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Self-Control: Effects of Ratio Size, Intra-Delay Reinforcers, and Response Requirement

Elbert Q. Blakely Jr.
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SELF-CONTROL: EFFECTS OF RATIO SIZE, INTRA-DELAY REINFORCERS, AND RESPONSE REQUIREMENT

by

Elbert Q. Blakely, Jr.

A Dissertation
Submitted to the
Faculty of The Graduate College
in partial fulfillment of the
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Department of Psychology

Western Michigan University
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SELF-CONTROL: EFFECTS OF RATIO SIZE, INTRA-DELAY REINFORCERS, AND RESPONSE REQUIREMENT

Elbert Q. Blakely, Jr., Ph.D.
Western Michigan University, 1988

This study tested the following hypotheses: (a) The preference reversal phenomenon will be found when the delays to reinforcement are defined by fixed-ratio schedules, (b) The preference reversal phenomenon will be observed when intra-delay reinforcers are programmed, and (c) Imposing response requirements during the delay to reinforcement will affect preference for a larger delayed reinforcer over a smaller more immediate reinforcer. In Experiment 1, pigeons chose between two schedules, each a sequence of two fixed-ratio schedules. The second schedule of one sequence offered a small reinforcer and the second schedule of the alternative offered a larger reinforcer. The latter sequence always required more responses than the former. The initial fixed-ratio schedules, which were always equal, programmed access to grain or a hopper flash. The results showed that preference shifted from the sequence with the smaller reinforcer to the sequence with the larger reinforcer (i.e., preference reversal) as the size of the initial fixed-ratio increased. Whether food or a hopper flash
followed the initial fixed-ratio did not greatly affect this relation. When the duration of the hopper flash was increased in other conditions, responding for the sequence with the larger reinforcer increased. These results showed the preference reversal phenomenon when the delays to reinforcement were defined by fixed-ratio schedules and when intra-delay reinforcers were programmed. Thus, the phenomenon is not restricted to procedures in which single time-based schedules define the delays. In Experiment 2, pigeons chose between two fixed-ratio schedules or two fixed-time schedules. One schedule of each pair programmed 2-s access to grain; the other, 8-s access to grain. Preference for the schedule with the 8-s reinforcer decreased in some conditions when subjects moved from a choice between the fixed-ratios to a choice between the fixed-time schedules. These results suggest that preference for a larger more delayed reinforcer is dependent on the type of schedule used to define the delays to reinforcement.
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Self-control: Effects of ratio size, intra-delay reinforcers, and response requirement

Blakely, Elbert Q., Jr., Ph.D.
Western Michigan University, 1988
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Elbert Q. Blakely, Jr.
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CHAPTER I

INTRODUCTION

Background of the Study

In traditional formulations of self-control, the locus of control resides within the person. According to Freud's interpretation, the ego restrains impulses, thereby postponing gratification (Karoly, 1982). Klein (1976) also posits that the ego develops adaptive controls which determine and control behavior. Mikulas (1986) suggests further that "Associated with self-control...is a sense of a personal, individualized self which is the seat of awareness and the agent of volitional change" (p. 302). But the "self" and its many aliases are at best, hypothetical causal variables of little or no practical value in predicting and controlling behavior (Skinner, 1953). In behavioral interpretations, however, self-control is a special class of behavior that is a function of environmental variables. Because of the focus on contingencies of reinforcement (Brigham, 1982; Rachlin, 1974; Skinner, 1953), such an approach affords opportunities for conditioning self-control behaviors. It is in this spirit that behavioral research has investigated the
environmental variables of which self-control is a function.

In one behavioral model of self-control, behavior that is determined by immediate consequences and relatively insensitive to more delayed outcomes is termed "impulsive" (Ainslie, 1974). Overeating, excessive smoking and drinking, and aggression are examples of such behavior. The problem for the individual and for others is that the delayed consequences of impulsive behavior are often harmful (e.g., injury, illness), and unfortunately, do not sufficiently weaken the behavior. Behavior that is a function of delayed, and often more important consequences, is said to exemplify "self-control" (Rachlin, 1974). Foregoing a delicious but fattening dessert, avoiding a drinking establishment, and counting to "10" to prevent a temper tantrum are examples of self-control. Unfortunately, self-control can be infrequent because there are immediate aversive consequences of such behavior (Rachlin, 1974), or the immediate consequences of impulsive behavior prevail. The beneficial long-term consequences of impulsive behavior make it important to find ways to encourage self-control.

Two behavioral approaches to studying self-control are noteworthy. In one, subjects are trained to use procedures, such as self-reinforcement, manipulation of
discriminative stimuli, and self-punishment, that are derived from their laboratory counterparts. Such procedures presumably increase the effectiveness of delayed consequences, although their mechanisms of action are unclear. Some interpret their actions as identical to those of the laboratory counterparts (Bandura, 1976); others posit more complex processes (Catania, 1975; Goldiamond, 1976). In the second approach, which is employed in the present study, subjects are given a choice between a less preferred reinforcer and a more preferred, but delayed, reinforcer (e.g., Rachlin & Green, 1972; Mischel & Ebbeson, 1970). Choosing the former is said to be "impulsive"; choosing the latter, "self-control" (Rachlin, 1974). The conditions under which subjects show self-control, or, in other words, select the more preferred delayed reinforcer, are then examined. Subjects are not trained to use a particular self-control skill, such as self-reinforcement, like those used in the first approach just discussed.

Early research investigated subject characteristics that were correlated with preference for larger delayed consequences. For example, Mischel and Metzner (1962) gave children of different ages a choice between a small candy bar delivered immediately, or a larger candy bar delivered later (i.e., from 1 day to 4 weeks after). Results showed that preference for the larger delayed
candy increased with age and with scores on intelligence tests. The results of other research suggested that preference for larger delayed consequences can be predicted by cultural group membership (Mischel, 1958). Although correlational, these studies suggest that self-control may be strongly determined by history. What specific variables are important were not investigated and are, as yet, unknown.

More recent research has manipulated characteristics of the choice situation, among them the temporal variables of and behavioral requirements during the delay to reinforcement. Investigators have used two general procedures.

**Intra-Delay Choice Procedures**

In intra-delay procedures, subjects either wait for a preferred reinforcer that is delayed, or respond during the delay for a less preferred immediate reinforcer. The general research question is the following: Given an opportunity to wait for a preferred delayed reinforcer, under what conditions will subjects instead choose a less preferred immediate reinforcer during the delay?

Some research manipulated the time to the larger reinforcer (Logue & Pena-Correal, 1984). Pigeons chose between 6-s access to food delayed by $t$ s and 2-s access to food delayed by $0.11$ s. Pecks during the delay to the
larger reinforcer immediately produced 2-s access to food. When \( t \) was low (i.e., .11 s), most initial choices were for the larger delayed reinforcer. As \( t \) increased (i.e., to 6 s), pecking during the delay increased in almost one-half of the birds. Thus, as the differences in the delays increased (i.e., as the delay to the larger food delivery increased), responding for the smaller reinforcer during the delay also increased.

Studies have shown that events or behavior during the delay affect self-control. Children could wait for a preferred reinforcer (i.e., a treat identified in pre-testing), or signal for a less preferred reinforcer that was delivered immediately after the signal (Mischel & Ebbeson, 1970). Subjects waited longer for the more preferred reinforcer when the reinforcers were concealed than when they were visible. Using a similar procedure, children waited longer for the more preferred reinforcer when they were instructed to think about "fun" activities (e.g., singing, swinging) than when they were instructed to think about the reinforcers, or if they were not instructed at all (Mischel, Ebbeson, & Zeiss, 1972). In addition, more waiting was observed when the children were provided with toys during the delay. These results suggest that waiting for a more preferred delayed reinforcer may be increased by "distractions" (i.e., the emission of incompatible behaviors unrelated to
reinforcer consumption).

Similar results were reported with pigeons (Grosch & Neuringer, 1981). A more preferred and less preferred type of grain were identified during pre-experimental sessions. During experimental sessions, the preferred grain was available after a delay; the less-preferred grain was available during the delay, but was contingent on key-pecks. Waiting for the preferred grain occurred more often when the grain was concealed than when it was visible. More waiting was also observed when a concurrent response and reinforcement schedule (i.e., FR 20) was available. In another phase, some birds earned access to the preferred grain by not responding for 3 s. When later tested, these birds waited longer for the preferred grain, which was contingent on waiting for 20 s, than birds with a history of pecking for the less preferred immediate grain. Thus, a history of reinforcement for behavior incompatible with responding for the less-preferred grain increased waiting for the preferred delayed grain.

**Pre-Delay Choice Procedures**

Pre-delay choice procedures assay responding for large and small reinforcers without permitting responding for the smaller reinforcer during the delays. The general research question with this class of procedures
is this: Given a choice between a small reinforcer and one that is larger but more delayed, under what conditions will subjects choose the latter when a choice once-made cannot be changed? In discrete-trials procedures, the choice is usually made by emitting a single response on one of two response operands after which the selected delay is timed and the appropriate reinforcer is delivered. An intertrial interval (ITI) follows each trial. "Preference" for one of the alternatives is defined by the proportion of trials on which that alternative was selected. A second assay is the concurrent chains schedule. The initial schedules of each chain, which are available simultaneously, are typically variable-interval (VI) schedules. When the response requirement for either of the VI schedules is completed, entry into the terminal link schedule of the chain that was selected is accompanied by a stimulus-change. At this time, the other chain schedule is inoperative. Reinforcement is delivered after the completion of the terminal link schedule, followed by a return to a choice between the initial link schedules. "Preference" for the terminal schedules is assessed by examining the distribution of responding to the initial link schedules (Reynolds, 1975).

Under both discrete-trials procedures and concurrent-chains schedules, the reinforcer delays are
usually defined by the values of time-based schedules (i.e., the terminal schedules in the concurrent-chains schedule). For example, fixed-time (FT) or fixed-interval (FI) schedules that offer different magnitudes of reinforcement are programmed. The larger delayed reinforcer is programmed by linking the schedule with the longer time requirement and the larger food delivery; the smaller more immediate reinforcer is arranged by linking the schedule with the shorter time requirement and the smaller food delivery.

Some research with pigeons investigated different methods of introducing delays to reinforcement (Logue, Rodriguez, Pena-Correal, & Mauro, 1984). Under a discrete-trials procedure, pigeons chose between two schedules, one of which was an FT 6 s that delivered 6-s access to food, and the other, an FT t s that delivered 2-s access to food. If t was slowly decreased from 6 to .1 s, the birds chose the larger delayed reinforcer more often than when t was rapidly decreased. When differences in reinforcement delay were gradually introduced in other research, preference for larger delayed reinforcers increased (Mazur & Logue, 1978; Logue & Mazur, 1981).

Other studies manipulated the temporal characteristics of the delays to reinforcement. Green and Snyderman (1980) exposed pigeons to a concurrent-
chains schedule with VI schedules in the initial links. The terminal schedules (the delays) were an FI x s that delivered 6-s access to food and an FI y s that delivered 2-s access to food. The delays were varied while holding constant the proportional differences between them. For example, in the 6:1 group, delays were 12 s/2 s (i.e., FI 12 s & FI 2 s), 24 s/4 s, 60 s/10 s, and 120 s/20 s. Two other groups were exposed to schedules in which the proportions were 3:1 and 3:2. For the 6:1 and 3:1 groups, responding for the large delayed food increased with the absolute duration of the delays; for the 3:2 group, there was an inverse relation between the two variables. Subsequent research that eliminated procedural confounds in the above study reported for all three groups increased responding for the large delayed food as absolute delays increased (Snyderman, 1983).

Navarick and Fantino (1976) varied the delays while holding constant the absolute differences between them. Pigeons were exposed to a concurrent chain schedule with FT or FI schedules in the terminal links. The time requirements for the two schedules were t s and t-10 s and the food deliveries were 6 s and 2 s, respectively. Results showed that responding for the larger more delayed reinforcer increased with t. In some conditions, preference shifted from the small more immediate reinforcer to the larger delayed reinforcer. Adult
humans were exposed to a similar procedure. Subjects chose between escape from white noise for short periods of time, or escape for a longer period of time that was presented after a delay (Solnick, Kannenberg, Eckerman, & Waller, 1982). When the short escape was immediately available, subjects chose this alternative almost exclusively. When a 15-s delay was added to both alternatives, subjects preferred the larger delayed escape. Both studies show that when the absolute difference in the delays is held constant, increasing the duration of the delays can shift preference from a smaller reinforcer to a larger reinforcer.

Rachlin and Green (1972) reported similar results when the absolute differences in the delays were held constant. Pigeons were exposed to a concurrent-chains schedule. If the 25th response occurred on the right key, a $t$ s blackout was followed by a choice between 2-s access to food and 4-s access to food delayed by 4 s. If the ratio was completed on the left key, the $t$ s blackout was followed by 4-s access to food delayed by 4 s. When $t$ was low, subjects generally preferred the initial link that produced a choice in the terminal link, and in that link they always chose the smaller immediate food. As $t$ increased to 16 s, preference switched to the non-choice terminal link which offered only the large delayed food. According to the authors, the birds used a "commitment"
strategy. When $t$ was large, the birds chose the link in which a choice was unavailable, and therefore, they were committed to the larger delayed reinforcer because the smaller more immediate reinforcer was unavailable. This commitment phenomenon was demonstrated in other research with humans (Solnick et al., 1982).

The effects of varying delays while holding constant the absolute differences were also studied under an autoshaping procedure (Poling, Thomas, Hall-Johnson, & Picker, 1985). Pigeons received pairings of 6-s blue key illuminations followed by 3-s access to grain, and pairings of 6-s red key illuminations followed by 9-s access to grain. Access to grain was delivered after, on the average, one-half of the trials. The duration of both key illuminations was then increased by adding a constant to each. For two of three birds, responding to the stimulus correlated with larger food deliveries increased with the duration of the stimulus. These results and those of previous investigations (Navarick & Fantino, 1976; Rachlin & Green, 1972; Solnick et al., 1982) show that subjects will often select a small reinforcer that is immediately available over a larger delayed reinforcer. As both delays are incremented by a constant, responding increasingly shifts to the larger more delayed reinforcer. This relation obtained under both response-dependent and response-independent
procedures.

Similar results were reported when spatial distance was manipulated (Boehme, Blakely, & Poling, 1986). In a two-lane runway experiment, rats were given a choice between one pellet delivered immediately upon entry into the goal box, and four pellets delivered 8 s after goal box entry. When runway length was 40 cm, subjects either preferred the smaller immediate reinforcer or they were indifferent; when runway length was increased to 240 cm, all subjects strongly preferred the larger delayed reinforcer. Because spatial distance, effort, and time to reinforcement covaried in this study, the singular effects of each were unclear.

The effects of effort, independent of those of time to reinforcement, were elucidated in a recent study (Grossbard & Mazur, 1986). Pigeons were given a choice between a constant FR schedule that delivered 2-s access to grain and an adjusting FR that offered 6-s access to grain. The constant FR varied across conditions; the adjusting FR was varied within each session until subjects chose the two schedules equally often. Values of the adjusting FR at which subjects were indifferent were identified for each value of the constant FR. In other conditions, FT schedules were yoked to the FR schedules such that the value of the FT schedule equaled the average run time under the FR schedules. Summarizing
results from many conditions, Grossbard and Mazur (1986) concluded that "...the time to the large reinforcer tended to be slightly longer when the alternatives were two FR schedules than when they were two FT schedules" (p. 312). This implies that the relative value of the larger reinforcer is greater under two FR schedules than under two FT schedules, and that effort is a factor in determining responding for larger delayed reinforcers.

Many of the above studies showed that self-control is a function of characteristics of the delays to reinforcement. Other research reported different results (Logue, Pena-Correal, Rodriguez, & Kabela, 1986). Subjects earned points that could be exchanged for money after each session. The delays to money delivery were manipulated in various ways. The results showed that subjects usually chose the larger reinforcer irrespective of the delays. In fact, when queried after the experiment, subjects reported that they attempted to earn the maximum number of points in each session (also see Blakely, Starin, & Poling, in press). The authors suggested that the nature of the reinforcer in their experiment may have strongly affected the results: "All of the previous experiments with pigeons used food-deprived pigeons and food as the reinforcer. In such situations, depending on the degree of food deprivation, there might be some advantage to obtaining food quickly"
It should be noted that many researchers have generated mathematical models in an effort to describe and predict behavior under various self-control procedures. For example, one was suggested by Baum and Rachlin (1969) and is presented below:

\[
\frac{R_1}{V_1} = \frac{A_1}{D_2} = \frac{R_2}{V_2} = \frac{A_2}{D_1}
\]

This equation generally holds that when an organism chooses between two schedules, the ratio of the responses to two alternatives (R1/R2), or the ratio of the values of the alternatives (V1/V2), is directly related to ratio of the magnitudes of reinforcement (A1/A2), and inversely related to the ratios of the delays of reinforcement (D2/D1) of the two alternatives. The extent to which this and other equations predict observed behavior has been addressed in many studies (e.g., Navarick, 1982; Navarick & Fantino, 1976; Snyderman, 1983; Snyderman & Green, 1980). The results of some research (e.g., Navarick & Fantino, 1976; Snyderman, 1983) have suggested that the equation has limited predictive utility and other more complex equations have been proposed (see Snyderman, 1983). The present study will not examine the generality of any particular equation, but instead will focus on general functional relations without
Focus of the Study

The investigations above show that self-control, when defined as choosing a preferred delayed consequence over a less preferred more immediate consequence, is a function of environmental variables, among them the temporal characteristics of the delays, response requirements during the delay, and nature of the reinforcer. More specifically, a major finding is that self-control is a function of where, in time, the subject is required to make the choice. When the choice point is close in time to contact with the immediate reinforcer, that reinforcer is selected. But when the choice point is temporally separated from the reinforcers, by adding a constant to both delays, responding shifts to the larger reinforcer (see Rachlin, 1974). This preference reversal has been shown in many studies (e.g., Navarick & Fantino, 1976; Rachlin & Green, 1972; Solnick et al., 1982).

Experiment 1 of the present study will examine further the preference reversal phenomenon. In studies that demonstrated the phenomenon, the delays were defined by single time-based schedules (Green, Fisher, Perlow, & Sherman, 1981; Navarick & Fantino, 1976; Rachlin & Green, 1972). It is, therefore, unclear the extent to which preference reversal is procedure-bound. In an effort to
extend this research, Experiment 1 of the present study defined the delays with two FR schedules. A discrete-trials procedure (see Hall-Johnson & Poling, 1984) was employed in which pigeons chose between two schedules, each comprising a sequence of two FR schedules. The second schedule of one sequence was an FR 5, which offered 2-s access to grain, and that of the alternative was an FR 45 which offered 8-s access to grain. The choice point was temporally separated from the reinforcers by increasing the size of the initial FR schedule of each sequence. The effects of this manipulation were studied when completion of the initial FR was followed by (a) a hopper flash, and (b) access to food. This procedure assayed the effects on self-control of adding equal ratios to two FR schedules of different sizes, and offering different magnitudes of reinforcement, and the extent to which such effects were attenuated by reinforcers presented after the initial FR.

In Experiment 1, manipulating FR size varied both time to reinforcement and effort. The effects of each variable were, therefore, unclear. Experiment 2 attempted to separate their effects. In it, pigeons were given a choice between an FR 5 schedule that offered 2-s access to grain, and a varied FR schedule that offered 8-s access to grain. The value of the varied FR schedule was manipulated across conditions. After exposure to
each varied FR value, yoked FT schedules were programmed to assay the effects on self-control of deleting response requirements during the delay to reinforcement. The results of previous research suggests that self-control should decrease when subjects move from a choice between two FR schedules to a choice between two yoked FT schedules (Grossbard & Mazur, 1986).
CHAPTER II

EXPERIMENT 1

Method

Subjects

Four White Carneaux pigeons, maintained at approximately 80% of their free-feeding weights, served as subjects. Two birds were experimentally naive (P1, P3), and the other two had responded under ratio schedules in a previous experiment (P2, P4). Each bird was individually housed with unlimited access to water and grit in a constantly illuminated room.

Apparatus

Four Lehigh Valley Electronics operant conditioning chambers, measuring 32 cm long, 36 cm high, and 35 cm wide, were used. Three response keys, 2.5 cm in diameter and 5.5 cm apart, were mounted on the front wall 23 cm from the floor. Each could be transilluminated red, or blue/green, and operated by a force of 0.2 N. An aperture centered on the front wall 7.5 cm from the floor permitted feeding from a grain hopper. When raised, the hopper was illuminated by a 7-W bulb and provided access
to mixed-grain. A 7-W bulb centrally located on the ceiling provided ambient illumination, and a white-noise generator provided masking noise.

A PDP-8A minicomputer (Digital Equipment Corporation, Maynard, MA) equipped with SUPERSKED software (State Systems, Kalamazoo, MI) and electromechanical interfacing collected data and scheduled experimental events.

Procedure

Subjects were exposed to a variable time (VT) 45-s schedule of grain deliveries until each reliably ate from the hopper. Birds then received pairings of 6-s key illuminations, and 3-s access to grain presented under a VT 45-s schedule. Responses had no programmed consequence. Key color (red or blue/green) and key position (right, center, or left) were randomly determined on each trial with the restriction that each color/position combination occurred an equal number of times each session. Sessions terminated after 36 key-light/food pairings. When subjects key-pecked on at least 80% of the trials, they were exposed to fixed-ratio (FR) schedules of grain delivery programmed on one of the three keys. The schedule, initially FR 1, was gradually increased to FR 65 over a number of sessions. The key color and position were randomly determined although each
color/position combination occurred equally often within sessions. Reinforcers were followed by a 15-s intertrial interval (ITI), and sessions terminated after 36 reinforcers. When all 36 ratios were completed within 45 minutes in three consecutive sessions, the experiment proper began.

In the experiment proper, subjects responded under two sequences of FR schedules, each sequence comprising two FR schedules. In one sequence, the second schedule was always an FR 5 followed by 2-s access to grain; in the other, it was an FR 45 followed by 8-s access to grain. The initial schedules of each sequence were always equal and were varied as described below. The sequence with the 8-s reinforcer always required 40 more responses than the sequence with the 2-s reinforcer. Eighteen forced-exposure trials were followed by 18 choice trials in each session. During forced-exposure trials, one of the three keys was lighted red or blue/green, and one of the two sequences was programmed on that key. Each sequence was programmed on 9 forced-exposure trials each session. During choice trials, two of the three keys were lighted, and the two sequences were presented simultaneously. After a response to one of the illuminated keys, the other key was darkened and that sequence was inoperative. Both forced-exposure and choice trials were followed by an ITI, the duration of
which was adjusted such that the overall rates of reinforcement offered by two sequences were equal. Key lights were darkened and responses had no programmed consequence during the ITI. Each key color/position combination, in forced exposure and choice trials, occurred an equal number of times per session. Sessions terminated after 36 trials or 60 minutes, whichever came first.

In Phase 1, the initial FR schedule was FR 1, FR 5, FR 20, FR 35, or FR 50. Each bird received all values, but in a different irregular order across conditions. Two conditions were programmed at each initial FR value. In the food condition, 3-s access to grain followed completion of the initial FR of each sequence. In the hopper flash condition, a 0.25-s hopper flash followed completion of the initial FR. The order of the food and hopper flash conditions at each initial FR value was randomly determined.

As the data were collected in Phase 1, it was clear that when the initial schedule of each sequence was an FR 1, responding was biased more toward the sequence with the larger reinforcer (i.e., 8-s access to grain) under the food condition than under the hopper flash condition. Increased responding for the sequence with the larger reinforcer under the food condition might be a function of the food deliveries per se. But imposing food
deliveries also increased the delay to the 2-s and 8-s reinforcers because the duration of the food deliveries was 2.75-s more than that of the hopper flashes. To investigate the effect of adding a 2.75-s delay to the 2-s and 8-s reinforcers, Phase 2 manipulated the duration of the hopper flash. The sequences were arranged in the same way as in Phase 1, and the initial schedule was always FR 1. In the first condition, completion of the FR 1 was followed by a 3 s hopper flash. In the second condition, the hopper flash was 0.25 s; in the third, 3 s. Following this sequence of conditions, P3 was re-exposed to the 0.25 s, and then the 3 s condition, because there were large differences between the first and second exposure to the 3 s condition.

In both phases, the dependent variable was the percentage of choice trials on which the sequence with the larger reinforcer was selected. Conditions were changed after a minimum of 10 sessions, and when there was no visible trend in the data over the last 5 sessions. The key color associated with each sequence varied across birds and was occasionally changed after exposure to both conditions at a particular FR value. The number of sessions and key color correlated with the sequence with the larger reinforcer in each condition are presented in Table 1.
<table>
<thead>
<tr>
<th>Initial FR</th>
<th>Subject</th>
<th></th>
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</thead>
<tbody>
<tr>
<td></td>
<td>P1</td>
<td>P2</td>
<td>P3</td>
<td>P4</td>
</tr>
<tr>
<td>Phase 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FR 1</td>
<td>10 (25)</td>
<td>24 (10)</td>
<td>47 (10)</td>
<td>24 (35)</td>
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<tr>
<td></td>
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<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>FR 5</td>
<td>24 (14)</td>
<td>17 (22)</td>
<td>10 (27)</td>
<td>32 (13)</td>
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<td>Red</td>
</tr>
<tr>
<td>FR 20</td>
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<td>32 (27)</td>
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<td>Red</td>
<td>Blue/Green</td>
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<td>Red</td>
</tr>
<tr>
<td>FR 35</td>
<td>10 (16)</td>
<td>19 (19)</td>
<td>44 (20)</td>
<td>14 (19)</td>
</tr>
<tr>
<td></td>
<td>Blue/Green</td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
</tr>
<tr>
<td>FR 50</td>
<td>10 (10)</td>
<td>12 (22)</td>
<td>22 (38)</td>
<td>30 (44)</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>Phase 2</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3 s H.F.</td>
<td>38</td>
<td>24</td>
<td>27 (14)</td>
<td>33</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>0.25 s H.F.</td>
<td>40</td>
<td>10</td>
<td>10 (10)</td>
<td>10</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
</tr>
<tr>
<td>3 s H.F.</td>
<td>20</td>
<td>16</td>
<td>29</td>
<td>34</td>
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<tr>
<td></td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
</tr>
</tbody>
</table>

**Note.** For Phase 1, the first number of the pair and the number in parentheses represents the number of sessions in the food and hopper flash condition, respectively. For Phase 2, the number in parentheses represents the number of sessions in re-exposures to that condition.
Results and Discussion

Figure 1 shows for each subject the percentage of choices to the sequence with the larger reinforcer in the hopper flash and food conditions as a function of initial FR size. Each data point represents the mean of the last 5 sessions in each condition, and vertical lines through each point represent the range. In both the hopper flash and food conditions, the percentage of choices for the sequence with the larger reinforcer (i.e., self-control) increased with the size of the initial FR for all birds. All birds showed preference reversal, although the initial FR value at which the shift occurred varied substantially across birds. For PI, the increase in responding for the sequence with the larger reinforcer was proportionally smaller than that for the other birds, because preference for the sequence with the smaller reinforcer at low initial FR values approached indifference. Casual observations suggested that this bird showed a preference for the right key, particularly under the food condition, at lower values of the initial FR. Nevertheless, the relation between initial FR size and self-control still obtained. It should be noted that when the initial schedule was FR 1, there was more self-control for all birds under the food than under the hopper flash condition.
Figure 1. The Percentage of Choices to the Sequence with the Larger Reinforcer as a Function of the Size of the Initial FR Schedule. Data Points Represent the Mean of the Last Five Sessions of Each Condition; Vertical Lines, the Range Across the Five Sessions.
Figure 2 shows the percentage of choices to the sequence with the larger reinforcer as a function of hopper flash duration. Data are presented from each of the last five sessions for individual birds. For P1, P2, and P4, the sequence with the larger reinforcer was chosen more often when the hopper flash was 3 s than when it was 0.25 s. The differences were on the order of 30-40%. For P3, there was only a small difference when the hopper flash was first decreased from 3 s to 0.25 s, but a much larger difference upon subsequent exposure to the two conditions.

In this study, reinforcement delays were defined by FR schedules. Equal response requirements were added to the FR 5 and FR 45 schedules by increasing the initial FR size. The results showed that as initial FR size increased, preference shifted from the sequence with the smaller reinforcer to the sequence with the larger reinforcer that also required more responses. Previous research has reported similar results when the delays were defined using other schedules. For example, Navarick and Fantino (1976) programmed two FT (FT t s & FT t-10 s) or two FI (FI t s & FI t-10 s) schedules as terminal links of a concurrent-chains schedule. The larger reinforcer was programmed under the former schedule of each pair. As t increased, responding to the schedule offering the larger reinforcer increased. In
Figure 2. The Percentage of Choices to the Sequence with the Larger Reinforcer as a Function of Hopper Flash Duration for Individual Pigeons. Data are Presented for Each of the Last Five Sessions of Each Condition.
many cases, preference reversal was obtained. Rachlin and Green (1972) programmed a blackout of $t$ seconds before contact with the terminal links of a concurrent-chains schedule. As $t$ increased, preference shifted from the smaller to the larger more delayed reinforcer. Finally, Boehme, Blakely, and Poling (1986) manipulated runway length. Rats chose between 1 pellet delivered immediately after goal box entry, and 4 pellets delivered 8 s after goal box entry. When distance to both goal boxes was increased from 40 cm to 240 cm, preference shifted from the smaller to the larger reinforcer. Taken together, the results of these studies show that irrespective of how the delays are defined, adding a constant to both delays shifts preference from the smaller reinforcer to the larger, more delayed, reinforcer. When the delays were defined in non-temporal dimensions (e.g., ratio size, distance), however, time to reinforcement and effort covary. Therefore, the singular effects of each are unclear in these investigations.

When the initial schedule was an FR 1, in the present study, there was more responding for the sequence with the larger reinforcer under the food condition than under the hopper flash condition. Two possible interpretations may be offered for this result. First, because the hopper flashes were only 0.25 s and food deliveries were 3 s, the 8-s and 2-s reinforcers were
delayed an extra 2.75 s in the latter condition. With the 8-s reinforcer, this change represented a relatively small proportional increase in delay to reinforcement. With the 2-s reinforcer, the proportional increase was larger and probably more discriminable. Thus, control by the 2-s reinforcer might be expected to be attenuated. Data from Phase 2 support this interpretation. Increasing the duration of the hopper flash from 0.25 s to 3 s generally decreased preference for the sequence with the 2-s reinforcer.

Second, access to grain after the initial FR might somehow obscure the differential effects of the second FRs. The present experiment did not evaluate the effects of access to grain per se on control by the second schedules. To answer this question, the effects of 3-s access to grain should be compared to those of a 3-s hopper flash. Previous research with sequences of ratio schedules showed, however, that the second ratio schedule in a sequence did affect choice when access to grain followed completion of the initial schedule of the sequence (Poling, Blakely, Pelletiere, & Picker, 1987). That study and the present research demonstrate that food deliveries do not completely obscure control by subsequent schedules.

In previous self-control research, reinforcement delays were defined by single schedules. The present
study extends this research by showing similar results delays were defined with a sequence of two schedules. Moreover, reinforcers were interposed during the delay (i.e., after the initial FR), which consisted of the time required to complete an FR schedule. That choice responses were sensitive to differential contingencies embedded in such complex delays is noteworthy. The preference reversal phenomenon is not dependent on defining the delays with single time-based schedules.
CHAPTER III

EXPERIMENT 2

Method

Subjects

Four White Carneaux pigeons, maintained at approximately 80% of their free-feeding weights, served as subjects. Two (S3, S4) were experimentally naive; the other two (S2, S2) responded under ratio schedules in previous research. Each bird was individually housed with free access to water and grit in a constantly illuminated room.

Apparatus

The apparatus used in Experiment 1 was also employed in Experiment 2.

Procedure

The same procedures as those in Experiment 1 were used to train the birds to eat from the hopper, peck the key, and complete FR 65 schedules. In the experiment proper, forced exposure trials, choice trials, and the ITI were arranged in a manner identical to that described
in Experiment 1. In the present experiment, subjects chose between a constant and a varied schedule. In the first condition, the constant and varied schedules were FR schedules. The constant FR schedule in this and all other conditions was an FR 5 that provided 2-s access to grain. The varied schedule was either FR 5, FR 20, FR 35, FR 50, or FR 65 and each programmed 8-s access to grain. The four subjects received a different varied schedule in this first condition. In the next condition, the constant and varied FR schedules were changed to yoked chain FR 1 FT schedules that provided, respectively, 2-s and 8-s access to grain. Under the yoked schedules, completion of the FR 1 schedule darkened key lights and initiated the FT schedule, the completion of which produced access to grain and entry into the ITI. The time requirements of the constant and varied FT were equal to the average run time of the constant and varied FR schedule, respectively, in the last 5 sessions of the previous condition. The run time on a given trial was the time between the first response and last response of the FR. Average run times for each schedule were computed by dividing the total run time by the number of forced trials on which the subject responded under that schedule.

In the remainder of the conditions, birds were exposed to all other values of the varied FR schedule in
a different order across subjects; after exposure to each, a yoked chain FR 1 FT was programmed as above. When there were clear changes in responding under the yoked schedules, birds were re-exposed to the FR schedules. The dependent variable was the percentage of choice trials on which the varied schedule was selected. Conditions lasted a minimum of 10 sessions and were changed when there was no visible trend in the data over 5 consecutive sessions. The key color associated with each schedule varied across birds and was occasionally changed after all conditions at a particular value of the varied FR schedule. The number of sessions and key color associated with the varied schedule in each condition are presented in Table 2.

Results and Discussion

Figure 3 shows, for each subject, the percentage of choices directed to the varied schedule (i.e., the larger reinforcer) when the varied and constant schedules were two FR or two chain FR 1 FT schedules. Each data point represents the mean of the last 5 sessions in each condition. As the varied FR size increased, choice responses allocated to that schedule systematically decreased. Moreover, the same general relation held for the chain FR 1 FT schedules when the time requirement of the varied FT schedule increased.
Table 2

The Number of Sessions and Key Color Associated With the Varied Schedule in Each Condition for Each Bird

<table>
<thead>
<tr>
<th>Varied FR Schedule</th>
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<tr>
<td></td>
<td>FR 5</td>
<td>FR 20</td>
<td>FR 35</td>
<td>FR 50</td>
</tr>
<tr>
<td></td>
<td>78 (16)</td>
<td>20 (36)</td>
<td>23 (29)</td>
<td>19 (12)</td>
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<tr>
<td></td>
<td>Blue/Green</td>
<td>Red</td>
<td>Red</td>
<td>Blue/Green</td>
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<tr>
<td></td>
<td>27 (14)</td>
<td>13 (25)</td>
<td>30 (96)</td>
<td>61 (16)</td>
</tr>
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<td></td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
</tr>
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<td></td>
<td>11 (10)</td>
<td>23 (26)</td>
<td>29 (11)</td>
<td>10 (10)</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Blue/Green</td>
<td>Red</td>
<td>Blue/Green</td>
</tr>
<tr>
<td></td>
<td>21 (12)</td>
<td>55 (22)</td>
<td>32 (10)</td>
<td>14 (10)</td>
</tr>
<tr>
<td></td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
<td>Red</td>
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<tr>
<td></td>
<td>FR 65</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>22 (10)</td>
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<td></td>
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<td></td>
<td>Blue/Green</td>
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<tr>
<td></td>
<td>16 (11)</td>
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<td></td>
<td>Blue/Green</td>
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<td></td>
<td>21 (38)</td>
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<td>Red</td>
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<td></td>
<td>18 (10)</td>
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<td></td>
<td>Red</td>
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</table>

Note. The first and third number (when present) in each cell represents the number of sessions in the first and second exposure, respectively, to the FR schedules. The number in parentheses represents the number of sessions under the chain FR 1 FT schedule.
Figure 3. The Percentage of Choices Directed to the Varied Schedule as a Function of the Size of the Varied FR Schedule. Data Points Represent the Mean of the Last Five Sessions of Each Condition; Vertical Lines, the Range Across the Five Sessions. Asterisks (*) Indicate the FR Schedules That Were Re-presented After Exposure to the Chain FR 1 FT Schedule.
There were, however, clear and reproducible differences in behavior between the FR and chain FR 1 FT conditions. Under FR 20 for S1, S3, and S4, FR 35 for S1 and S3, and FR 50 for S1, subjects chose the larger reinforcer on fewer trials under the chain FR 1 FT schedules than under the FR schedules. A similar effect was obtained for S2 at FR 5 and FR 20, and for S4 at FR 35, but the differences, although reproducible, were quite small. At the extreme values of the varied FR schedule (i.e., FR 5 and FR 65), differences in responding between the FR and chain FR 1 FT were generally not obtained.

The results of this experiment showed an inverse relation between responding for the varied schedule and that schedule's ratio size or time requirement (FT size). Other studies demonstrated similar control by ratio size (e.g., Schwartz, 1969) and temporal requirement (e.g., White & Davison, 1973). This relation was evident in the present study when there were large differences (2-s vs. 8-s access to grain) in reinforcement magnitude offered by the varied and constant schedules, a result that suggests unequal magnitudes do not preclude effects of differences in ratio size or temporal requirement. A similar outcome was reported by Grossbard and Mazur (1986).
The present study also showed that at the extreme values of the varied FR schedule (i.e., FR 5 and FR 65), changing from FR to chain FR 1 FT schedules did not affect responding for the larger reinforcer. At FR 65, floor effects precluded any potential decrease in responding. At FR 5, perhaps differences in magnitude were prepotent. But at the intermediate values (i.e., FR 20 and FR 35), there was generally more responding for the larger reinforcer under the FR schedules than under the chain FR 1 FT schedules. These results are consistent with those reported by Grossbard and Mazur (1986). In their study, pigeons were given a choice between a constant FR schedule that delivered 2-s access to grain and an adjusting FR that offered 6-s access to grain. The adjusting FR was varied within each session until subjects chose the two schedules equally often. Values of the adjusting FR at which subjects were indifferent were identified for different values of the constant FR. The indifference points were compared to those obtained under FT schedules that were yoked to the FR schedules.

Summarizing results from many conditions, Grossbard and Mazur (1986) concluded that indifference points, when defined as time to the larger reinforcer, were generally higher under the FR schedules than under the FT schedules. This implies that the relative value of the
larger reinforcer is greater under two FR schedules than under two yoked FT schedules. Therefore, responding should be biased toward self-control under the former schedules. This was the case in Experiment 2 of the present study, at least under the intermediate values of the varied FR schedule. The effects obtained by Grossbard and Mazur (1986) were observed only at relatively large constant FR values (e.g., FR 40). The present study did not vary the constant FR across conditions so the extent to which the effects depended on the value of this schedule were unclear.

One caveat, noted by Grossbard and Mazur (1986) bears mention. When the varied and constant schedules were FR schedules, the run times undoubtedly varied across individual ratios. Under the chain FR 1 FT, however, the yoked "run" times (i.e., the value of the FT schedules) were held constant. Thus, the decrease in self-control under the chain FR 1 FT schedules could have been a function of changing from variable to constant run times. Inspection of the raw data from the present study suggested that the range of run times was, however, relatively small under the FR schedules. Nevertheless, variable-time schedules, with individual intervals yoked to the individual run times under the FR schedules, might yield different results.
The results of the present study are consistent with other research which showed that behavior during the delay can affect self-control. Grosch and Neuringer (1981) gave pigeons a choice between waiting for a preferred type of grain, or responding during the delay for less preferred grain that was immediately available. In one phase, a key was mounted on the back wall of the chamber. In some conditions, the key was covered. In another condition, an FR 20 schedule of access to grain was programmed on the key; in a third, the key was uncovered but no schedule of grain delivery was programmed. The results showed that pigeons consistently waited for a delayed reinforcer when the FR 20 schedule was available during the delay, or when the key was just uncovered. Response rates on the key were approximately equal under both conditions. When the key was covered, waiting occurred infrequently. Using a similar procedure, children waited for preferred treats when toys were available during the delay (Mischel, Ebbeson, & Zeiss, 1972). The present research extends these studies by suggesting that alternative response options during the delay are not necessary to increase self-control. Imposing a response requirement for both the large and small reinforcers can, in some conditions, produce the same effect.
Previous research showed that subjects given a choice between a small immediately available reinforcer and a larger more delayed reinforcer often chose the former. When the delays to both alternatives are increased by adding a constant to each, preference shifts to the larger reinforcer (e.g., Green et al., 1981; Navarick & Fantino, 1976; Rachlin & Green, 1972; White & Pipe, 1987). Experiment 1 showed a similar effect with a procedure never before used to study self-control. In this procedure, the delays were defined by FR schedules and a constant was added to each delay by increasing the value of the initial FR of each sequence. Interposing reinforcers during the delays did not generally affect the relation, although preference was a function of hopper-flash duration when the initial schedule of each sequence was an FR 1.

The results of Experiment 1 are consistent with Rachlin's (1974) interpretation of self-control. He suggested that preference for a larger delayed reinforcer is a function of when the subject is required to choose between the reinforcers. When the choice response is
quickly followed by contact with the smaller reinforcer, subjects usually choose that alternative. As the choice point is temporally separated from the reinforcers, preference shifts to the larger reinforcer. Rachlin (1974) and Ainslie (1975) suggested that preference reversal is due to gradients of delayed reinforcers of unequal magnitude. When, for instance, a small and large reinforcer are delayed by 1 and 8 s, respectively, adding a constant (e.g., 6 s) to both delays decreases the reinforcing efficacy of the former more than that of the latter. Increasing the value of the constant further decreases the relative efficacy of the more immediate reinforcer, and at some point preference shifts to the larger reinforcer.

Two separate processes might contribute to changes in the relative value of two reinforcers. First, discriminability between the schedules that define the delays may be a factor. For example, Hobson (1975) reported that as the larger of two FR schedules increased, the absolute discriminable difference (i.e., JND) between the schedules also increased. This suggests that decreasing the proportional differences between two schedules, while holding constant their absolute differences, decreases their discriminability. Increasing the initial FR schedule in Experiment 1 of the present study decreased the proportional differences
between the sequences and their discriminability with respect to responses per sequence. As a result, control by the sequence with fewer responses (i.e., the sequence with the 2-s reinforcer) was attenuated and control by the sequence with the larger reinforcer could then emerge.

Second, moving the choice point in time may directly affect behavior, that is, without altering the discriminability of the alternatives. This effect was demonstrated in studies in which pigeons (Navarick & Fantino, 1976; Snyderman, 1983; White & Pipe, 1987) and rats (Ito & Asaki, 1982) were exposed to a concurrent-chains schedule with two equal FI or FT schedules in the terminal links that offered unequal magnitudes of reinforcement. The results showed that responding for the larger reinforcer increased with schedule size, suggesting that separating the choice point increases the value of the larger reinforcer even when the discriminability of the two schedules does not change. The size of the changes, though, were not sufficient to account completely for the preference reversal shown in Experiment 1 of the present study and in other self-control investigations. Also, the phenomenon was demonstrated under concurrent-chains schedules. Whether it obtains under discrete-trials procedures like that in the present study is unknown. Interestingly, Experiment
1 of the present study showed exclusive preference for the larger reinforcer when the delays were defined by two FR 5 schedules. That preference was not exclusive with short delays under concurrent-chains schedules suggests the phenomenon is procedure-dependent.

In Experiment 1, the delays were defined by FR schedules. Under these schedules, time to reinforcement and effort covaried and, thus, the singular effects of the latter were unclear. The effects of effort were also unclear in other self-control studies (e.g., Green et al., 1981; Ito & Asaki, 1982; Navarick & Fantino, 1976). The results of Experiment 2 suggest that there are effects of variations in effort, independent of those of time. Specifically, imposing response requirements biased responding under some conditions toward self-control (see also Grossbard & Mazur, 1986). Thus, the schedule used to define the delays in self-control research may determine, in part, allocation of responding to the larger reinforcer.

Other research has attempted to separate the effects of effort and time to reinforcement. With respect to pausing under FR schedules, some researchers have concluded that the number of responses per reinforcer has no effect on pausing (Killeen, 1969; Neuringer & Schneider, 1968) but others have shown just such an effect (Crossman, Heaps, Nunes, & Alferink, 1974). With
regard to choice, however, the results of Experiment 2 of the present study and those of previous investigations (Dukich, 1971; Grossbard & Mazur, 1986) suggest that preference is jointly determined by time to reinforcement and effort. The singular effects of the two variables may well depend on experimental parameters and the dependent variable under study. Disentangling their actions is a formidable but important task for future studies.

In closing, both Experiment 1 and 2 have implications for human self-control. Experiment 1 showed that the preference reversal phenomenon is not closely tied to one or two particular procedures in which the delays are defined by single time-based schedules. Thus, perhaps researchers will be encouraged to study the phenomenon in even more complex circumstances, including those that approximate genuine self-control problems in humans. More generally, if the preference reversal phenomenon is shown in humans, manipulating the choice point might be part of a strategy to increase self-control in real-life situations. The results of Experiment 2 suggest that the effects of such manipulations may depend on the effort requirements during the delay to reinforcement.
BIBLIOGRAPHY


