Thus, low density reinforcement periods could function as an S^D to occasion precurrent responding. It should be noted that this type of discriminative control over nonverbal responding in no way implies discriminative control over verbal responding in the self-reports (so-called "awareness" of the contingencies). It is interesting to note, however, that the reports of some subjects under the PPC condition were consistent with the possibility of low density reinforcement for current responding becoming an S^D for precurrent responding; see, e.g., S8, Session 8.

The ease of the discrimination, and therefore the degree of efficiency, would presumably depend on the magnitude of the precurrent contingency, i.e., the degree to which a precurrent response raised the reinforcement probability for current responding. The larger the magnitude of the precurrent contingency, the greater the relative difference between low density reinforcement periods preceding a precurrent response and high density reinforcement periods following a precurrent response. Consistent with this suggestion, the highest levels of the PiPc CP were obtained during Conditioning sessions for S1 and S2, the defining feature of which was a precurrent contingency of large magnitude.

(While increasing the magnitude of the precurrent contingency may improve discriminative control, note that this manipulation changes the consequence. If the magnitude of the precurrent contingency as defined here is analogous to the magnitude of primary reinforcement as defined with infrahumans (e.g., the length of exposure to grain as a reinforcing consequence with pigeons: Catania, 1963b), then it is possible that a resultant increase in precurrent responding might be due in whole or in part to the enhanced magnitude of the reinforcing consequence.)

Discriminative control based on low density reinforcement periods would hamper efficiency under the precurrent contingency. Suppose the present state is <u>Pn</u> and a subject emits a precurrent response and then switches to current responding. The present state becomes <u>Pc</u> and a high density of reinforcement (relative to prior to the precurrent response) is programmed for 15 s. As there is no S^D for precurrent responding, current responding continues throughout this interval and beyond. After 15 s, <u>Pn</u> becomes the present state and thus when current responses are emitted a low density of reinforcement (relative to the 15 s following the precurrent response) is experienced. Now the S^D is present to occasion precurrent responding, but only after some current responses were emitted under <u>Pn</u>. (The distribution of periods of high and low reinforcement densities would not always occur in this way due to the random nature of the schedules, and thus this scenario is based on what would happen on average given a precurrent response followed by current responding.) Overall, this would result in less than optimal efficiency (PiPc CP) since not all current responses would be emitted under Pc. The performances of subjects with the precurrent contingency present, as seen in the cumulative records, often reveal this pattern of responding (e.g., see Figure 35).

The present analysis suggests a direction for future research. Perhaps efficiency could be improved by enhancing the discriminative control over precurrent responding. Suppose that the precurrent contingency is present and exteroceptive stimuli are correlated with Pn (a blue light) and Pc (a red light). Assuming some contact with the precurrent contingency, over time the red light would signal high density reinforcement and the blue light low density reinforcement. If the blue light comes to function as the S^D for precurrent responses, its onset, and thus the immediate onset of Pn, would occasion precurrent responding. Current responses would not have to occur under Pn to produce the S^D, and thus it is possible that all current responses would be emitted under Pc (i.e., maximum efficiency).

There is an indication of efficiency separate from the PiPc CP measure: responding under the present paradigm could be said to be inefficient if more than one precurrent response per CO occurs. A response "run" of only one precurrent response is required in the precurrent contingency to raise the reinforcement probability for current responding. Each subsequent response in a precurrent response run uses time during which current responses could be emitted and reinforced. For five of the eight subjects exposed to the PPC condition (S2, S3, S4, S5, S6), precurrent response runs under this condition were almost always less than five responses (see Appendices C1-C8). Assuming an average rate of 5 responses/s, these subjects "wasted" relatively little time emitting precurrent responses while a high density of reinforcement was scheduled for current responding. For the other three subjects (S1, S7, S8), precurrent response runs were almost always less than 20 responses, a somewhat less efficient mode of responding that did not improve with repeated exposure to the precurrent contingency.

Response induction combined with adventitious reinforcement may account for the persistence of precurrent response runs greater than one response. Research (Lattal & Crawford-Godbey, 1985; Starin, 1987) has shown that under identical Chain VI VI schedules, responding is greater in the initial link when the response components are of the same topography (i.e., homogeneous) than when they are of different topography (i.e., heterogeneous). These results have been interpreted in terms of induction from terminal link responses strengthened by direct reinforcement to initial link responses of similar topography (Starin, 1987). In the present study, a precurrent-current response sequence could be considered as a two-link homogeneous chain, with precurrent responding functioning as the initial link and current responding as the terminal link. The schedule of reinforcement for current responding (random ratio) generated extremely high current response rates. Although the precurrent contingency calls for only one precurrent response, the high rates generated by the random ratio schedule for current responding may have generalized to responding on the precurrent button which required the very same topography (i.e., pressing a button). Under the precurrent contingency, precurrent response runs of any length would be followed by a higher reinforcement probability for current responding. This consequence could strengthen any behavior that precedes it, which, due to induction, may consist of bursts of precurrent responses. Reinforcement may produce a functional response unit different from that specified in the reinforcement contingency (cf., Catania, 1984; Arbuckle & Lattal, 1988). Future research might examine how precurrent response runs under the precurrent contingency are affected when the precurrent and current responses are of similar and dissimilar topography.

Again, a way to counteract inefficient responding, in this case precurrent response runs greater than one response, could be to correlate exteroceptive stimuli with _Pn_ and _Pc_. Technically, the precurrent-current response sequence in the present study is a tandem schedule since there are no exteroceptive stimuli associated with the different reinforcement schedules. Thus, this procedural change would transform the precurrent-current response sequence from a tandem to a chain schedule. The rationale for why efficiency could improve is similar to that described above for improving the _PiPc_ CP. Again, assume the precurrent contingency is present, exteroceptive stimuli are correlated with _Pn_ (a blue light) and _Pc_ (a red light), and there is some contact with the precurrent contingency. Over time the red light would signal high density reinforcement for current responding and the blue light low density reinforcement. If the red light comes to function as the S^D for current responding, its onset, and thus the _immediate_ onset of _Pc_, would occasion current responding. Precurrent responses would presumably be less likely to continue under _Pc_ since the onset of the red light would occur following the first precurrent response. Consistent with this suggestion, D'Andrea (1969) demonstrated that the acquisition of a two-link response sequence was slower under tandem than under chain schedules with identical response requirements. The effect was most apparent for the first link response.

Signalling the Pn and Pc states might also improve conditioning when the precurrent contingency is presented after an initial period of absence. As described in the Literature Review (see Appendix A), when the component schedules were not signalled in a concurrent operant paradigm, the performance of some pigeons was unaltered by substantial changes in the contingencies; under the typical set-up with the component schedules signalled, this "insensitivity" was not seen (Miller, Saunders, & Bourland, 1980).

The Changeover Delay (COD)

Imposing a 2-s COD onto the precurrent contingency produced inconsistent effects on the maintenance of the precurrent operant. For S2, precurrent responding was significantly reduced with the introduction of the COD, an effect which was reversed with its removal. (Here is another case in which the standard precurrent contingency was sufficient to recondition the precurrent operant whereas prior to implementing special conditioning procedures it had no effect.) For S3, responding was unaffected by the COD. For S7, the PiPc CP was slightly reduced with the COD present, but the precurrent response rate remained unaffected. For S8, the first phase of exposure to the COD produced results comparable to S2; a second phase of exposure produced results comparable to S7. These data suggest that exposure to a 2-s COD over a few sessions can disrupt the precurrent operant to varying degrees, or not at all. In other words, reinforcement for current responding immediately following a precurrent response can affect the maintenance of a precurrent operant. In terms of acquisition, the data for S9 suggest that a precurrent operant can develop with a 2-s COD present. Thus, reinforcement immediately following precurrent responding is not necessary for the acquisition of a precurrent operant.

Under the precurrent contingency, every current response was eligible for reinforcement, whether it be emitted under _Pn_ (p = .02) or _Pc_ (p = .08). By imposing a COD onto this contingency, a precurrent response removed all possibility of reinforcement for current responding for the duration of the COD. Thus, the COD represents a time-out from reinforcement, which has been shown to be an effective punisher with both infrahumans (Azrin & Holz, 1966) and humans (Brantner & Doherty, 1983). The data for S2 and S8 suggest that a time-out can also be an effective punisher in the present paradigm. S8's data further suggest that repeated exposure to the COD may attenuate its punishing effect. While the presence of a 2-s COD decreased precurrent responding during the phase when it was first introduced, this effect was not replicated following reconditioning. This is consistent with the punishment literature: extended exposure to mild punishment produces a characteristic recovery from punishment (Azrin & Holz, 1966).

The finding for S8 that increasing the duration of COD across successive sessions produced no effect on precurrent responding is also interpretable by considering the punishment literature. When the intensity of a punisher is gradually increased, behavior can maintain at punisher intensity levels even greater than an intensity level which will reduce behavior upon sudden introduction (Azrin & Holz, 1966). Since "the effectiveness of time-out as a punishing stimulus has been found to be a function of the duration of the time-out" (Azrin & Holz, 1966, p. 392), the length of the time-out (i.e., the COD duration) could be considered as its "intensity". Had a 4-s COD been introduced in the second COD phase for S8, a reduction in precurrent responding might have been observed. The effect of (1) repeated exposure to the COD and (2) gradually increasing the duration of the COD are two lines of research that could be considered in the future. Other questions to consider might include whether the punishing effects of a COD can be attenuated by programming a precurrent contingency of large magnitude, or by introducing the COD as an intermittent consequence of precurrent responding and then gradually decreasing the intermittency.

Under the COD condition, a precurrent response had two consequences: an immediate time-out from reinforcement and a subsequent greater than normal probability of reinforcement for current responding for a period of time. This is analogous to self-control as discussed in behavior analysis (cf., Skinner, 1953). For example, Rachlin (1978) considers self-control to be a "now" versus "later" situation. Going to the dentist produces a short-term punishing consequence (e.g., time-out from reinforcing activities) and longer-term reinforcing consequences (e.g., avoidance of pain from a toothache). In this situation, a person is said to demonstrate self-control when she produces the future reinforcer in return for punishment in the present. Overall, there appears to be a net gain, as is the case in the present paradigm when a person produces a brief time-out from reinforcement in return for a greater than normal reinforcement probability for current responding. As described in Experiment 1D for S2, had precurrent responding continued throughout the COD phase as it had prior to the introduction of the COD, there would have been a net gain in reinforcement. According to this analysis, S3, S7, S8 (second COD phase), and S9 demonstrated self-control by continuing to emit precurrent responses in spite of the consequence of an immediate time-out; self-control was not demonstrated by S2 and S8 (first COD phase). Absence of self-control in this regard has been reported with both infrahumans (Hineline, 1977; Thomas, 1981) and humans (Wasserman & Neunaber, 1986). For example, Wasserman & Neunaber (1986) presented a response-independent reinforcer at fixed intervals; the first response in an interval produced the immediate delivery of the reinforcer scheduled for that interval but also cancelled the reinforcer scheduled for the next interval. Responding continued throughout this phase at rates substantially higher than during a control phase in which reinforcer delivery occurred at fixed intervals regardless of responding. In other words, the short-term effect of responding (i.e., the immediate delivery of an impending reinforcer) masked the overall negative correlation between response rate and reinforcer rate. Examining the effects of a COD as part of the precurrent contingency in the present paradigm could contribute to the literature on self-control. As previously described, it may be possible to "inoculate" subjects to the effects of the COD, a short-term consequence which for some subjects blocked control by the precurrent contingency. Within the context of the present discussion, such an attempt could represent "teaching self-control".

Current Responding

A high stable rate of current responding developed early (see Session 1 cumulative records) and maintained throughout the experiment for all subjects, a finding consistent with Taylor (1980). Specifically, a high stable current response rate was observed within sessions (see cumulative records), between sessions, and between conditions regardless of the condition. Sometimes fluctuations were noted within a session following a change in contingencies (e.g., compare the cumulative records in Figures 41 and 43), but stability always returned (see Figure 44). Thus, current responding was generally unaffected by manipulating the consequences of precurrent responding.

Verbal Reports

The post-session verbal report data in Experiment 2 produced some interesting findings. First, with the precurrent contingency present, every subject at some point suggested that precurrent responding did increase the reinforcement of current responding. Like efficiency, however, improvements in the accuracy of these descriptions did not occur. In fact, the reports often shifted in focus away from the precurrent contingency (S4, S6, S7, S8) despite the continued presence of the precurrent contingency and the continued maintenance of the precurrent operant. Second, the presence of the precurrent contingency continued to be reported after it was removed and changes in precurrent responding were noted (S9). Third, a precurrent operant was repeatedly conditioned and extinguished in the absence of any verbal behavior about precurrent responding (S7). Fourth, for the one subject for whom efficiency did improve with continued exposure to the precurrent contingency (S5), the description of the precurrent contingency did not change; had responding been consistent with this description, improvement in efficiency would not have been expected. Fifth, the COD reduced precurrent responding (S7) and efficiency (S7, S8) in the absence of verbal behavior about its presence. Sixth, subjects reported unprogrammed (adventitious) contingencies between odd forms of behavior and reinforcement both when the precurrent contingency was present (S8) and when it was absent (S4, S8). These descriptions often persisted for more than one session. In the case of S4, her insistence in the initial three sessions that reinforcement was dependent on mouse movement clearly ran counter to the experimental instructions (i.e., "Do not move the mouse.") Overall, these data suggest that post-session verbal reports did not accurately describe the events that occurred during the sessions. In support of this conclusion, whenever a subject was debriefed and extensively interviewed following the experiment (S2, S7, S8), surprise was always expressed as to the purpose of the experiment and the orderly changes in behavior that were observed. These results are consistent with reports in the human operant literature (e.g., Bruner & Revusky, 1961; Hefferline & Keenan, 1963; Wasserman & Neunaber, 1986), as well as reports in other areas of psychology, such as social psychological research into cognitive dissonance and attribution. With regards to the latter, an extensive review by Nisbett & Wilson (1977) concluded that:

(a) Subjects frequently cannot report on the existence

> of the chief response that was produced by the manipulations; (b) even when they are able to report the existence of the responses, subjects do not report that a <u>change process</u> occurred, that is, that an evaluational or attitudinal response underwent any alterations; and (c) subjects cannot correctly identify the stimuli that produced the response. (p. 233)

The post-session verbal reports indicated that some subjects (S8, S9) were engaging in "hypothesis testing". The confirmation of an hypothesis for S8 apparently affected her behavior for the remainder of the experiment; i.e., she responded differently when exposed to contingencies for a second time. This is consistent with literature showing that rules may produce insensitivity to changes in contingencies (e.g., Hayes et al., 1986). In future research, subjects could be reinforced for accurate and inaccurate descriptions of the precurrent contingency (see, e.g., Torgrud & Holborn, 1990) to examine the effects on the development and maintenance of the precurrent operant.

<u>Other Possibilities For Future Research</u>

There are other interesting directions for future research (in addition to those discussed). For example, are differential performances generated by continuous and intermittent reinforcement of precurrent responding? The precurrent contingency specified that every precurrent response enhance the probability of reinforcement for current responding (or maintain the enhanced level) for 15 s. Could this consequence be scheduled less and less frequently over time and yet still maintain precurrent responding? What would be the effect if only the first precurrent response after a fixed (FI) or variable (VI) interval produced this consequence or if this consequence was dependent on a fixed (FR) or variable (VR) number of precurrent responses? Human performances under these standard reinforcement schedules often differ from that of infrahumans (cf., Lowe, 1983; Weiner, 1983). Would this also be the case for precurrent responding? Two lines of research hint otherwise. First, there is evidence to indicate that when a reinforcer is intermittently produced by a response but another "consummatory" response is required to collect the reinforcer, human performance under the standard reinforcement schedules approximates that of infrahumans (Holland, 1958; Matthews, Shimoff, Catania, & Sagvolden, 1977). Thus, like precurrent responding, the behavior under schedule control in these studies was one step removed from the reinforcer. Second, Lowe (1983) suggested that self-generated rules by verbal human subjects about the experimental contingencies may account for the discrepant human-infrahuman performances observed under the standard reinforcement schedules. Consistent with this hypothesis, FI scallops (the typical pigeon performance under FI schedules: Ferster & Skinner, 1957) were obtained with human subjects when a concurrent verbal shadowing task was included as part of the procedure (Lowe, 1979). Furthermore, animal-like performances under FI schedules were obtained with pre-verbal human infants but not older children (Bentall, Lowe, & Beasty, 1985). The present data showed that descriptions of the precurrent contingency were often vague, inaccurate, or lacking altogether, in contrast to descriptions of the contingency between current responding and reinforcement. Perhaps because current responses produce the reinforcer, subjects are more likely to focus (i.e., generate rules) on the contingency between current responding and reinforcement and less likely to focus on the precurrent contingency. And perhaps as a result of the absence of rules about precurrent behavior, schedule effects for precurrent responding may be obtained which are comparable to those observed with infrahumans.

The precurrent contingency in the present set-up specified a sequential order: (1) precurrent response, (2) current response, (3) reinforcer. In everyday experience, however, this order is not always essential. For example, crying (precurrent behavior) may increase the probability that saying "Give me a cookie" (current behavior) produces a cookie (reinforcer), regardless of whether crying precedes, overlaps with, or follows the request. Or, threatening someone (precurrent behavior) may increase the probability of compliance (reinforcer) to the demand "Give me your money" (current behavior), again regardless of whether the precurrent behavior precedes or follows the current behavior. One way to study precurrent contingencies of this type could be as follows. At the end of fixed intervals (e.g., 5 s) reinforcers are scheduled with a given probability (e.g., $p = .02$) if a current response is emitted during an interval; if a precurrent response is also emitted during the same interval, then the probability of reinforcement is greater (e.g., $p = .08$). Of course, this arrangement is not limited to non-sequential precurrent contingencies; one could specify that the last response during an interval be a precurrent or current response. A further advantage of this paradigm is that efficiency can be more easily evaluated. There is only one measure of efficiency in terms of producing maximal reinforcement: did at least one current response and at least one precurrent response occur during an interval? Under the precurrent contingency in the present paradigm, the picture is more complicated; rate of reinforcement is a function of the proportion of current response emitted under Pc, the current response rate, the length of precurrent response runs, and the degree to which precurrent responding interrupts current responding under Pc.

Final Comments

The concept of precurrent behavior plays a large role in Skinner's discussions of such complex phenomenon as self-control (1953), verbal behavior (1957), education (1968), problem solving (1969), and thinking (1957; 1974). Surprisingly, little research has been generated. It is clear that one behavior can affect the three-term contingency of reinforcement for another behavior such that the second behavior is more likely to occur or more likely to be reinforced (see Literature Review in Appendix A). That is, it is clear that many behaviors serve a precurrent function. It is less clear what role, if any, precurrent contingencies play in the development and maintenance of precurrent behavior. As noted in the Introduction, Skinner (1953; 1969) suggests that precurrent behavior is unlikely to develop in the absence of direct reinforcement (often arranged by a verbal community) but might maintain once established. In other words, once precurrent behavior is at strength due to direct reinforcement, control may shift to the consequence of altering the three-term contingency of reinforcement for current behavior. The present data are consistent with this speculation: with the precurrent contingency present, a precurrent operant did not always develop, but once precurrent responding was at strength (sometimes due to special conditioning procedures), maintenance was observed. In some cases, however, maintenance was fragile, as evidenced by the precurrent rate-reducing effect of a COD. Continued research into precurrent contingencies may discover common characteristics between such seemingly diverse behaviors as stepping on the accelerator pedal before starting the car, qualifying statements in a scientific report, repeating a telephone number given by the operator, tying a string on one's finger to remember to pay the rent, looking at someone when you speak, highlighting a school textbook, and setting the mood by playing romantic music on the stereo. These behaviors are related in the sense that they are not directly reinforced when emitted alone but do contribute to reinforcement through another behavior. Are they also related in the sense that this type of consequence produces similar effects on the behaviors?

APPENDIX A

Literature Review

The purpose of this review is to examine areas of research in behavior analysis that relate to the development and maintenance of precurrent operants. Most of the studies to be reviewed did not directly stem from Skinner's discussions of precurrent behavior, and thus reinterpretation is often necessary.

Sample-Specific Behavior in Matching-to-Sample

In the matching-to-sample paradigm, a sample stimulus is presented, the organism is often required to observe the sample by physically touching it (observing behavior), and then comparison stimuli are presented. Sometimes the sample remains in the presence of the comparison stimuli (simultaneous matching) and sometimes it is terminated and the comparison stimuli are presented after a period of time (delayed matching). Reinforcement is contingent on the organism making a response to the comparison stimulus determined by the experimenter to be the "correct" one. The correct comparison can either be identical to the sample (identity matching) or different (non-identity matching). If there are two comparison stimuli and the organism responds nondifferentially, or if the organism is under the stimulus control of some irrelevant property of the comparison stimuli controlled for by the experimenter (e.g., position), a matching response will be reinforced on approximately 50% of the trials. The research to be reviewed in this section has shown that when the observing behavior to each sample is topographically distinct (sample-specific), the result is faster acquisition and greater resistance to factors affecting the maintenance of accurate matching behavior. To the extent that sample-specific behavior (precurrent behavior) increases the probability of a correct matching response (current operant response) and is conditioned and/or maintained because of this consequence, sample-specific behavior may be considered to be a precurrent operant. Note that the sample-specific behavior does not change the probability of reinforcement for a correct matching response, which remains the same whether or not this precurrent behavior is emitted.

There have been reports that sample-specific behavior can develop without explicit programmed contingencies and that this behavior improves matching accuracy (Blough, 1959; Cohen, Looney, Brady, and Augella, 1976; Torgrud and Holborn, 1989). In the most comprehensive of these studies, Blough (1959) observed four pigeons' behavior during various delay intervals of a delayed identity matching task. The sample stimulus was either a flickering or a steady light. Sample-specific behavior developed for two birds. For example, following the flickering sample, one bird "backed quickly away from the keys and waved its head slowly throughout the delay interval", while "following a steady sample, the bird spent the delay pecking rapidly at the top of the vertical sample bar" (p. 153). Within 20 sessions this bird was matching correctly more than 90% of the time at all delays. On those flickering sample trials when the bird pecked at the sample bar during the delay, the bird almost always pecked the incorrect comparison. Later in the experiment, the top of the bird's cage was opened for a number of sessions to film the bird. This disruption resulted in undifferentiated behavior during the delay, and accurate matching deteriorated; the poor performance was especially pronounced at the longer delay intervals. Despite reinstatement of the original condition, the poor performance continued for over 35 sessions. Eventually behaviors specific to each sample reappeared but they were of similar topography, and intermediate matching accuracy levels were obtained.

While Blough's two other subjects "exhibited striking superstitious behavior during the presentation of the sample and in the delay periods...in neither bird did this behavior occur as two distinct patterns" (p.155). Accurate matching for these two birds at delays greater than zero seconds was consistently lower than for the two birds which developed sample-specific behavior.

Other research has included sample-specific behavior as part of the reinforcement contingency for producing the comparison stimuli. In a simultaneous non-identity matching procedure, Eckerman (1970; Experiment 1) employed a wide key on which the sample stimulus was presented. For one group of pigeons, the observing response was required at the same location on the sample key regardless of which sample was presented on any given trial; for two other groups, the observing response to each sample was required at locations either three or six inches apart. The rapidity of accurate matching acquisition and the highest level of accuracy obtained was directly related to the amount of separation between the location of the two observing responses.

Cohen et al. (1976) also employed a simultaneous non-identity matching procedure with pigeons. Facilitated acquisition of accurate matching was demonstrated with sample-specific behavior that involved FR 16 and DRL 3-s responding. In addition, for sample-specific birds, rates of acquisition did not differ across conditional discrimination tasks which typically produce a continuum from easy to difficult to teach. Subsequent research by the same authors (Cohen, Brady, & Lowry 1981) demonstrated: (1) after achieving criterion accuracy under a simultaneous matching procedure, switching to a zero-delay matching procedure disrupted accurate matching for sample-nonspecific birds but not for sample-specific birds;

(2) during training under a zero-delay matching procedure, acquisition of correct matching was more rapid for sample-specific birds; (3) the introduction of increasing delay intervals depending upon stable performance at any given delay value disrupted matching accuracy for sample-nonspecific birds but not for sample-specific birds. One sample-specific bird was eventually exposed to a delay interval of 55 s without a drop in matching accuracy at any point along the way. Perhaps even more remarkable was the fact that although this bird was very active during the delay periods, "it showed no patterns of behavior that were discriminable...as sample specific" (p.342).

Parsons, Taylor, & Joyce (1981) employed a identity matching procedure with children. The subject's panel contained five circular keys arranged in a Greek Cross pattern. Two sample stimuli (a "bright" stimulus and a "dim" stimulus) were randomly presented on the center key. An observing response to the sample illuminated the top and bottom keys and turned off the sample. Subjects were exposed to one of three pretraining conditions. In the Differential condition, subjects were reinforced for pressing the top key when the bright-sample was presented and to press the bottom key following the presentation of the dim-sample. In the Common condition, subjects were reinforced for pressing the top key following sample presentation regardless of sample type. In the Nondifferential condition, subjects received reinforcement for pressing either the top or the bottom key after sample presentation despite the sample type. Subjects were then shifted to a .1-s delayed identity matching task. Now, following the presentation of a sample on the center key, a response to the top or bottom key appropriate to the pretraining condition turned off the sample and lead to the presentation of two comparison stimuli on the side keys. A response to the side key that was identical to the sample resulted in reinforcement. Accurate matching was acquired by one of the four Common subjects, three of the four Nondifferential subjects, and three of the four Differential subjects. The patterns of acquisition for the Differential subjects differed from that of the other two groups. While those Common and Nondifferential subjects who acquired accurate matching did so gradually over the course of eight sessions, the three accurate matching Differential subjects exceeded 90% accuracy during the first session and maintained this high performance. The Differential subject who did not acquire accurate matching over the course of eight training sessions had adopted a Common strategy when the sample was presented. In Experiment 2, the seven high accuracy subjects were exposed to a condition in which variable delays (0, 5, or 10 s) were introduced between sample offset and onset of the comparisons. The onset of the comparisons was still contingent upon mediating behavior appropriate to a subject's pretraining history. Accurate matching performance was a decreasing function of delay for Common and Nondifferential subjects, while Differential subjects maintained accurate matching across all delay values. Differential subjects maintained appropriate sample-specific behavior during all delays. When all subjects were prohibited from making pretrained mediating responses during the delay, Common and Nondifferential subjects matched more accurately at the two longer delay values than when the pretrained mediating behavior was required; the Differential subjects showed marked decrements in matching at the two longer delay values.

Torgrud & Holborn (1989) replicated and extended the findings of Parsons et al. (1981) using only two groups, Common and Differential. They reported: (1) while high matching accuracy was obtained for all subjects when the delay interval was short (1 s), the Common, and not the Differential, subjects showed decrements in matching accuracy with increasing delay intervals (3, 5, 10, 15 s); (2) when Differential subjects were prevented from making the sample-specific responses, their performances were indistinguishable from the Common subjects. In a subsequent condition, subjects were required to choose the comparison that was not identical to sample (oddity matching). Subjects were told that the mediating behavior was optional. All subjects continued to emit mediating behavior specific to their previous training history on almost every trial. Again, only Differential subjects showed high (oddity) matching accuracy at all delay intervals. One Common subject was later exposed to the Differential condition, and high matching accuracy was obtained across all delay intervals for both identity matching and oddity matching tasks.

In all of the matching-to-sample studies, with the exception of Blough (1959) and Torgrud & Holborn (1989), sample-specific behavior always produced the comparison stimuli. Note that the comparison stimuli probably functioned as a conditioned reinforcers due to their association with the primary reinforcer. Although each of these studies demonstrated that sample-specific behavior can increase the likelihood of a correct matching response (and ultimately, reinforcement), it is unknown whether sample-specific behavior maintains because of this effect, or because of its effect of producing a conditioned reinforcer (the comparison stimuli), or both. The results of Torgrud & Holborn (1989) suggest that mediating behavior during the delay interval may be maintained for reasons other than producing an increased likelihood of a correct matching response. Recall that these authors reported that Common subjects continued to emit mediating behavior after it no longer produced the presentation of the comparison stimuli even though it did not increase the probability of a correct matching response. Caution should be noted in accepting this result as representative, however since, more than any other study reviewed here, detailed instructions were involved which, as the authors noted, may have included inherent demand characteristics.

The Torgrud & Holborn (1989) study points up a problem with control conditions. To test if mediating behavior would maintain in the absence of a contingency between it and a correct matching response, these researchers included a condition under which Common mediating behavior was optional. However, previously a Common mediating response was required to produce the comparisons. Thus, even if a Common subject was performing at chance accuracy levels, a correct matching response would follow Common mediating behavior on approximately 50% of the trials. When the Common mediating behavior was no longer required to produce the comparisons, the intermittent occurrence of a correct matching response following the Common mediating behavior may have been sufficient to maintain Common mediating behavior on every trial. The problem is that a Common subject would not be exposed to the absence of a contingency so long as matching responses did not occur in the absence of the Common mediating behavior. For the subject to experience no contingency, a correct matching response must be emitted with equal probability in the presence <u>and</u> absence of the Common mediating behavior. To ensure exposure to the absence of a contingency, Common mediating behavior could be required on some trials and be prohibited on others. In a subsequent condition, Common mediating behavior could then be optional to test if it maintains following forced exposure to the absence of a contingency between it and a correct matching response.

<u>Summary and Extension</u>. Sample-specific behavior in the matching-to-sample procedure can increase the probability that a correct matching response (i.e., current operant response) is emitted, and thus functions as precurrent behavior. The studies reviewed in this section suggest the following very tentative conclusions which should be subjected to more detailed analysis: precurrent behavior can develop without direct reinforcement (Blough, 1959; Cohen et al., 1976; Torgrud & Holborn, 1989); precurrent behavior results in faster acquisition of the current operant (Eckerman, 1970; Cohen et al., 1976; Cohen et al., 1981; Parsons et al., 1981); precurrent behavior inoculates the current operant against variables typically affecting maintenance of the current operant, e.g., increasing delays in delayed matching-to-sample (Blough, 1959; Cohen et al. 1981; Parsons et al. 1981; Torgrud & Holborn, 1989). Another interesting research question studied by Torgrud & Holborn (1989), for which the results are unclear, concerns

the degree to which precurrent behavior generalizes to new related tasks.

It may be instructive to note how the sample-specific behavior is discussed in these studies.. Blough (1959) offers the following account of his birds' sample-specific behavior in matching-to-sample. The comparison stimuli were presented after a delay regardless of a bird's behavior during the delay, and then a single peck at either comparison brought food on at least half of the trials. If comparison stimulus presentation served as a conditioned reinforcer, then behavior occurring immediately prior to it would be strengthened, as Skinner (1948) demonstrated in his classic "superstition" experiment. By chance it is possible that at some point during training one behavior (R1) had a greater likelihood of reinforcement in the presence of one sample stimulus while the same was true for another behavior (R2) in the presence of the other sample stimulus (cf., Morse & Skinner, 1957). Once two different (R1 and R2) responses under the control of the two different samples (S1 and S2) were set up in this way, a new reinforcement contingency begins to operate. Selecting Comparison 1 will always be reinforced after R1 and never reinforced after R2; similarly, selecting Comparison 2 will always be reinforced after R2 and never reinforced after R1. A "correct" matching response is therefore strengthened in the presence of the appropriate sample-specific behavior. Blough notes:

> The entire development of mediating behavior is seen as a self-strengthening process that may proceed rapidly from small beginnings. <u>It might be noted that once they begin to control matching responses, the stereotyped chains cease by definition to be "superstitious", since they result in an increased rate of reinforcement.</u> (p.157, emphasis mine).

Thus, the precurrent behavior itself is considered to serve a discriminative function. There is support for this notion. For example, Eckerman (1970; Experiment 3) eliminated the sample presentation for high accuracy sample-specific subjects and instead presented only a white light on the sample key. On half of the trials one sample-specific behavior lead to comparison stimuli presentation, while on the other half of the trials the other sample-specific behavior had this effect. The result was above chance responding to the "correct" comparison stimulus (i.e., the one that matched the sample-specific behavior that produced the comparison stimuli), suggesting that the sample-specific responses had acquired discriminative control over which comparison was selected, independent of sample stimulus presentation.

<u>Collateral Behavior Under DRL</u>

In a differential reinforcement of low rate (DRL) schedule, a response is reinforced only if it is preceded by a minimal time without a response of the same type. For example, if reinforcement is contingent upon responses spaced at least three seconds apart, this schedule is called DRL 3 s. The reinforced operant under this schedule can be conceptualized as "consisting of an IRT (inter-response time) plus a response, in that order" (Catania, 1984, p. 117). Note that an organism can increase the probability that a response will fall within the limits of the reinforced class if, following a reinforced response, it engages in any behavior or chain of behaviors, excluding the reinforced response, for a period of time. Such behavior, if acquired or maintained because of this effect, can be considered as a precurrent operant.

Wilson & Keller (1953) conditioned rats to respond on DRL schedules with progressively larger intervals. As delay intervals increased, rate of responding decreased and IRT values increased. They noted:

> [I]n the case of each animal there developed an easily recognizable and predictable form of collateral response....Rat no. 1 went to the water bottle, poked its nose through the food cup opening, returned to the water bottle, and returned to the bar. Rat no. 2 turned away from the bar and groomed, poked its nose through the food-cup slot, and returned to the bar. Rat no. 3 went to the water bottle and climbed on it, climbed the ventilation holes in the rear of the cage,

poked its nose at the glass cover over the cage, and returned to the bar...With the increase in delay intervals, more links were conditioned to the chain of collateral behavior. (p. 193)

Bruner & Revusky (1961) recorded collateral behavior during a DRL 8.2 s IH 2.25 s schedule with four high school boys as subjects. (IH stands for "limited hold". In this particular schedule, a response is reinforced only if it is spaced between 8.2 and 10.25 s from the last response.) A subject's keyboard consisted of four response keys, only one of which had the scheduled consequence. During the DRL schedule, "responses on the three irrelevant keys took the form of definite patterns and were observed to maintain a required temporal spacing of presses on the reinforced key" (p. 350). During a postexperimental interview, all subjects stated that responses were dependent upon certain patterns of responses and no subject reported that reinforcement in any way depended on the passage of time.

Collateral behavior under DRL schedules has been reported in other studies with rats (e.g., Davis & Wheeler, 1967) and humans (e.g., Kapostins, 1963) as well as with pigeons (e.g., Zuriff, 1969; Schwartz & Williams, 1971).

Laties, Weiss, Clark, & Reynolds (1965) examined a number of factors affecting the maintenance of collateral behavior during the DRL 22-s component of a multiple schedule for a single rat. The rat was observed to nibble its tail during the DRL component, and the longer the duration of mouth-tail contact, the more likely reinforcement was to follow a lever press. When reinforcement was discontinued (extinction), mouth-tail contact duration became more variable and then ceased altogether; beyond this point, lever pressing continued with greater IRT variability and then also ceased. With the reintroduction of reinforcement, the collateral behavior returned almost immediately. In another condition, the lever was alternately protracted and retracted. During lever-retracted periods, tail nibbling duration increased in variability and gradually decreased in frequency until by the fifth lever-retracted period it was no longer observed; tail nibbling continued as usual during lever-protracted periods. In a third condition, the rat's tail was painted with an aversive tasting substance (cycloheximine). Mouth-tail contact was abolished and the rat earned substantially fewer reinforcements. In a final condition, the administration of amphetamine led to infrequent mouth-tail contact and the rat pressed the lever prematurely more often, resulting in fewer reinforcements.

In a subsequent experiment with rat subjects (Laties, Weiss, & Weiss, 1969), various oral collateral behaviors were observed between lever press responses during a DRL 18 s schedule for three subjects (e.g., nibbling the grid bar). For two other subjects that did not exhibit collateral behavior, a piece of wood was provided in the experimental chamber, and wood nibbling eventually developed. When collateral behavior first appeared, it was always accompanied by an increase in lever press responses spaced far enough to earn reinforcement. Preventing collateral behavior (e.g., covering the grid bar with plexiglass), always lead to a decrease in reinforced lever press responses. Discontinuing the reinforcement contingency lead to the elimination of the collateral behavior prior to the cessation of lever pressing, thus replicating Laties et al. (1965). When a limited hold was added to the contingency (DRL 18 s LH 3 s), collateral behavior did not extinguish; in fact, more reinforcers were earned when collateral behavior was visible than when it was absent. One rat was eventually exposed to a DRL 48 s schedule. During the last of eight such sessions, the rat nibbled 5.4 grams of wood and made 82 responses, 34 of which were reinforced. The collateral behavior was then prevented (no wood was available to nibble) and on the eighth session under this condition the rat made 171 responses, only three of which were reinforced.

Summary and Extension. Collateral behavior can increase the probability that a pause-plus-response sequence (i.e., a current operant response) occurs, and thus functions as precurrent behavior. In all of the studies discussed in this section, precurrent behavior developed and maintained in the absence of direct reinforcement. Other interesting findings discussed in this section that could be subjected to more detailed analysis include: a precurrent operant functions in the absence of accurate descriptions of the reinforcement contingency by human subjects (Bruner & Revusky, 1961); when reinforcement is discontinued for the current operant, precurrent responding extinguishes sooner than current responding (Laties et al., 1965; Laties et al., 1969); the immediate return of precurrent responding following extinction during reconditioning (Laties et al., 1965).

Like Blough's (1959) analysis of sample-specific behavior in the matching-to-sample paradigm, Laties et al. (1965) consider collateral behavior under DRL schedules to be a discriminative stimulus.

> [T]he ease with which we were able in several ways to show covariation between amount of tail nibbling and efficiency of spaced responding suggests to us that the most parsimonious account of _this_ rat's performance is in terms of its behavior _vis-a-vis_ its tail becoming a source of discriminative stimuli for appropriate spacing of lever pressing. (p. 114)

However, other researchers have provided evidence that indicates otherwise. Hemmes, Eckerman, & Rubinsky (1979) suggest that support for the claim that collateral behaviors are a discriminated chain of responding in which each response serves as a discriminative stimulus for the next response will be demonstrated when:

> (1) the precision of timing under DRL schedules is functionally related to properties of the collateral behavior; (2) the collateral behavior is highly stereotyped and deviations from the stereotyped pattern lead to nonreinforcement; (3) the sequences of collateral behaviors are heterogeneous, thereby providing a set of discriminable stimuli to be used for mediation. (p. 328)

In their procedure, the response manipulandum was a strip divided into 20 independent pecking keys. Reinforcement was contingent on pecking at a particular area of the strip on various DRL schedules. For two of the three pigeon subjects, the amount of collateral pecking was highly correlated with DRL efficiency, thus meeting the first criterion above. By considering pecks at locations on the strip other than the reinforced location as the collateral behavior, they found little evidence of stereotypy (repeated patterns). When the rare instance of stereotypy was found, the pattern was homogeneous (the repeated pattern consisted of pecks at the same location). They also found that locations of the first or last response of collateral runs was differentially associated with reinforcement. Specifically, collateral pecks preceding reinforced pecks were further away from the reinforced location than were collateral pecks preceding nonreinforced pecks. From these results they argue collateral behaviors facilitate DRL performance merely by interfering with and thereby delaying the DRL response.

The defining feature of the precurrent response class under DRL schedules is that the response occupy time (as do all responses) and be topographically distinct from the DRL response. Thus, the topography is free to vary within the confines of a response class that provides considerable leeway. If there is substantial variation in the topography of precurrent responses, a current operant response may not be more likely in the presence of any specific precurrent response topography and thus precurrent behavior may not come to function as a discriminative stimulus. (Of course it is possible that the complex dimension "response topographically distinct from DRL response" could come to function as a discriminative stimulus since current operant responses would be more likely in its presence. However, this would appear to be a considerably more difficult discrimination, if it is at all possible.) Thus, there may be cases in which precurrent behavior increases the probability of a current operant response and yet does not function as a discriminative stimulus for current operant responses.

<u>Changeover Behavior in the Concurrent Operant Paradigm</u>

Ferster and Skinner (1957) defined <u>concurrent operants</u> as:

> Two or more responses, of different topography at least with respect to locus, capable of being executed with little mutual interference at the same time or in rapid alternation, under the control of separate programming devices. (p. 724)

There are two procedures for studying concurrent operants (cf., Catania, 1966). In the <u>two-key procedure</u>, there are two separate schedules of reinforcement programmed on two separate operanda and the organism can switch between the schedules by moving back and forth between these operanda. In the <u>changeover (CO)-key procedure</u>, responding on one operandum (the CO-key/operandum) changes the schedule of reinforcement programmed for responding on the other (the main-key/operandum). In both procedures, each schedule of reinforcement is correlated with a different stimulus (in addition to key locus in the two-key procedure). A <u>changeover response (CO)</u> in the two-key procedure involves a switch from responding on one schedule to responding on another; in the CO-key procedure, CO responding is measured directly by responses on the CO-key.

With regards to precurrent operants, concurrent operants involving interval schedules are of particular interest.

> ...consider concurrent interval schedules, such as VI 30-sec reinforcement for pecks on one key and VI 60-sec reinforcement for pecks on the other. In this case, the pigeon could produce 120 reinforcers per hour by pecking only the first key, and 60 reinforcers per hour by pecking only the second key. By pecking both keys, however, it could produce all the reinforcers of both schedules, or 180 reinforcers per hour. (Catania, 1984, p. 183.)

Thus, under concurrent interval schedules, an organism can increase the frequency of reinforcement by emitting CO responses, although note that CO responses do not directly produce the reinforcer. As the studies to be reviewed will show, organisms do distribute their responses to both keys (i.e., emit CO responses) under concurrent interval schedules.

The case is different for concurrent ratio schedules. Under concurrent ratio schedules with unequal ratio components (e.g., Conc VR 25 VR 50), the frequency of reinforcement will be maximal if the organism responds exclusively under the component with the smaller ratio requirement (e.g., VR 25). In fact, this is the performance obtained (MacDonall, 1988).

Skinner (1950) has stated the following about concurrent interval schedules:

> We are no longer dealing with just two responses. In order to analyze "choice" we must consider a final single response, striking, without respect to the position...of the key, and in addition the response of changing from one key...to the other. (p. 211)

The CO response under concurrent interval schedules fits the present definition of a precurrent operant: presumably, it is acquired and maintained because it increases the likelihood of reinforcement for another operant (striking a key). In the typical concurrent operant paradigm, a CO response also produces an exteroceptive stimulus change from the stimulus associated with the present schedule to the stimulus associated with the schedule produced by the CO response.

To maintain maximal independence between concurrent operants, specifically so that the concurrent operants remain under the control of separate programming devices, a changeover delay (COD) is introduced into the procedure which temporally separates the first reinforced response on one operandum from the last CO response (Catania, 1966). In this way, a CO response is never closely followed by reinforcement and therefore is unlikely to be strengthened for this reason. With the COD present under concurrent VI schedules, CO (precurrent) responding is reduced and overall (current) responding increases, regardless of the interval values (Catania, 1966; Leigland, 1987).

The reason for the inclusion of a COD in the concurrent operant literature perhaps represents a point of separation between research concerning the matching law, which predominates the concurrent operant literature (see, e.g., de Villiers, 1977), and precurrent operant research. While the former is concerned with ensuring maximal independence between two concurrent operants, the latter is concerned with how the schedules interact. Catania (1966) recognized the need for this latter research:

> ...the explicit nature of COs in the two-key and CO-key procedures indicates that, at least in these cases, CO responses are also operants that can be defined as a class in terms of their consequences. Because these operants function differently from the concurrent operants that are maintained by separate schedules of reinforcement, their relationship to concurrent performances and to other multi-operant performances must be considered. (p. 226)

In the remainder of this section, Findley's (1958) original study that dealt specifically with CO behavior under concurrent schedules will be reviewed. Then, a summary of more recent literature concerning general relations between CO behavior under concurrent schedules and variables affecting its maintenance (and thus the maintenance of precurrent operants) will be presented.

Findley (1958). Findley (1958) was the first researcher to specifically examine the CO response in a concurrent operant paradigm. His subjects were pigeons. In one experiment, two VI schedules were programmed on the main-key, one associated with the colour red and the other with the colour green. The VI schedules were paired in various combinations over a number of conditions. No COD was present. CO responding occurred consistently, but the rates were said not to vary in an orderly way with changes in the reinforcement schedules (although no specific data are reported). Findley speculated that this lack of an orderly relationship resulted because the VI schedules ran continuously regardless of the colour on the main key, and therefore a reinforcer could accrue in the schedule associated with the absent colour and not be obtained until the subject emitted a CO response. Thus, the CO rate could vary in a number of ways without affecting the overall reinforcement rate in such a way as to "maximize" the total reinforcements determined by the mean values of the schedules. He speculated that the maintenance of switching was "perhaps to a greater extent due to the occasional delivery of reinforcement closely following a switch in colors" (p. 130). When Findley changed his procedure so that each VI schedule timed only when its associated colour was present on the main-key, CO's were neither maintained under equal nor unequal concurrent interval schedules; when the schedules were unequal, responding under the shorter mean interval schedule was found to predominate. Note that prior to the procedural change, CO responding would increase the overall frequency of reinforcement for main-key responding as described earlier by Catania (1966); with the procedural change, maximal reinforcement would be maintained by remaining under the shorter mean interval schedule.

Findley (1958) also studied CO behavior under progressive contingencies on the main-key. Two colours, red or green, could illuminate the main-key. After each reinforcement on the main-key, the contingency for the next reinforcement became less favorable. A CO response, however, changed the colour of the main-key and returned the progressive schedule to its initial value. For example, the first value on the main-key may be FR 100. After this requirement is met and a reinforcer is delivered, an FR 200 requirement would be in effect, and then an FR 300, etc. A CO response at any time other than under the FR 100 requirement changes the colour of the key and returns the schedule to FR 100. Similar progressive contingencies were scheduled for time intervals of FI schedules. Note that delivery of a reinforcer closely following a switch was not possible because the subject always had to complete the initial value of the progressive schedule following a CO response before a reinforcer could be delivered. Whereas CO rates were minimal and difficult to maintain under Conc FI FI or Conc FR FR, the progressive contingencies maintained relatively high CO rates. The more rapid the reinforcement contingency was scheduled to increase under the progressive schedule the more prevalent the CO behavior.

In another phase of his study, Findley introduced an FR requirement for the CO response. The first peck on the switching key darkened the main-key, and the main-key was re-illuminated with the alternative colour when the FR requirement was met. A progressive ratio contingency was scheduled on the main-key. The greater the response requirement on the CO-key, the longer a pigeon worked in the presence of a particular colour before switching. Thus, the CO rate was a decreasing monotonic function of the ratio required on the CO-key.

Concurrent Schedule Parameters. With a COD present and fixed, CO rates are maximal when concurrent VI schedules are equal and decrease as a function of inequality (Davison & McCarthy, 1988). There is no systematic relationship between the equality of concurrent VI schedules and total response output under the schedules (current responding) (Catania, 1963a). (In the concurrent operant literature, schedules are said to be equal to the extent that their relative reinforcement ratios are equal. The relative reinforcement ratio for each component schedule is calculated by the number of reinforcers produced by responding under that schedule divided by the total number of reinforcers produced by responding under both schedules. Thus, when the two component schedules are equal, the relative reinforcement ratio for each schedule is .5; as inequality increases, the relative reinforcement ratio for one schedule approaches one to the same extent that the relative reinforcement ratio for the other schedule approaches zero.)

In addition to observing the stated relationship between CO rate and equality of relative reinforcement ratios, Stubbs & Pliskoff (1969) reported another interesting finding: local rates of responding on the two keys (i.e., total responses under a key color divided by the total time spent under that key color) were approximately equal regardless of the relative reinforcement ratios. Similar results have been reported elsewhere (for reviews, see de Villiers, 1977; Davison & McCarthy, 1988). An implication is that main-key behavior might best be considered a single operant rather than two operants under the control of the two different key colours, at least with respect to concurrent VI schedules (cf., Skinner, 1950, p. 211).

MacDonall (1988) studied concurrent VR schedules using a CO-key procedure and no COD with rat subjects. In one condition (schedule-independent), responses on the main-lever incremented only the ratio correlated with the stimulus that was currently present; CO's were infrequent and the rats responded almost exclusively under the schedule with the smaller ratio requirement. In another condition (schedule-dependent), responses on the main-lever incremented both ratio counters and a reinforcer could only be obtained if a response occurred in the presence of the stimulus correlated with the ratio that had been completed; CO responding was maximal when the relative reinforcement ratios were equal and tended to decrease as a function of inequality. This latter finding is consistent with the relationship described for CO responding and relative reinforcement ratios under concurrent VI schedules. Note that CO responding maintained only under the condition (schedule-dependent) in which it would increase the frequency of reinforcement for main-key responding.

The relationship between CO rate and relative reinforcement ratio equality is affected by whether or not the component schedules are "signalled". Bourland & Miller (1981) employed a CO-key procedure with a 2-s COD. Pigeons were exposed to two types of schedules: (1) a typical Conc VI VI schedule in which the main key illuminated red during one VI component and green during the other; (2) a Conc VI VI schedule in which the colour of the main-key never changed (referred to as a parallel schedule by the authors). With the concurrent schedules, the typical relation between CO rate and the relative reinforcement ratios was observed: CO rates decreased as the relative reinforcement ratios deviated from equality. On the parallel schedules, however, there was no consistent relationship between CO rates and the relative reinforcement ratios. In a similar study by the same authors (Miller, Saunders, & Bourland, 1980), it is interesting to note the performance of two of the four pigeons exposed to the parallel schedules. S522 was initially run under Parallel VI 90 s VI 30 s and then switched to a Parallel VI 30 s VI 30 s; S520 was initially run under a Parallel 90 s 270 s and then switched to Parallel 90 s 30 s. Following these shifts, both birds continued to respond as in the initial reinforcement contingency and did not change over for extended periods. This performance persisted for 87 and 312 sessions for the two birds, respectively. Such performances were not shown by birds with comparable shifts under concurrent schedule conditions. Thus, with no exteroceptive stimulus change associated with a CO response, these birds were insensitive to changes in the reinforcement contingencies.

Why should CO responding be directly related to the degree of equality of reinforcement ratios under concurrent VI schedules? Dreyfus et al. (1982) have shown that the distribution of a pigeon's responses on the two component VI schedules in a CO-key procedure was such that the likelihood that a reinforcer had been arranged on the alternate schedule while responding on the current schedule was highest when the relative reinforcement ratios were equal and decreased as a function of inequality. Thus, like CO responding, the probability of reinforcement for main-key responding immediately following a CO response (and a 2-s COD in their case) was also directly related to the degree of equality of the relative reinforcement ratios. They conclude:

> The basic notion is that choice is between staying on a schedule that produces reinforcers irregularly, or changing to an alternate schedule and producing a reinforcer that is more likely to occur but after a short delay [i.e., after a COD]...The data are consistent with this view of concurrent schedules. For example, changeover rates vary in appropriate ways as relative reinforcement rates change. And, as relative reinforcement rates approach .50, the total changeover rate increases...as does the number of reinforcers following a changeover. (p. 337)

In sum, precurrent (CO) response rate appears to be directly related to the probability of reinforcement for current (main-key) responding following a precurrent response. (It should be noted that Herrnstein (1961) reported that, given no COD, higher CO rates were observed when the relative reinforcement ratios were unequal than when they were equal. This finding appears to run counter to Dreyfus et al.'s argument.)

COD Duration. Another commonly reported result is that CO rates under concurrent VI schedules decrease as the length of the COD increases (Davison & McCarthy, 1988). Stubbs, Pliskoff, & Reid (1977) conducted an extensive analysis of six relevant studies (Shull & Pliskoff, 1967; Brownstien & Pliskoff, 1968; Stubbs & Pliskoff, 1969; Silberberg & Fantino, Experiment 2, 1970; Pliskoff, 1971; Silberberg & Schrot, 1974). They found that despite (1) equal or unequal relative reinforcement ratios, (2) response-dependent or response-independent reinforcer delivery, (3) different reinforcers (food, brain stimulation), and (4) different species (pigeons, rats), CO responding was a decreasing function of COD duration. Bourland & Miller (1978) found that this relationship held whether or not the component schedules were signalled, although for any given COD duration CO rates were lower under the unsignalled condition. Thus, it appears that the greater the minimum separation in time from a precurrent (CO) response to reinforcer delivery, the lower the precurrent (CO) response rate.

The relation between COD duration and total response output under the concurrent VI schedules (current responding) has not typically been reported in the literature. Leigland (1987) used a CO-key procedure and found that, regardless of the relative reinforcement ratios, the presence of a 2-s COD generally reduced CO responding _and_ enhanced total response output on the main-key relative to the absence of a COD. With relative reinforcement ratios fixed, Stubbs & Pliskoff (1969) also employed a CO-key procedure and found that CO rate decreased as a function of COD duration; CO responding was significantly highest when there was no COD. A close inspection of their raw data reveals that main-key responding was generally greater when a COD was present; however, no consistent relation is observed between COD duration and main-key responding, although main-key responding was greatest at the longest COD duration for two of the three subjects.

Other Variables. CO behavior under concurrent VI schedules has recently been studied in relation to overall reinforcement density using a two-key procedure with a 2-s COD (Alsop & Elliffe, 1988). At each overall reinforcement density value, CO rate decreased as the relative reinforcement ratios deviated from equality, i.e., CO rate was an inverted U-shaped function of the relative reinforcement ratio, peaking at .5. However, it was also reported that the inverted U-shaped function was less peaked as the overall reinforcement density increased. Furthermore, CO rate decreased with reductions in overall reinforcement density. Because total response output (current responding) also declined with decreases in the overall reinforcement density, the average consecutive responses under each component schedule prior to a CO response remained constant at all overall reinforcement density values. Note that the greater the overall reinforcement density, the greater the frequency of reinforcement for responses immediately following a CO (and a 2-s COD in this case).

Three studies examined various methods of punishing CO behavior under concurrent VI schedules. Todorov (1971) consequated CO responding in a CO-key procedure with electric shocks in one condition and timeouts in another. During a timeout period, all the lights were turned off and all schedules ceased to function. CO rate was inversely related to shock intensity and timeout duration. Pliskoff (reported in Stubbs et al., 1977) varied the ratio requirement of a functional CO response. For FR values from 5 to 20, changing over was a decreasing function of the FR requirement (cf., Findley, 1958). Baum (1982) studied the effects of impeding a pigeon's CO response by introducing a travel requirement between the CO-key and the main-key, e.g., a partition of increasing lengths and a hurdle of increasing heights. As the travel impediment became larger, CO rate decreased and a preference for the favored alternative (i.e., the shorter interval schedule) increased.

<u>Summary and Extension</u>. Under some conditions in the

concurrent operant paradigm (e.g., concurrent VI schedules, progressive schedules, schedule-dependent VR schedules), a CO response can function to increase the frequency of reinforcement for main-key responding in the CO-key procedure or responding on either key regardless of position in the two-key procedure. If a CO response is acquired and/or maintained because of this function, it may be classified as a precurrent operant.

The studies reviewed in this section suggest the following tentative conclusions that should be subjected to future research. First, the relationship between relative reinforcement ratios and CO responding, as analyzed by Dreyfus et al. (1982), and the relationship between overall reinforcement density and CO responding suggest that precurrent responding may be a function of the likelihood that a reinforced current response immediately follows a precurrent response. This relationship appears to hold only when a precurrent response also produces an exteroceptive stimulus change (Bourland & Miller, 1981). Second, the relationship between COD duration and CO responding suggests that precurrent responding may be a function of the minimum interval that a precurrent response can be followed by a reinforced current response. This relationship also appears to be affected by whether or not a precurrent response produces an exteroceptive stimulus change; when it does, higher rates of precurrent responding are observed at each each interval value (Bourland & Miller, 1978).

The conclusions stated above are based on a molecular analysis of precurrent and current responses. Conclusions based on the molar relationship between precurrent response rate and overall frequency of reinforcement as described earlier by Catania (1966) are not possible since no study reviewed in this section reported on how overall frequency of reinforcement varied as a function of the observed changes in CO responding. CO responding did not produce more reinforcement in these studies since the standard procedure was to run a session until a specified number of reinforcers were obtained. However, the very nature of concurrent VI schedules suggests that more reinforcers would be obtained in a shorter period of time given CO responding. Future research should address this issue.

Some studies reviewed in this section demonstrated that punishment in the form of response cost, timeout, and shock can effectively reduce precurrent responding. Unanswered is the question of how the effectiveness of punishment is related to what maintains the precurrent behavior, e.g., the degree to which a precurrent response increases the likelihood of reinforcement for current responding (cf., Catania, 1984, p. 84). Another interesting unstudied question is how punishment of precurrent behavior affects current responding.

There are two features lacking in many of the studies reviewed in this section. First, no study directly assessed covariations in precurrent (CO) and current (total response output) responding as a function of the same independent variable. A close examination of those studies in which the appropriate data were reported reveals the following. An independent variable (i.e., relative reinforcement ratios) can affect precurrent responding without affecting current responding. An independent variable (i.e., COD duration) can produce opposite effects on precurrent and current responding. An independent variable (i.e., overall reinforcement density) can produce the same effect on precurrent and current responding. These results emphasize the importance of maintaining a functional distinction between precurrent and current operants.

Second, the studies reviewed in this section were concerned with steady-state behavior (maintenance) and not transitions from one condition to another (acquisition). As Skinner (1986) has recently noted about "choice":

> When a schedule is suddenly changed so that the current rate of responding does not match the frequency of reinforcement, the behavior does not immediately change. Mediating processes must be conditioned before the new performance matches and the conditioning is presumably the same as that which explains all schedule

effects. (p. 232)

In sum, the independent variables described throughout this section need to be examined more systematically in terms of the effects on both precurrent _and_ current responding during both maintenance _and_ acquisition.

Most of the studies reviewed in this section were primarily concerned with the effects of the above variables on response and time allocation on the concurrent operant schedule components. The major finding is that organisms distribute their behavior and time between the alternatives in the same proportion that reinforcements are distributed across those alternatives. This has come to be known as the _matching law_. An organism which shows a stronger preference than predicted by the matching relation for the schedule providing the more frequent reinforcement is said to demonstrate _overmatching_; conversely, a weaker preference than predicted for the richer schedule is called _undermatching_ (cf., de Villiers, 1977, pp. 239-242).

In the concurrent operant paradigm the matching relation holds with a COD "of sufficient value" (see de Villiers, 1977, p. 243). Otherwise,

> too brief a COD may permit patterns of responding that involve two or more alternatives. If a pigeon's pecking at the two keys falls into patterns that include both keys (e.g., alternation), the performance effectively combines the two manipulanda into one and

reduces the two supposed alternatives to one. By breaking up patterns of responding across alternatives, the COD functionally separates the alternatives and allows choice between them to occur. Indeed, the COD may not only lengthen bouts of responding but also may enforce truly independent bouts at the alternatives. To the extent that the COD fails, the two alternatives are treated as one, and undermatching occurs. (Baum, 1979, p. 279).

Evidence was provided earlier to indicate that CO rate is inversely related to the length of the COD. This combined with the fact that matching law only holds with COD's of sufficient value lead Pliskoff (1971) to ask "whether changeover responding is a by-product of response distribution and/or time allocation or whether the latter are by-products of changeover responding" (p. 255). Similarly, Dreyfus et al. (1982) suggested that "the matching relation might be the outcome of specific patterns of changing over, which are a function of the changing probabilities of reinforcement for staying on a schedule or changing to the alternate schedule (pp. 337-338). While "the changeover model more easily employs the language of response and consequence common to behavior analysis" (Pliskoff, 1971, p. 255), results contrary to it have been reported. For example, while Stubbs & Pliskoff (1969) found that CO rate decreased as a function of increases in the COD, they also reported that relative response and relative time measures approximated the matching law at all COD values. Scown (1983; reported in Davison & McCarthy, 1988) found the matching relation to hold using a two-key procedure with COD's varying from 2 to 15 s and undermatching to occur when there was no COD.

The matching law does not hold up as well when other variables that affect CO rate are manipulated. Pliskoff & Fetterman (1981) reported overmatching for both response rate and time allocation measures when an FR 4 requirement was placed on the CO-key. Baum (1982) also reported overmatching for both response rate and time allocation measures when the travel requirement for a CO response was increased. In addition, Baum (1982) reanalyzed the data of Todorov (1971) and found overmatching when a CO response was punished with a shock or a blackout, although it was less extreme for time allocation than for response rate. Overmatching is an extremely rare phenomenon in the matching literature: of 103 data sets reviewed by Baum (1979) only three revealed overmatching that was statistically significant. As previously described, each of the aforementioned variables has also been found to reduce CO rate, suggesting that overmatching may be the result of a reduced CO rate. However, contrary to this speculation, Alsop & Elliffe (1988) found greater undermatching the lower the overall reinforcement rate;

recall that these authors also reported that lower overall reinforcement rates were correlated with lower CO rates. Because of these divergent findings, it is premature to conclude just how CO behavior (or, in our terms, precurrent behavior) is related to the matching law.

Observing Behavior

In the observing procedure, reinforcement for responding on one manipulandum (current response) is programmed according to a mixed schedule such that Schedule A alternates impracticably with Schedule B; a response on a second manipulandum (observing response or, in our terms, precurrent response) produces a stimulus correlated with the schedule presently in effect for current responding. The basic finding, replicated with a variety of species and a variety of responses, is that when the stimuli are correlated with reinforcement and extinction, their production maintains a substantial level of observing; when there is no correlation, observing is not maintained (Dinsmoor, 1983).

The question arises as to the individual reinforcing effects of the stimuli correlated with reinforcement and extinction. The results strongly support the conclusion that observing is maintained only by the stimulus correlated with reinforcement (S^D); in fact, the production of an S-delta punishes observing behavior (Mueller & Dinsmoor, 1986). In general terms, bad news about behavioral consequences, even though informative, is not reinforcing. This relation appears to hold for human subjects even though they may report using a strategy that takes the "informativeness" of the stimuli into account (Case, Fantino, & Wixted, 1985; Experiment 1). In another study (Fantino & Case, 1983), no subject reported observing to produce information that reinforcement was not forthcoming.

In the typical observing procedure described above, observing could be said to provide temporal information, i.e., <u>when</u> current responding will be reinforced. Bowe & Dinsmoor (1983) set up a condition under which observing produced spatial information, i.e., <u>where</u> current responding will be reinforced. Specifically, an observing response produced a stimulus signalling which of two keys must be pecked in order to produce reinforcement. Spatial information, unlike temporal information, did not maintain observing even though subjects acquired the spatial discrimination. These results imply that it is important to maintain a functional distinction between a stimulus as discriminative and the same stimulus as a conditioned reinforcer. For present purposes, we could conclude that precurrent responding will not necessarily be maintained by the production of an S^D.

Dinsmoor, Bowe, Green & Hanson (1988) addressed the question as to whether stimuli differentially correlated with contingent (VI) and non-contingent (VT) reinforcement would reinforce observing. They found that current response rates were low during VT and relatively high during VI; thus, a differential response effort was involved. The stimuli maintained observing at higher rates when correlated with the VI and VT schedules than under a control condition when there was no correlation. However, by far the highest rates of observing were noted when the stimuli were correlated with reinforcement-extinction, regardless of whether the reinforcement schedule was VI or VT. Thus, the production of a stimulus correlated with the presence/absence of response effort to produce a reinforcer has minor reinforcing effects relative to a stimulus correlated with the presence/absence of reinforcer delivery.

Each of these findings is not intuitively obvious. If a behavior produces an S-delta, a stimulus clarifying which of two responses will be reinforced, or a stimulus signalling whether or not responding is required to produce a reinforcer, we might say that the behavior, using Skinner's terminology, "makes subsequent behavior more effective" (1968, p. 124). The observing response research has helped clarify which consequences of this type reinforce precurrent behavior.

What maintains observing when the mixed schedules are reinforcement and extinction? Reinforcement is no more likely following observing than at other times. Or is it? Dinsmoor (1983) extensively reviewed the observing literature and concluded that results support a "selective observing" account. In many observing response studies, continual observing (e.g., holding down a perch or standing in the appropriate locus in the chamber) maintains continual contact with the discriminative stimulus; alternatively, the organism can terminate contact with the discriminative stimulus by ceasing to observe. The data clearly show that considerable more time is spent under the S^D. In such cases, the S^D (S+) and S-delta (S-)

> ...serve not only as discriminative stimuli for the food-reinforced response...but also as discriminative stimuli for maintaining or terminating the observing response. This is the discrimination that enables the subject to select more of the available S+ time for observing than it does of the S- time. (Dinsmoor, 1983, p. 701)

Note that selective observing can occur even when the experimenter determines the duration of the discriminative stimuli produced by observing. The organism may continue to look at the S^D for the full duration of its presentation but may immediately look away when the S-delta is presented even though the programmed duration of each discriminative stimulus is equal. Dinsmoor (1983) presents evidence that this is indeed what pigeons appear to do in conventional discrimination experiments. He speculates that

> since the subject spends a larger proportion of its VI (S+) time than of its extinction (S-) time depressing the perch or standing in the appropriate locus in the chamber, it follows that the frequency with which food is delivered must be higher while the subject is performing the behavior necessary to contact S- or S+ than while it is not performing that behavior. To put it simply, the probability of the behavior that produces contact is correlated with the probability of reinforcement. In a sense, this is a superstitious contingency, since the behavior in question is not required for the reinforcer to be delivered. In fact, it has no influence on the frequency of reinforcement. Observing is correlated with the scheduling of reinforcement through the action of the subject rather than the delivery of reinforcement being correlated with the occurrence of the response through the action of the programming circuit. Nevertheless, it seems plausible that the higher density of reinforcement while observing than while not observing may have something to do with the acquisition and maintenance of the particular topography involved...Furthermore, the fact that the response is accompanied by repeated deliveries of the primary reinforcer when it is

> maintained in the presence of S+ but not when it is maintained in the presence of S- may have a bearing on the selective way in which the organism reacts to these two stimuli. That is, the discriminative control of observing behavior may in whole or in part be a product of the selective association of the response itself with reinforcement. (p. 702)

Blough's (1959) analysis of sample-specific behavior in matching-to-sample, Dreyfus et al.'s (1982) analysis of CO behavior under concurrent schedules, and Dinsmoor's (1983) analysis of observing behavior all have a common element: in the presence of precurrent behavior, reinforcement contingent on current behavior occurs more often, even though this contingency may not be explicitly arranged by the experimenter. Note that this enhanced reinforcement frequency can be produced by increasing the likelihood of the current behavior while holding its reinforcement probability constant, or by holding the likelihood of the current behavior constant and increasing its reinforcement probability.

Practical Applications

Teaching is simply the arrangement of contingencies of reinforcement for desired behaviors (Skinner, 1968). Often, the arranged contingency involves providing direct reinforcement for the desired behaviors. However, another arrangement is possible. As noted earlier, precurrent behavior can increase the probability that a current operant response occurs. A series of studies have applied this notion to teaching arithmetic problem solving behavior to preschool children (Parsons, 1973a; 1976) and young developmentally disabled children (Parsons, 1973b; Grimm, Bijou, & Parsons, 1973). In one representative, and the most comprehensive, study (Parsons, 1973a; 1976), children were required to circle from an array of symbols presented on the right side of a page the same number as were presented on the left side (current operant). The dependent variables were percent correct, rate of correct solutions, and overall rate. Initially, the experimenter instructed and then modeled a correct solution response by pointing to each symbol and then circling the appropriate number. In the baseline phase, reinforcement was contingent on correct solution responses. Three of the eight children rapidly acquired accurate solution responses under this condition. It should be noted that two of these three subjects emitted precurrent behaviors very similar to those that were to be explicitly trained. In the training phase, children were prompted and reinforced with praise for going through all the symbols on the left side of the page by marking each one as it was vocally counted, and then doing the same thing on the right side (precurrent behavior). If the precurrent behaviors were omitted or incorrectly emitted prior to a solution response, the experimenter stopped the child and instructed him/her to begin again. As in baseline, a correct solution response was reinforced. Later during this training phase, praise reinforcement for precurrent behavior was thinned from VR 2 to VR 7. Accuracy and rate of correct solutions increased for the five remaining subjects during training. When these children were returned to the initial baseline condition, precurrent behavior and high accuracy levels maintained for all subjects. In a third phase, reinforcement was delivered for neither precurrent nor current behavior. Accuracy level, rate correct, and total rate decreased for two subjects, accompanied by unreliable precurrent behavior (e.g., marking too many symbols); for another subject only rate correct and total rate decreased; for the fourth subject there were no performance differences. A return to baseline lead to a return to pre-extinction performances. Preventing precurrent behavior by explicit instruction in a subsequent phase reduced accuracy and rate correct for all five subjects exposed to this phase (i.e., those for whom low accuracy levels were obtained during initial baseline), the levels being comparable to the initial baseline condition. A subsequent return to baseline with precurrent behavior permitted lead to a recovery of post-training levels of precurrent behavior and a return to pre-prevention accuracy levels. Three subjects were exposed to a final phase under which they were progressively instructed to engage in less and less of the precurrent behavior (e.g., vocal counting might be permitted on only one side of the problem). Relative to their performances under the earlier phase in which precurrent behavior was prohibited, "covert" problem solving improved slightly for two subjects while the third subject showed no change.

The data of Parsons (1973a; 1976) clearly show that the precurrent behavior was responsible for increasing the probability that a current operant response was emitted. Consistent with Skinner (1968), precurrent behavior required explicit training (i.e., prompting and reinforcement), and once at strength, continued to be emitted even in the absence of direct reinforcement. (Unfortunately, while Parsons noted that precurrent behavior occurred during post-training baseline phases, no specific data are reported.)

It is worth noting a very important point discussed by Parsons (1973a; 1976). His baseline condition, continual differential reinforcement for correct answers, has often been applied as the treatment or experimental condition in behavior modification studies. However, such a condition improved the performance of only three of eight subjects. Unfortunately, reinforcing correct answers (and punishing incorrect ones) is frequently the method of instruction in classrooms. As Skinner (1968) notes, "this method does not teach; it simply selects those who learn without being taught" (p. 118). A teacher who focuses solely on the reinforcement contingency for current responding may look to more powerful reinforcers or different schedules of reinforcement, probably to no avail. For Parsons, focusing on precurrent behaviors proved a fruitful course to enhance academic learning of all subjects.

Other related studies in applied behavior analysis concentrate primarily on demonstrating that one behavior can increase the probability of another. While this is part of the task of analyzing precurrent behavior, it is only half the picture. As Skinner (1957) has noted: "Men act upon the world, and change it, and are changed in turn by the consequences of their actions" (p. 1). Thus, the other half of the picture involves studying the effects of the consequences of precurrent behavior on the probability of the precurrent behavior.

Two recent studies in the Journal of Applied Behavior Analysis illustrate this point. Guevremont, Osnes, & Stokes (1988) employed a self-instructional package with four, 4-5 year old children. The task was to identify and circle sequences of letters within words that contained the sample phonetic unit (current behavior).

Self-instructional training included four steps:

(a) problem orientation (e.g., "What do I have to do first?", (b) task statement (e.g., "I have to circle words that have the same letters"), (c) guiding self-verbalizations (e.g., "Not this one so I won't circle it" or "This one so I will circle it"), and (d) self-acknowledgement (e.g., "Good job"). (p. 47)

During training, the children "received specific praise for correct self-instruction use (e.g., saying the instructions appropriately) when the self-verbalizations were congruent with correct performance" (p. 47). Incorrect self-instruction, off-task behavior, and circling the wrong items were consequated with corrective feedback. Following each training session, there was a work period which was preceded by the teacher telling the student to say the instructions out loud. In this work period, the teacher stood behind the child and praise was delivered only for on-task behavior. In a generalization condition, praise was delivered for on-task behavior in a classroom setting. Overt self-instruction enhanced accuracy during work periods but self-instruction did not generalize to the classroom condition and accuracy remained low. When children were told to say the instructions out loud in the classroom, accuracy levels increased for three of the four children. When this instruction was removed, two of these three children ceased using overt self-instructions and accuracy levels dropped accordingly, while high accuracy and self-instruction was maintained for the third child. In a subsequent condition, the children were told to say the instructions to themselves in the classroom and accuracy levels maintained for the high-accuracy subject and rose for the other two. In this latter condition, the authors noted that the three children "were anecdotally observed to use lip movements during covert instructions conditions, suggesting that self-instructions were being used" (p. 51). When the instruction for covert self-instruction was removed, the frequency of self-instruction declined for the same two subjects and once again their accuracy levels fell.

This study clearly showed that self-instruction increased the probability of a correct solution response. However, an equally relevant unanswered question is why the precurrent behavior did not maintain for some subjects without explicit instruction from the teacher. Self-instruction was probably an example of rule-governed behavior (Skinner, 1969), insensitive to consequences other than the consequence provided by others for not following the rules. In this study, a current operant response is to be distinguished from a correct solution response. Reinforcement in the classroom was provided for staying on task, and thus on-task behavior was the current operant. Had reinforcement been provided for correct solution responses, then perhaps the contingency between self-instruction and an increased probability of a correct answer may have maintained self-instruction.

Another case in point involves a study about improving athletic performance, specifically, tennis (Zeigler, 1987). The precurrent behavior consisted of a stimulus cueing technique: (1) vocalize the word "ball" when the ball was fired from the machine, (2) vocalize the word "bounce" as the ball contacted the surface of the court, (3) vocalize the word "hit" when the ball contacted the racket, and (4) vocalize the word "ready" in preparation for the next ball. The results clearly showed that stimulus cueing (precurrent behavior) increased the probability of a correct hit (current operant). Again, however, a question not considered in this study is whether this contingency would maintain the precurrent behavior. In the treatment condition, subjects were instructed to use the stimulus cueing technique. Like the previous study, the precurrent behavior may be rule-governed rather than maintained by its effect of increasing the probability of the current operant.

The point here is that it is not enough to show that precurrent behaviors such as self-instruction and stimulus cueing can increase the probability of another "correct" behavior; such relationships undoubtedly occur. Clearly precurrent behavior can be induced by instructions or supplemental direct reinforcement; but will such behavior maintain due to its effect on the current operant? Must a child always be told to say "please" when asking for something? Must he always be told to think before he speaks? Must contrived reinforcers always be present to ensure the continued emission of these behaviors? Or, can we rely on "behavioral traps" to maintain precurrent behavior in the natural environment (cf., Stokes & Baer, 1977)? The answers to these questions have a direct bearing on the degree to which "self-control" is possible (cf., Skinner, 1953). A laboratory analysis of precurrent operants may provide some of these answers.

APPENDIX B

Informed Consent Form

This is to confirm that I am volunteering to take part in this experiment and that I am under no external pressure to do so.

I understand that I am free to discontinue my participation in this experiment at any time.

I understand that information concerning my participation will be held in confidence.

I will not divulge any information about the nature of my participation at least until the end of the experiment.

I understand that it is possible to obtain a summary of the experiment following completion of the research if I leave my address with the experimenter or if I wish to contact the experimenter at a later time.

I understand that it is possible to earn money during the experimental sessions.

I understand that if I participate for a total of at least 6 hours then I will be paid a bonus of $1.00 for every one of these hours on the last day of my involvement in this experiment.

____

(printed name and signature of participant)

____

(signature of experimenter)

____

(date)

APPENDIX C1

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S1.

SESSION	MEAN RESPONSE RUN[a]			
	PRECURRENT		CURRENT	
2	4.7	(3.6)	72.6	(118.9)
3	13.8	(12.2)	319.6	(275.0)
4	4.3	(3.1)	1281.7	(1232.7)
5	5.0	(0)	2801.5	(2699.5)
6	0	(0)	5549.0	(0)
7	3.5	(0.5)	1773.7	(2034.9)
8	3.5	(2.5)	1771.3	(2011.8)
9	4.5	(1.5)	1642.0	(930.0)
10	9.1	(6.7)	637.6	(578.3)
11	13.0	(12.0)	1763.0	(1419.3)
12	2.4	(1.8)	839.2	(880.2)
13	3.0	(1.3)	1345.0	(1343.0)
14	3.0	(0)	2657.5	(2643.5)
15	3.0	(2.0)	1109.8	(825.0)
16	22.0	(20.0)	978.2	(1059.1)
17	5.0	(0)	2625.0	(2592.0)
18	1.5	(0.5)	1639.0	(785.3)
19	4.5	(2.5)	2416.5	(2413.5)
20	2.0	(0)	2577.5	(2533.5)
21	6.0	(5.0)	985.0	(1432.4)
22	7.5	(6.5)	1744.7	(1105.8)
23	6.4	(5.3)	734.5	(634.5)
24	8.5	(4.5)	1564.0	(1588.7)
25	6.5	(2.1)	23.1	(17.5)
26	8.5	(3.5)	11.9	(5.3)
27	9.3	(4.1)	21.7	(11.4)
28	8.3	(3.4)	28.4	(17.4)
29	6.5	(2.3)	30.8	(22.4)
30	8.8	(4.4)	59.3	(64.6)
31	10.0	(4.4)	48.6	(41.8)
32	9.6	(5.5)	59.9	(59.5)
33	10.0	(4.4)	475.0	(475.6)
34	7.0	(2.5)	128.4	(171.7)
35	13.6	(5.6)	29.9	(17.7)
36	15.3	(4.6)	41.4	(31.9)
37	17.8	(4.4)	48.4	(36.8)
38	13.9	(4.8)	28.8	(13.9)
39	17.2	(4.3)	36.0	(22.1)
40	19.1	(5.6)	51.5	(30.3)
41	18.0	(4.7)	82.3	(45.5)
42	11.7	(4.6)	178.9	(154.1)

APPENDIX C1 (continued)

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
43	20.5 (5.7)	90.1 (77.3)
44	18.1 (7.0)	614.2 (251.0)
45	13.2 (4.7)	330.9 (329.4)
46	16.7 (5.0)	56.2 (53.8)
47	19.7 (6.3)	169.5 (159.6)
48	13.2 (5.6)	56.4 (50.4)
49	11.0 (2.7)	1259.5 (647.5)
50	1.0 (0)	2688.5 (1711.5)

[a]Number in parentheses indicates mean deviation.

APPENDIX C2

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S2.

SESSION	MEAN RESPONSE RUN[a]			
	PRECURRENT		CURRENT	
1	15.0	(12.1)	108.0	(186.3)
2	1.0	(0)	1067.5	(1178.7)
3	3.5	(3.2)	1285.0	(950.8)
4	0	(0)	6943.0	(0)
5	1.0	(0)	1796.7	(779.7)
6	1.0	(0)	2486.7	(1602.4)
7	1.1	(0.2)	876.4	(463.3)
8	1.0	(0)	2630.3	(2429.1)
9	1.0	(0)	3971.0	(2669.0)
10	1.0	(0)	4010.5	(13.5)
11	1.0	(0)	1955.0	(967.3)
12	0	(0)	8036.0	(0)
13	1.0	(0)	2754.3	(2539.8)
14	6.7	(6.2)	2101.2	(1491.7)
15	1.0	(0)	2575.3	(1716.2)
16	2.0	(1.5)	2102.7	(1943.1)
17	1.0	(0)	4086.0	(3454.0)
18	1.0	(0)	3024.0	(2820.0)
19	2.6	(1.9)	1788.8	(1532.6)
20	0	(0)	8843.0	(0)
21	1.3	(0.4)	2018.2	(2552.9)
22	1.0	(0)	1486.2	(990.2)
23	217.5	(152.5)	3404.0	(3401.0)
24	6.3	(3.2)	70.5	(121.7)
25	2.5	(1.6)	36.3	(29.1)
26	2.5	(1.4)	66.6	(63.5)
27	2.2	(1.3)	70.5	(72.4)
28	2.1	(1.0)	84.5	(75.7)
29	2.2	(1.1)	87.9	(91.7)
30	1.9	(1.1)	150.7	(136.4)
31	1.8	(1.0)	92.6	(81.7)
32	1.6	(0.7)	94.7	(77.8)
33	1.3	(0.5)	81.4	(70.5)
34	1.2	(0.4)	368.4	(306.2)
35	1.9	(1.0)	139.5	(120.1)
36	1.6	(0.8)	148.1	(136.1)
37	2.1	(1.0)	70.5	(70.4)
38	1.8	(0.9)	85.1	(69.0)
39	1.6	(0.7)	164.0	(93.1)
40	1.8	(0.8)	110.1	(75.8)
41	2.0	(1.0)	112.3	(82.3)

APPENDIX C2 (continued)

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
42	1.8 (0.8)	215.5 (152.4)
43	1.8 (0.8)	185.6 (136.0)
44	1.4 (0.5)	285.7 (221.6)
45	1.6 (0.9)	363.9 (338.9)
46	1.8 (0.8)	716.1 (469.4)
47	2.0 (0.9)	93.0 (76.2)
48	1.7 (0.8)	111.5 (68.2)

[a]Number in parentheses indicates mean deviation.

APPENDIX C3

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S3.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	2.5 (2.5)	116.4 (139.8)
2	3.3 (4.2)	191.7 (197.7)
3	4.3 (5.6)	115.8 (187.2)
4	1.2 (0.4)	322.1 (302.2)
5	3.8 (5.0)	631.9 (813.0)
6	9.1 (13.4)	601.7 (969.6)
7	1.4 (0.7)	715.4 (982.4)
8	1.0 (0)	1215.5 (1338.0)
9	1.0 (0)	1389.8 (1304.2)
10	1.0 (0)	1199.5 (1312.7)
11	1.0 (0)	1322.0 (920.8)
12	1.3 (0.4)	114.6 (148.5)
14	1.0 (0)	1561.2 (1377.9)
15	1.3 (0.6)	4.9 (6.9)
16	1.4 (0.6)	224.2 (245.4)
17	1.5 (0.8)	9.6 (15.9)
18	1.1 (0.1)	34.0 (36.5)
20	1.1 (0.2)	6.9 (6.0)
21	1.0 (0)	13.4 (15.6)
22	1.0 (0.0)	18.0 (25.5)
23	1.1 (0.1)	20.4 (23.8)
24	1.0 (0.1)	12.4 (13.5)

[a]Number in parentheses indicates mean deviation.

APPENDIX C4

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S4.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	8.1 (5.9)	119.3 (207.0)
2	8.7 (6.0)	309.9 (562.3)
3	9.1 (9.1)	772.7 (1246.4)
4	0 (0)	5028.0 (0)
5	0 (0)	3546.0 (0)
6	1.0 (0)	144.3 (139.5)
7	1.1 (0.1)	110.9 (55.4)
8	1.0 (0.0)	126.4 (48.9)

[a]Number in parentheses indicates mean deviation.

APPENDIX C5

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S5.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	8.9 (11.6)	195.1 (270.1)
2	4.9 (5.0)	121.7 (189.8)
3	20.0 (0)	3445.5 (2584.5)
4	0 (0)	6939.0 (0)
5	0 (0)	6933.0 (0)
6	4.0 (3.7)	318.2 (366.5)
7	4.8 (2.3)	196.0 (149.2)
8	3.5 (1.7)	135.1 (75.2)
9	2.5 (1.6)	110.0 (51.0)
10	3.5 (1.9)	116.1 (41.8)
11	3.7 (1.9)	89.8 (39.8)
12	4.3 (2.9)	74.8 (56.4)
13	6.8 (7.0)	124.7 (97.8)
14	7.8 (5.8)	127.3 (101.1)
15	5.5 (3.0)	159.5 (114.4)
16	6.9 (3.2)	174.3 (130.4)

[a]Number in parentheses indicates mean deviation.

APPENDIX C6

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S6.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	2.3 (1.5)	32.2 (29.1)
2	2.0 (1.5)	38.2 (24.7)
3	5.0 (5.9)	128.9 (116.4)
4	1.8 (1.3)	52.8 (52.2)

[a]Number in parentheses indicates mean deviation.

APPENDIX C7

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S7.

SESSION	MEAN RESPONSE RUN[a] PRECURRENT		CURRENT	
1	7.9	(1.0)	7.5	(9.9)
2	5.4	(5.2)	9.3	(6.8)
3	4.6	(3.8)	53.9	(59.4)
4	2.2	(1.7)	19.8	(25.1)
5	4.5	(4.6)	44.9	(52.1)
6	8.2	(5.2)	125.0	(128.1)
7	10.2	(6.4)	83.8	(79.4)
8	11.0	(7.6)	106.7	(131.9)
9	6.7	(6.6)	393.7	(551.6)
10	2.0	(1.0)	1984.3	(1503.8)
11	12.4	(7.4)	99.9	(75.9)
12	7.7	(5.5)	63.4	(65.0)
13	8.8	(7.4)	49.9	(43.2)
14	8.2	(5.6)	91.3	(80.9)
15	7.2	(5.2)	532.4	(783.9)
16	0	(0)	6573.0	(0)
17	3.5	(1.5)	2047.3	(2179.8)
18	0	(0)	6344.0	(0)
19	5.6	(2.8)	134.8	(168.3)
20	6.0	(4.0)	44.1	(36.9)
21	5.5	(3.2)	27.2	(20.9)
22	9.0	(4.6)	49.7	(41.2)
23	9.3	(4.6)	88.5	(57.0)
24	11.0	(5.8)	105.4	(57.7)
25	11.4	(4.8)	89.0	(65.3)
26	12.1	(6.3)	76.5	(47.6)
27	8.4	(3.6)	78.4	(40.0)
28	10.1	(4.2)	75.8	(37.8)

[a]Number in parentheses indicates mean deviation.

APPENDIX C8

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S8.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	8.6 (7.0)	145.9 (157.9)
2	30.7 (36.9)	550.6 (547.2)
3	10.0 (4.5)	1063.4 (1510.2)
4	19.0 (0)	2772.0 (2674.0)
5	0 (0)	5826.0 (0)
6	4.0 (0)	2734.5 (758.5)
7	18.0 (8.8)	130.4 (117.8)
8	24.1 (7.9)	134.0 (54.1)
9	15.0 (3.5)	80.9 (48.9)
10	18.4 (2.6)	118.3 (42.0)
11	15.4 (2.0)	133.3 (64.0)
12	17.4 (3.5)	164.7 (54.5)
13	15.7 (1.7)	209.2 (164.2)
14	18.7 (4.4)	833.4 (528.8)
15	12.7 (5.9)	1455.5 (1662.2)
16	16.1 (0.3)	184.2 (82.2)
17	15.1 (2.6)	148.3 (66.1)
18	16.6 (3.4)	153.1 (46.1)
19	15.3 (1.6)	162.2 (66.6)
20	15.9 (0.3)	291.0 (113.3)
21	16.0 (0)	589.1 (358.9)
22	17.1 (6.8)	586.6 (393.6)
23	0 (0)	6202.0 (0)
24	16.1 (0.3)	159.3 (52.9)
25	16.5 (1.4)	175.5 (62.6)
26	15.9 (0.5)	169.3 (70.5)
27	15.9 (0.6)	200.2 (62.8)
28	16.2 (0.4)	239.6 (95.3)
29	16.2 (0.4)	195.9 (77.2)
30	16.5 (1.2)	191.9 (54.5)
31	16.2 (1.3)	228.5 (76.5)
32	16.2 (0.4)	259.4 (80.3)
33	16.0 (0)	249.5 (83.7)
34	16.4 (0.6)	270.8 (108.1)
35	16.0 (0)	267.9 (119.2)
36	17.7 (2.7)	271.3 (150.9)

[a]Number in parentheses indicates mean deviation.

APPENDIX C9

Mean Precurrent and Current Response Run and Their Mean Deviations for Each Session for S9.

SESSION	MEAN RESPONSE RUN[a]	
	PRECURRENT	CURRENT
1	12.6 (11.5)	45.5 (40.6)
2	24.2 (3.8)	105.7 (19.8)
3	11.6 (9.8)	85.8 (41.5)
4	26.4 (5.2)	111.3 (24.6)
5	31.6 (9.5)	147.6 (84.2)
6	36.5 (8.6)	128.2 (62.4)
7	19.2 (7.5)	149.4 (116.8)
8	35.3 (10.0)	896.3 (847.2)

[a]Number in parentheses indicates mean deviation.

APPENDIX D

Formula for Calculating Mean Deviation.

$$\text{Mean Deviation} = \frac{\sum |X_i - \bar{X}|}{N}$$

APPENDIX E1

Obtained Pn, Pi, and Pc Values Across All Sessions for S1.[a]

SESSION	Pn	Pi	Pc
2	.042 (.04)		.034 (.04)
3	.038 (.04)		.038 (.04)
4	.043 (.04)		.035 (.04)
5	.036 (.04)		.042 (.04)
6	.041 (.04)		—— (.04)
7	.042 (.04)		.064 (.04)
8	.042 (.04)		.080 (.08)
9	.040 (.04)		.095 (.08)
10	.045 (.04)		.093 (.08)
11	.037 (.04)		.120 (.08)
12	.043 (.04)		.090 (.08)
13	.041 (.04)		.059 (.08)
14	.042 (.04)		.058 (.08)
15	.017 (.02)		.074 (.08)
16	.020 (.02)		.086 (.08)
17	.020 (.02)		.073 (.08)
18	.023 (.02)		.087 (.08)
19	.020 (.02)		.104 (.12)
20	.022 (.02)		.079 (.12)
21	.022 (.02)		.126 (.12)
22	.018 (.02)		.106 (.12)
23	.021 (.02)	.267 (.32)	.122 (.12)
24	.016 (.02)	.133 (.32)	.107 (.12)
25	.016 (.02)	.489 (.50)	.120 (.12)
26	.048 (.02)	.253 (.24)	.078 (.08)
27	.022 (.02)	.097 (.12)	.081 (.08)
28	.027 (.02)		.084 (.08)
29	.022 (.02)		.085 (.08)
30	.019 (.02)		.084 (.08)
31	.014 (.02)		.080 (.08)
32	.024 (.02)		.079 (.08)
33	.019 (.02)		.067 (.08)
34	.021 (.02)		.081 (.08)
35	.018 (.02)		.075 (.08)
36	.021 (.02)		.083 (.08)
37	.024 (.02)		.083 (.08)
38	.016 (.02)		.092 (.08)
39	.022 (.02)		.082 (.08)
40	.025 (.02)		.074 (.02)
41	.018 (.02)		.080 (.08)
42	.022 (.02)		.019 (.02)
43	.017 (.02)		.022 (.02)

APPENDIX E1 (continued)

SESSION	*Pn*	*Pi*	*Pc*
44	.020 (.02)		.009 (.02)
45	.022 (.02)		.022 (.02)
46	.023 (.02)		.086 (.08)
47	.023 (.02)		.075 (.08)
48	.017 (.02)		.091 (.08)
49	.021 (.02)		.042 (.08)
50	.023 (.02)		.047 (.08)

[a]Number in parentheses indicates scheduled value.

APPENDIX E2

Obtained Pn, Pi, and Pc Values Across All Sessions for S2.[a]

SESSION	Pn	Pi	Pc
1	.044 (.04)		.036 (.04)
2	.042 (.04)		.027 (.04)
3	.039 (.04)		.057 (.04)
4	.038 (.04)		---- (.04)
5	.041 (.04)		.049 (.04)
6	.040 (.04)		.088 (.08)
7	.042 (.04)		.085 (.08)
8	.045 (.04)		.065 (.08)
9	.045 (.04)		.081 (.08)
10	.042 (.04)		.082 (.08)
11	.046 (.04)		.080 (.08)
12	.032 (.03)		---- (.08)
13	.030 (.03)		.061 (.08)
14	.023 (.02)		.078 (.08)
15	.020 (.02)		.047 (.08)
16	.018 (.02)		.074 (.08)
17	.018 (.02)		.061 (.08)
18	.019 (.02)		.102 (.08)
19	.020 (.02)		.095 (.08)
20	.019 (.02)		---- (.08)
21	.010 (.01)		.082 (.08)
22	.010 (.01)		.118 (.08)
23	.010 (.01)		.079 (.08)
24	.011 (.01)	.252 (.24)	.064 (.08)
25	.007 (.01)	.123 (.12)	.058 (.06)
26	.018 (.02)		.065 (.06)
27	.021 (.02)		.057 (.06)
28	.018 (.02)		.057 (.06)
29	.021 (.02)		.060 (.06)
30	.021 (.02)		.058 (.06)
31	.023 (.02)		.064 (.06)
32	.018 (.02)		.059 (.06)
33	.016 (.02)		.055 (.06)
34	.023 (.02)		.063 (.06)
35	.019 (.02)		.077 (.08)
36	.019 (.02)		.084 (.08)
37	.022 (.02)		.080 (.08)
38	.022 (.02)		.079 (.08)
39	.023 (.02)		.088 (.08)
40	.023 (.02)		.073 (.08)
41	.014 (.02)		.072 (.08)
42	.020 (.02)		.085 (.08)

APPENDIX E2 (continued)

SESSION	*Pn*	*Pi*	*Pc*
43	.024 (.02)		.085 (.08)
44	.021 (.02)		.101 (.08)
45	.020 (.02)		.083 (.08)
46	.023 (.02)		.072 (.08)
47	.018 (.02)		.085 (.08)
48	.019 (.02)		.083 (.08)

[a]Number in parentheses indicates scheduled value.

APPENDIX E3

Obtained Pn, Pi, and Pc Values Across All Sessions for S3.[a]

SESSION	Pn	Pi	Pc
1	.019 (.02)	.026 (.02)	.095 (.08)
2	.019 (.02)	.026 (.02)	.082 (.08)
3	.022 (.02)	.045 (.02)	.057 (.08)
4	.019 (.02)	.020 (.02)	.079 (.08)
5	.019 (.02)		.070 (.08)
6	.018 (.02)		.062 (.08)
7	.019 (.02)		.062 (.08)
8	.020 (.02)		.064 (.08)
9	.020 (.02)	.107 (.16)	.042 (.08)
10	.022 (.02)	.149 (.16)	.059 (.08)
11	.021 (.02)	.244 (.20)	.081 (.08)
12	.017 (.02)	.225 (.20)	.075 (.08)
13	.018 (.02)	.196 (.20)	.110 (.08)
14	.020 (.02)	.360 (.20)	.069 (.08)
15			.080 (.08)
16	.009 (.01)		.093 (.08)
17			.080 (.08)
18	.009 (.01)		.078 (.08)
20	.007 (.01)		.079 (.08)
21	.006 (.01)		.083 (.08)
22	.010 (.01)		.075 (.08)
23	.009 (.01)		.096 (.10)
24	.009 (.01)		.110 (.10)

[a]Number in parentheses indicates scheduled value.

APPENDIX E4

Obtained Pn, Pi, and Pc Values Across All Sessions for S4.[a]

SESSION	Pn	Pi	Pc
1	.016 (.02)		.011 (.02)
2	.020 (.02)		.024 (.02)
3	.023 (.02)		.028 (.02)
4	.020 (.02)		--- (.08)
5	.021 (.02)		--- (.08)
6	.019 (.02)		.078 (.08)
7	.019 (.02)		.087 (.08)
8	.019 (.02)		.074 (.08)

[a]Number in parentheses indicates scheduled value.

APPENDIX E5

Obtained Pn, Pi, and Pc Values Across All Sessions for S5.[a]

SESSION	Pn	Pi	Pc
1	.018 (.02)		.029 (.02)
2	.022 (.02)		.024 (.02)
3	.021 (.02)		.045 (.02)
4	.019 (.02)		--- (.08)
5	.020 (.02)		--- (.08)
6	.019 (.02)		.085 (.08)
7	.020 (.02)		.086 (.08)
8	.018 (.02)		.079 (.08)
9	.017 (.02)		.082 (.08)
10	.018 (.02)		.083 (.08)
11	.022 (.02)		.083 (.08)
12	.019 (.02)		.074 (.08)
13	.018 (.02)		.019 (.02)
14	.019 (.02)		.020 (.02)
15	.022 (.02)		.022 (.02)
16	.018 (.02)		.019 (.02)

[a]Number in parentheses indicates scheduled value.

APPENDIX E6

Obtained Pn, Pi, and Pc Values Across All Sessions for S6.[a]

SESSION	*Pn*	*Pi*	*Pc*
1	.018 (.02)		.080 (.08)
2	.024 (.02)		.074 (.08)
3	.022 (.02)		.071 (.08)
4	.020 (.02)		.081 (.08)

[a]Number in parentheses indicates scheduled value.

APPENDIX E7

Obtained Pn, Pi, and Pc Values Across All Sessions for S7.[a]

SESSION	Pn	Pi	Pc
1	.015 (.02)		.085 (.08)
2	.014 (.02)		.073 (.08)
3	.022 (.02)		.081 (.08)
4	.022 (.02)		.079 (.08)
5	.015 (.02)		.080 (.08)
6	.020 (.02)		.086 (.08)
7	.019 (.02)		.077 (.08)
8	.019 (.02)		.021 (.02)
9	.022 (.02)		.016 (.02)
10	.019 (.02)		.049 (.02)
11	.019 (.02)		.074 (.08)
12	.023 (.02)		.074 (.08)
13	.017 (.02)		.085 (.08)
14	.023 (.02)		.079 (.08)
15	.018 (.02)		.018 (.02)
16	.020 (.02)		--- (.02)
17	.020 (.02)		.096 (.08)
18	.019 (.02)		--- (.08)
19	.017 (.02)		.078 (.08)
20	.022 (.02)		.078 (.08)
21	.018 (.02)		.078 (.08)
22	.021 (.02)		.093 (.09)
23	.018 (.02)		.095 (.09)
24	.021 (.02)		.098 (.09)
25	.022 (.02)		.093 (.09)
26	.025 (.02)		.077 (.08)
27	.016 (.02)		.080 (.08)
28	.019 (.02)		.074 (.08)

[a]Number in parentheses indicates scheduled value.

APPENDIX E8

Obtained Pn, Pi, and Pc Values Across All Sessions for S8.[a]

SESSION	Pn	Pi	Pc
1	.021 (.02)		.062 (.08)
2	.020 (.02)		.076 (.08)
3	.022 (.02)		.080 (.08)
4	.018 (.02)		.097 (.08)
5	.018 (.02)		--- (.08)
6	.019 (.02)		.083 (.08)
7			.071 (.08)
8	.022 (.02)		.094 (.08)
9	.020 (.02)		.082 (.08)
10	.024 (.02)		.082 (.08)
11	.027 (.02)		.082 (.08)
12	.020 (.02)		.077 (.08)
13	.021 (.02)		.023 (.02)
14	.019 (.02)		.017 (.02)
15	.019 (.02)		.012 (.02)
16	.020 (.02)		.088 (.08)
17	.019 (.02)		.081 (.08)
18	.017 (.02)		.087 (.08)
19	.018 (.02)		.083 (.08)
20	.020 (.02)		.089 (.08)
21	.023 (.02)		.077 (.08)
22	.018 (.02)		.071 (.08)
23	.021 (.02)		--- (.08)
24	.021 (.02)		.085 (.08)
25	.016 (.02)		.073 (.08)
26	.020 (.02)		.077 (.08)
27	.023 (.02)		.075 (.08)
28	.020 (.02)		.085 (.08)
29	.023 (.02)		.079 (.08)
30	.016 (.02)		.081 (.08)
31	.020 (.02)		.068 (.08)
32	.019 (.02)		.079 (.08)
33	.019 (.02)		.078 (.08)
34	.022 (.02)		.019 (.02)
35	.022 (.02)		.022 (.02)
36	.015 (.02)		.024 (.02)

[a]Number in parentheses indicates scheduled value.

APPENDIX E9

Obtained Pn, Pi, and Pc Values Across All Sessions for S9.[a]

SESSION	Pn	Pi	Pc
1	.018 (.02)		.079 (.08)
2	.019 (.02)		.078 (.08)
3	.019 (.02)		.084 (.08)
4	.013 (.02)		.082 (.08)
5	.022 (.02)		.015 (.02)
6	.023 (.02)		.017 (.02)
7	.023 (.02)		.020 (.02)
8	.023 (.02)		.012 (.02)

[a]Number in parentheses indicates scheduled value.

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