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Fixed – Interval Timeout from Avoidance with Humans

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DISSERTATION

Submitted to the Eberly College of Arts and Sciences of West Virginia University

in partial fulfillment of the requirements for the degree of

Doctor of Philosophy

in

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Abstract

On fixed-interval (FI) schedules of reinforcement, humans and other animals often have different response patterns. For example, the pattern typically associated with animals is the scallop: a pause followed by a gradual acceleration in responding. Humans generally show terminal-minimum (i.e., pause until the end of the interval, then make 1 or 2 responses) or constant-rate patterns. There have been numerous investigations of the variables that control such different response patterns. The most common variables in those studies are instructions, verbal ability, response cost, concurrent tasks, and food and points as reinforcers. The purpose of the present experiments was to investigate a variable that has received little experimental attention in this area: effects of an immediately consumable reinforcer, timeout from avoidance. In Experiment 1, adult human subjects responded on a concurrent schedule with avoidance of point-loss in one component, and timeout from avoidance in the other. Timeout was scheduled on FI with inter-reinforcement intervals ranging from 30 s to 480 s. Functions relating response rate and post-reinforcement pause to schedule value were similar to those reported for animals, but running-rate functions were not. Subjects showed terminal-minimum response patterns in most intervals. In Experiment 2, there were three conditions: (1) FI 240 s for point reinforcers, (2) concurrent FI 240 s for points and avoidance, and (3) FI 240-s timeout from avoidance. Response rates were highest and post-reinforcement pauses were shortest in conditions with point-gain only. Response rate was lowest and post-reinforcement pause was longest in timeout-from-avoidance conditions. There were few intervals with scalloped response patterns. The most terminal-minimum intervals occurred in timeout-from-avoidance. There are three main implications of the present results: (1) timeout from avoidance was a reinforcer which produced differential responding across FI values, but it was not more valuable than points as reinforcers

in the present procedure; (2) scalloped response patterns on FI may be primarily due to averaging data over intervals; and (3) the best way to compare data across studies is to use strict stability criteria and quantitative measures that minimize data averaging.

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CHAPTER 1: Introduction

There is still considerable disagreement among behavior analysts concerning whether environment-behavior relations discovered with nonhuman animals (hereafter labeled animals) explain the behavior of humans (e.g., Baron & Perone, 1982; Buskist, Morgan, & Barry, 1983). Many behavior analysts assume that, because humans and animals are subject to the same fundamental laws of behavior, behavioral relations discovered with animals apply to humans (e.g., Skinner, 1953, 1957). Other behavior analysts, however, maintain that, because humans have verbal ability, different principles are required to explain their behavior (e.g., Lowe, 1979). Some evidence for that position is derived from the observation that human and animal subjects frequently have different response patterns on simple schedules of reinforcement such as the fixed interval (e.g., Bentall, Lowe, & Beasty, 1985; Lowe, Beasty, & Bentall, 1983). Proponents of that position have argued that (a) such differences in responding are produced by human subjects' self-generated rules about the experimental situation; (b) those rules are more powerful than experimental variables; (c) humans are consequently less sensitive to programmed contingencies; and (d) because such self-rules are idiosyncratic to individuals, it is common to find variable results between human subjects under apparently identical experimental conditions.

Humans are different from animals in many respects, and they may come under the control of self-generated rules (e.g., Skinner, 1969), but attributing unexplained variance to such rules is problematic for several reasons. First, self-rules are said to result from experimental variables and pre-experimental history (Lowe, 1979). By itself, this assertion is not problematic. What is troublesome, however, is the notion that, after they have been generated, self-rules are not sensitive to control by the experimental variables from which they were derived. Second, attributing variance to self rules does not explain response patterns of humans on reinforcement

schedules, but merely promotes investigation of the variables that control self rules. Because the rules cannot be controlled directly, environmental variables must be manipulated to explain why different subjects form different rules. Consequently, rules become an unnecessary link in the causal chain between environmental variables and behavior. Finally, attributing unexplained variance to self-rules is problematic because it is premature. The importance of rules has been inferred by comparing response patterns of humans and animals, but such comparisons may be of responding under functionally different experimental conditions.

Most experiments with animal subjects are based on well-established standardized procedures, and analysis of responding that has reached steady state. In contrast, procedures with human subjects have not evolved to the same level of standardization, and analyses are not always based on steady-state responding. For these reasons, the relevant differences between procedures typically used with humans and animals still are being investigated (e.g., Baron & Perone, 1982; Baron, Perone, & Galizio, 1991). There are numerous external experimental variables to consider before it is necessary to appeal to internal, inferred variables to explain variance. Such internal variables should be reserved as the last explanatory resort of a science much older than the experimental analysis of human behavior.

The broad objective of the present project was to investigate variables that may contribute to functional differences in operant procedures used with humans and animals. Of specific interest is the reinforcer. With animals, there typically is an immediately consumable reinforcer (i.e., food); with humans, however, the reinforcer typically is points that cannot be consumed until after the experiment. Because response patterns of humans and animals on fixed-interval (FI) schedules of reinforcement usually are different, they have been the center of considerable theoretical debate, and, therefore, are the focus of the present analysis. First, there is

a description of responding on FI schedules that has been labeled “typical” for animals and humans. Then, experimental variables that affect human responding on FI schedules are reviewed, followed by an assessment of the variables that have the most effect on the responding of humans on FI. In the present experiments, timeout from avoidance (described below) was the reinforcer for responding on FI because the timeout period is an immediately consumable reinforcer, which seems more similar in function to food for hungry animals than are points.

Responding on Fixed-Interval Schedules of Reinforcement

The most common way to assess response patterns on FI has been by describing cumulative records. Unfortunately, authors’ descriptions of cumulative-record patterns vary widely. Hyten and Madden (1993) performed a detailed analysis of common response patterns on FI, and consequently provided the following comprehensive list of categories to summarize those patterns (p. 492):

1. *Scallop*: Post-reinforcement pause followed by a gradual acceleration in responding to a terminal rate at the end of the interval.
2. *Break-run*: Post-reinforcement pause followed by an abrupt transition to a terminal rate.
3. *Terminal minimum*: Extended pausing until the end of the interval when only a few responses occur.
4. *Constant rate* (low, moderate, or high): A constant response rate throughout the interval.

These categories are used in the present analyses. In the following discussion, combinations of the scallop and break-run response patterns are labeled pause-respond patterns.

Animals

A scallop has been defined as a “positively accelerated portion of the cumulative record, usually used in speaking of interval or ratio segments.” (Ferster & Skinner, 1957, p. 733).

Figure 1 (Panel A) shows illustrations of cumulative response curves similar to those that Ferster and Skinner described as “typical of basic processes in FI,” (1957, p. 163). Panels B and C are illustrations of curves that are similar to those described by Ferster and Skinner as including “various kinds of deviations which may be imposed upon them.[the typical, basic processes in FI]” (p. 163). For example, the four curves in Panel B are examples of the break-run pattern with various degrees of pausing. The first three curves in Panel C show shallow scallops approximating constant-rate patterns, and the last two curves in Panel B are similar to terminal-minimum patterns. Overall, Ferster and Skinner’s definition of typical response patterns is broad, and includes various pause-respond patterns.

Although animals have produced scalloped response patterns (e.g., Ferster & Skinner, 1957), break-run patterns also are common (e.g., Cumming & Schoenfeld, 1958; Dukich & Lee, 1973; Ferster & Skinner, 1957; Gollub, 1964; Lowe & Harzem, 1977; Schneider, 1969). Various constant-rate and terminal-minimum patterns also have been found (e.g., Cumming & Schoenfeld, 1958; Ferster & Skinner, 1957), but break-run and scallop seem to be the most common intervals obtained with animals.

Humans

In early studies of humans responding on FI schedules, scalloped patterns were reported frequently, and similarities between the responding of humans and animals were emphasized. Recently, however, it has been shown that scalloping was less prevalent than many authors had concluded (Hyten & Madden, 1993). By the 1970s, differences between the response patterns of

Figure 1. Representation of fixed-interval patterns produced by pigeons responding on FI 8 min in Ferster & Skinner (1957).

humans and animals were being emphasized, rather than similarities. Today, within-species inconsistencies among animal and human response patterns are the emphasis (e.g., Madden, Chase, & Joyce, 1998; Perone, Galizio, & Baron, 1987)

Weiner (1962, 1964a, 1964b, 1965a, 1965b, 1969, 1972, 1983) compiled an extensive set of data on FI response patterns of humans. Figure 2 shows illustrations of the most common patterns found with humans. The response patterns illustrated in Figure 2 are similar to those reported in Weiner (1969) for subjects responding on FI 10-s and FI 600-s. Curves A and B depict constant-high and constant-moderate rate patterns (what Weiner labeled high-rate), respectively. Curves C and D show constant-low rate and, Curves G and H show terminal-minimal patterns (both of which Weiner labeled low-rate). Similar patterns also are presented in Baron, Kaufman, and Stauber (1969).

Variables that Affect Responding of Humans on FI Schedules

Experimental History

In early studies of response patterns of humans on FI schedules, both constant-rate and terminal-minimum patterns were found, and both patterns were found under the same experimental conditions (e.g., Weiner, 1969). Between-subject differences were attributed to humans' varying pre-experimental histories with button-pressing responses in the natural setting. To test this notion, Weiner manipulated experimental histories of responding and found that subjects' FI response patterns depended on whether they previously had been responding on fixed-ratio (FR; i.e., reinforcement follows a fixed number of responses) or differential-reinforcement-of- low- rate (DRL; i.e., reinforcement follows responses with a minimum inter-response time) schedules. Experimental histories on FR schedules produced the constant-high rate FI pattern, and histories on DRL schedules produced constant-low or

FI 10 s

FI 600 s

Figure 2. Representation of fixed-interval patterns produced by humans responding for points in Weiner (1969).

terminal-minimum FI patterns. Humans bring widely varying behavioral histories to the laboratory situation, and that history can affect responding, Weiner's work has shown that history effects also can be controlled by experimental operations.

Response Cost

Several authors have suggested that response cost (i.e., loss of reinforcers or effort of responding) affects FI response patterns (e.g., Buskist, Miller, & Bennett, 1980; Lowe, 1979; Matthews, Shimoff, Catania, & Sagvolden, 1977; Weiner, 1969). In one study (Weiner, 1962), adult humans pressed a button for points on an FI schedule, and the predominant response pattern was constant-high rate. When one point also was lost after every response, the response pattern changed to constant-low rate or terminal-minimum. In another study (Azrin, 1958), soldiers pressed a button with a force requirement of 15 g (0.15 N) for points arranged on an FI schedule. The predominant response pattern was constant-high rate. When the response-force requirement was increased to several hundred grams, the response pattern changed to break-run. It should be noted, however, that response pattern has not been changed by response effort in all experiments. In Lippman, Leander, and Meyer (1970), responding of humans was reinforced on FI schedules with a response-force requirement of either 0.2 N or 12 N. There was no significant difference in response rate or pattern between groups.

With animals, the ratio of operant-response force requirement to body weight is higher than it usually is for humans. In addition, animals generally are fully occupied by the operant response, so the experimental task might be considered effortful for animals because it requires all their "cognitive resources". In contrast, most humans have extensive experience in performing several tasks concurrently, so common operant tasks in the laboratory do not tax their "cognitive resources". One way to equate the response effort of procedures used with humans

and animals would be to increase the complexity of the operant task until it fully engages human subjects. Unfortunately, it is difficult to measure task complexity, and tasks that are sufficiently complex to fully occupy human subjects have not been thoroughly investigated in the context of operant responding in the laboratory. Nonetheless, the issue of response effort must be considered. In the present experiments, response force was used as an operational definition of response effort. Although response force has not been systematically investigated, it is easily measurable and controlled, and therefore is a convenient way to make procedures used with humans more similar to those used with animals.

Instructions

The easiest way to change response patterns of humans on FI schedules is with instructions. In one study (Buskist, Bennett, & Miller, 1981), different groups of subjects were given instructions about how to respond on an FI 27-s schedule. Some subjects were told to finish a session within a certain time limit, some were told to make a certain number of responses for each reinforcer, and others were told to make a certain number of responses and finish within a time limit. Furthermore, before each session, subjects were reminded to conform to the instructions if they had deviated during the previous session. Subjects generally responded as they were instructed, and it was concluded that instructions are more powerful than are programmed contingencies for controlling the behavior of humans (Buskist et al., 1981). Those authors may be correct, but it is important to note that the instructions were in perfect accord with the FI contingency. That is, responding according to any of the instructions resulted in the same overall rate of reinforcement. Feedback from the experimenters when subjects did not follow directions may have decreased the probability that subjects would vary their response patterns, thereby preventing subjects from contacting the programmed FI contingency. In most

experiments, subjects are not repeatedly given feedback during the experiment dependent upon their conformity to instructions. Consequently, the results of Buskist et al. may not be representative of the usual effects of instructions. In a better test of the effects of instructions (Buskist & Miller, 1986), subjects received accurate and inaccurate instructions about the interval length of an FI 30-s schedule. Subjects who were instructed that reinforcers were available after 15 s quickly increased post-reinforcement pauses to approximately 30 s. Subjects who were told that reinforcers were available after 60 s paused for less than 60 s, but for more than 30 s. That study suggests that instructions are followed for at least a few sessions if subjects do not contact contingencies that oppose the instructions. In another study (Baron et al., 1969), subjects responded on five different FI schedules arranged on a multiple schedule (i.e., all FI schedules were in operation each session with appropriate discriminative stimuli). Some subjects were told the correct length of each FI schedule, and some subjects were not. After 20 sessions, response rates of instructed subjects varied indirectly with FI length, but response rates of uninstructed subjects did not. Studies with instructions and other types of schedules (e.g., avoidance: Galizio, 1979) also have shown that instructions will be followed if a discrepancy between the instructions and the programmed contingency is not contacted. Because a wide range of response rates and patterns will not affect reinforcement frequency, and therefore discrepancies between response patterns and FI contingencies may not be contacted, responding on FI schedules may be particularly sensitive to instructional effects. Given that humans are so susceptible to instructions on FI, instructions about the nature of the FI contingency should be minimized if a procedure is to be made more similar to those used with animals. For that reason, only minimal instructions were used in the present experiments.

It also has been proposed that self-instructions, or subject-generated rules, affect response

patterns for humans (e.g., Lowe, 1979). Evidence for this notion includes: (a) correlations between subjects' performance and descriptions of their response "strategies" (e.g., Matthews, Catania, & Shimoff, 1985; Pouthas, Droit, Jacquet, & Wearden, 1990; Rosenfarb, Newland, Brannon, & Howey, 1992); and (b) differences in FI performance between preverbal infants and older children or adults (e.g., Bentall et al., 1985; Lowe et al., 1983; Pouthas et al., 1990). The causal status of subject reports cannot be inferred from correlations, however, so such inferences do not constitute experimental evidence (Weiner, 1983). It has been asserted that preverbal infants produce scalloped intervals on FI that are similar to those of animals, but that this pattern begins to deteriorate at age 2 ½ - 4 years, when children learn to speak (Bentall et al., 1985). A reanalysis of the cumulative records presented in Bentall et al., however, shows that "broad characterization of infant behavior as scalloped on FI schedules is inaccurate and incomplete." (Hyten & Madden, 1993, p. 495).

Although scalloped intervals were not predominant with infants, a general pause-respond pattern (which includes scallop and break-run patterns) was most common for three of the four infants (Hyten & Madden, 1993). These patterns generally were more similar to those found with animals than were the patterns of the older children. Three things should be noted, however: (a) the infants had different procedures from the older children; (b) some of the older children also showed pause-respond patterns; and (c) pause-respond patterns were not reliable across the two studies (Bentall et al., 1985; Lowe et al., 1983) in which similar procedures were used. Even though preverbal infants responded more like animals than did older children, the results are neither sufficiently clear nor reliable to conclude confidently that verbal ability – and no other external variable – was responsible for the difference.

Observing Response

The observing response is another variable that has produced pause-respond patterns with humans on FI schedules. In a typical observing procedure, subjects are told that some stimulus change (e.g., deflection of a meter) will occur periodically. When the stimulus change occurs, subjects must make a response (e.g., reset the meter) to earn a reinforcer. The stimulus change can be observed only by making some other response (i.e., the observing response). With this general procedure, observing responses typically have a pause-respond pattern (e.g., Azrin, 1958; Holland, 1958; Laties & Weiss, 1963; Lowe, Harzem, & Bagshaw, 1978; Schroeder & Holland, 1968).

It has been suggested (e.g., Harzem, Lowe, & Bagshaw, 1978) that the nature of the observing task prompts subjects that the schedule is based on time. In addition, observing procedures often include a limited hold on the availability of reinforcers (i.e., the stimulus change to be observed only occurs for a limited time; e.g., Barnes & Keenan, 1989; Lowe, Harzem, & Bagshaw, 1978; Lowe, Harzem, & Hughes, 1978). With the limited-hold procedure, overall reinforcement decreases if subjects do not promptly earn a reinforcer once it becomes available. The combination of the obviously time-based schedule and the limited availability of reinforcers could affect responding similarly to instructions. Although the observing procedure does produce pause-respond patterns that are similar to responding of animals, it is important to learn why. Is the procedure really more analogous to procedures used with animals, or is it less analogous because of the influence of instructions? Perhaps the limited hold is an important factor. The limited hold on the availability of reinforcement may promote pause-respond patterns because fewer reinforcers are missed when responding occurs near the end of the interval. Pause-respond patterns, however, also have occurred with observing procedures that did not

include a limited hold (e.g., Azrin, 1958; Laties & Weiss, 1963), and scalloped intervals occurred with two similar procedures: one with a limited hold (Barnes & Keenan, 1989), and one without it (Barnes & Keenan, 1993). In Lowe, Harzem, and Hughes (1978), responding on FI was compared between two groups. One group responded on FI for points, and the other group responded on FI for points on one button, and for a brief illumination of a clock showing time elapsed since the previous FI reinforcer on another button. There was a limited hold on the FI reinforcer for both groups. The FI-only group showed mostly constant-rate patterns, and the other group showed scalloped intervals. These data suggest that a limited hold is neither necessary nor sufficient to produce response patterns like those found with animals.

It also has been suggested that the consummatory response (i.e., collecting the reinforcer in observing procedures or eating the food for animals) is an important aspect of observing procedures that contributes to responding that is more similar to that of animals (Matthews et al., 1977). In one experiment reported in Matthews et al., subjects were divided into pairs. Responding of one member of the pair was reinforced on a variable-ratio schedule (VR; reinforcers follow varying numbers of responses), and responding of the other member of the pair was reinforced on a VI schedule. Reinforcers on the VR schedule were yoked to the VI schedule. That is, a reinforcer became available for the VI member of the pair whenever a reinforcer was earned by the VR member of the pair. With this procedure, the rate and timing of reinforcers were equal for both members of each pair. For some of the pairs, reinforcement was the opportunity to press another button (i.e., consummatory response) for 2 s. Each press on the consummatory-response button added one point to the subject's score. For other pairs, points were added to subjects' scores without a consummatory response. If the consummatory response improved sensitivity to the VR and VI schedules, then subjects responding on VI have would

have had lower response rates than their VR counterparts when a consummatory response was required, but not when it was not required. Actual results showed that subjects on VI had response rates that were lower, higher, and approximately the same as their VR counterparts. Furthermore, this range of response rates occurred for subjects with and without a consummatory response. In a second experiment, subjects responded on an FI schedule, and a consummatory response was required for point reinforcers. The resulting response patterns were terminal-minimum. Interpreting the results from those two experiments is further complicated because subjects participated for only one 90-min session. The only clear conclusion from those experiments (Matthews et al., 1977) is that the consummatory response was not systematically related to schedule sensitivity.

Other evidence also suggests that the consummatory response is not important. A third group in Lowe, Harzem, and Hughes (1978) responded on one button that produced both a brief illumination of the clock for every response, and points scheduled on FI. That is, there was no consummatory response for the single-response group. Responding on FI showed aggregate scallops which were similar to responding for the group that used separate buttons for points and for observing the clock (i.e., the group for which a consummatory response was required).

Matthews et al. (1977) suggested that the consummatory response is important because it interrupts ongoing behavior and requires the subject to contact the reinforcer. There is evidence that contact with the reinforcer is important in promoting schedule sensitivity with human subjects. For example, when subjects reported which component of a concurrent VI schedule produced each reinforcer, there was better sensitivity (as measured by the sensitivity parameter of the generalized matching equation; Baum, 1974) to changes in the ratios of reinforcement across different concurrent pairs of VI schedules (Madden, 1995). In addition, Madden

concluded that the consummatory response was not sufficient to produce sensitivity. Results from Matthews et al. (1977) and Lowe, Harzem, and Hughes (1978), however, suggest that the consummatory response *per se* is not critical. In conclusion, neither the limited hold nor the consummatory response can account for the pause-respond patterns often found with humans on observing tasks. Consequently, it seems that the time-based instructions or the concurrent activity are most important.

Concurrent Task

One important difference between procedures with humans and animals is that, during the experimental session, animals can emit most of their behavioral repertoires, whereas humans cannot. The effects of a concurrent response have been investigated in a few studies in which humans responded on FI. For example, in one study (Laties & Weiss, 1963), subjects subtracted numbers aloud while responding on an observing task arranged on FI. Without the subtraction task, the predominant pattern was break-run. With the subtraction task, however, the typical pattern was constant-high rate, constant-low rate, or terminal-minimum. Thus, adding a concurrent task resulted in fewer pause-respond patterns. In another study (Barnes & Keenan, 1993), responding was reinforced on FI schedules, and, in some conditions, subjects could watch television. With television, the pattern was scalloped intervals; without television, the pattern was terminal minimum. Thus, adding a concurrent task resulted in more pause-respond patterns. Effects of concurrent tasks have been described as both distracting subjects from counting intervals (e.g., Barnes & Keenan, 1993), and helping subjects to time intervals (e.g., Laties & Weiss, 1963), resulting in behavior that is respectively more and less similar to that of animals. Regardless of its effect on counting, the availability of some concurrent task seems an important feature for making procedures for humans analogous to those used with animals. For that reason,

a concurrent response was used in the present experiments.

Type of Reinforcer

The reinforcer has not been thoroughly investigated in studies of FI responding with humans. Structurally, food for a hungry animal is different from points that humans later exchange for money. If that structural difference produces different behavioral outcomes, then it is important to investigate why.

One difference between reinforcers used with humans and animals is that animals must stop to eat their food reinforcers, whereas points are often automatically added to a counter for humans. Some authors have assumed that the difference between food and non-food reinforcers is important (e.g., Buskist et al., 1981; Buskist et al., 1980; Buskist & Miller, 1986), and therefore have used food reinforcers for humans responding on FI schedules. In those studies, constant-high, constant-low, terminal-minimum, and pause-respond patterns were obtained. That is, food reinforcers did not produce response patterns that were more similar to those found with animals. Given that there are no advantages of using food reinforcers with humans, and because human subjects cannot be deprived of food, it is neither a good reinforcer, nor a critical one to account for differences between the responding of humans and animals.

Reinforcer consumability is another variable that has not been thoroughly investigated in the study of FI performance with humans. Hungry animals consume food immediately after it is delivered, whereas humans cannot consume their points until after the experiment when they cash a check or make a purchase, regardless of when the points were delivered during an experimental session. The importance of consumability has been suggested by results from the self-control and impulsivity literature. For example, in one study (Hyten, Madden, & Field, 1994), human subjects chose between fewer points delivered immediately or more points

delivered after some delay. Subjects chose the larger delayed reinforcer, which is consistent with other results with humans (e.g., Flora & Pavlik, 1992; King & Logue, 1990; Logue, Pena-Correal, Rodriguez, & Kabela, 1986). When the choice was between a smaller amount of money delivered immediately after the session, or a larger amount delivered days or weeks after the session, however, subjects chose impulsively, which is a common result with animals (e.g., Logue & Pena-Correal, 1984; Mazur & Logue, 1978). The relation between consumability and responding similarly to animals also has been investigated with video games and videos as reinforcers (e.g., Navarick, 1996). Those attempts have been inconclusive, however, perhaps because for many adult humans, videos are not reinforcing. Although videos are immediately consumable, the motivation required for videos to function as reinforcers cannot be controlled by the experimenter. That problem effectively precludes the use of videos as experimental analogs to food for hungry animals.

In summary, the most important variables affecting FI performance of humans are instructions, concurrent tasks, and response cost. In addition, reinforcer consumability seems to affect responding in choice situations, though it has not been investigated with regard to FI response patterns. Of these variables, those that seem to provide the most relevant similarities to animal procedures are response cost (in the form of response effort), concurrent tasks, and consumable reinforcers. Perhaps the most important and least investigated of these - consumable reinforcers - may be problematic for motivating adult humans. Some possible solutions to this problem are presented in the next section.

Negative Reinforcement

One way to provide adequate motivation is with a negative reinforcement procedure, in which the negative reinforcer (e.g., shock) provides the motivation for responding (e.g., avoiding

shock). The most common aversive stimuli used in studies of negative reinforcement with humans have been point loss (e.g., Baron & Kaufman, 1968; Galizio, 1979; Weiner, 1963), and time out from point gain (e.g., Baron & Kaufman, 1966). Those procedures have produced steady-rate responding and subjects contacted few aversive stimuli, demonstrating that humans respond reliably on avoidance procedures with point loss as the aversive stimulus. There have been two studies of self-control with humans in which escape from noise was an immediately consumable negative reinforcer (e.g., Navarick, 1982; Solnick, Kannenberg, Eckerman, & Waller, 1980). In both studies, subjects chose shorter, immediate periods of noise offset over longer delayed periods. That is, with escape from noise as a reinforcer, humans made impulsive choices as animals typically do, which suggests that reinforcer consumability may be important to the similarity of reinforcers used with humans and animals. One problem with noise, however, is that there are ethical constraints on the length and number of sessions, and the volume of noise that can be used (Crosbie, 1998). Consequently, conditions often are not run to stability, and safe noise levels may not be functionally aversive for some subjects.

Timeout from avoidance

The timeout from avoidance procedure - in which responding on one alternative produces a period of timeout from a concurrently programmed avoidance schedule - seems particularly well-suited for studying response patterns of humans on FI. The timeout period is an immediately consumable reinforcer, and it can be easily scheduled on FI. Motivation for the timeout reinforcer is the avoidance schedule, which also is a concurrent task. Studies of timeout from avoidance with rats and monkeys have shown that timeout maintains responding when arranged on variable-interval (e.g., Perone & Galizio, 1987), fixed-ratio (e.g., Sidman, 1962), and FI (e.g., Findley & Ames, 1965) schedules. In addition, when timeout from avoidance was

used as a baseline to study drug effects (e.g., Galizio & Allen, 1991; Galizio & Liborio, 1995; Galizio & Perone, 1987), cocaine affected timeout responding differently from avoidance responding. Furthermore, morphine, alcohol, and benzodiazepines all had effects on timeout responding that were similar to their effects on responding maintained by food. Those studies with animals suggest that timeout from avoidance is a reinforcer that can produce response patterns similar to those produced by food reinforcers.

There is controversy concerning what aspects of timeout from avoidance are reinforcing. Some authors (e.g., Herrnstein, 1969) argue that responding for timeout is maintained because, when a rat responds on the timeout lever, it gets shocked less frequently than when it does not respond on the timeout lever. That is, responding for timeout is reinforced by a reduction in shock frequency. Another proposition (e.g., Courtney & Perone, 1992) is that responding for timeout is reinforced by escape from the response effort required by the avoidance schedule. Using the generalized matching-law (Baum, 1974) to determine sensitivity of responding to various sources of reinforcement, Courtney and Perone (1992) found that responding for timeout was only weakly related to shock-frequency reduction when obtained reductions were 0.05 to 2.54 shocks per minute. Those data suggest that shock-frequency reduction is not necessary to maintain responding for timeout. Human subjects typically avoid virtually all aversive stimuli in avoidance procedures (e.g., Baron & Galizio, 1976; Baron & Kaufman, 1966), so any reinforcing effects of aversive-stimulus frequency reduction are likely to be minimal. Consequently, the response requirement on an avoidance schedule should be effortful so that humans will escape from it by responding for timeout. Having an effortful response also is more analogous to procedures used with animals.

Given all the factors discussed above, timeout from avoidance includes a comprehensive

set of variables relevant to differences in responding of humans and animals on FI.

Although there are no published reports of timeout from avoidance with humans, pilot work in our lab showed that humans respond to produce timeout from avoidance of point loss when the force requirement of the avoidance schedule is 30 N. In those pilot studies, both variable-cycle deletion (i.e., responses during a cycle cancel the point loss scheduled for the end of that cycle; Baron, 1991) and free-operant postponement (i.e., each response postpones point loss for a fixed period of time; Sidman, 1953) schedules were used as the avoidance component. On those procedures, humans responded reliably on FI schedules with intervals ranging from 30 s to 480 s when timeouts were 30 s and 60 s long.

Present Studies

The primary goal of the present studies was to investigate a procedure for human subjects that is functionally similar to those typically used with animal subjects, in an attempt to isolate variables responsible for discrepant results from animals and humans. Given what already is known about responding of humans on FI, timeout from avoidance with an effortful response seems a promising way to achieve that goal.

CHAPTER 2: General Method

Subjects

Six adults who were recruited by advertisements in the local newspaper served as subjects. Subjects H206, H213, and H218 are females, and subjects H212, H217, and H219 are males. Subjects participated for 10 to 20 hours each week, and were paid at the end of their participation. Payment amount was based on accumulated point totals, but approximated \$5.50 per hour. In addition, subjects received a bonus of \$50 for attending all scheduled sessions, and lost \$5 for every session they missed without first informing an experimenter.

Apparatus

All experimental sessions were conducted in a 2-m x 3-m partitioned area of a laboratory. Subjects sat in front of an IBM PC-compatible computer (Tagram 486 DX, 33-MHz) with a VGA color monitor and mouse. The computer presented stimuli and conditions, and recorded dependent measures. Air-conditioner fans masked extraneous noise.

The response device was a 25-lb (114-N) capacity load cell (Transducer Techniques MLP-25C), which was 1.5 cm X 3.5 cm X 2.0 cm, and was bolted to the left front corner of the subject's desk. The top 1.5-cm X 1.5-cm surface of the load cell, which subjects pressed (hereafter labeled the "button"), was covered with tennis-racquet grip for cushioning. The load cell was stationary, so presses were isometric and did not result in any discernible displacement of the response device. The load cell continuously recorded forces up to 114 N with a precision of 1 N. Only responses greater than 30 N on the avoidance schedule and 15 N on the FI schedule were eligible for programmed consequences. Requiring an effortful avoidance response helped to ensure that the avoidance schedule was aversive. When subjects made a press of at least criterion force followed by complete release, a small white box flashed at the bottom center of the screen

as response feedback.

General Procedure

Instructions. Before starting the experiment, each subject was shown the apparatus and the following typed instructions:

This is a situation in which you can earn money by pressing and releasing a button. Whenever a green square is on the screen, you can lose points. If the green square flashes and “-150” appears in the box above it, you have lost 150 points. You can avoid losing points by pressing and releasing the button. The computer has recorded your response when a white box flashes at the bottom of the screen.

Sometimes, there will be two squares on the screen. Button presses only count for the square that is bigger. Sometimes, pressing the button when the red square is bigger will make the screen go blank for a while. You can make a small square big by moving the mouse cursor into the small square and pressing the left button. Don’t forget, whenever the green square is on the screen, you can lose points, even if the green square is small.

You will be given 10,000 points at the start of each session. Your point total for the session will be shown in the box above the green square. At the end of the session, any points you have left will be added to your total score, which will be shown in points and dollars at the end of each session. At the end of the experiment, you will receive 27.5 cents for every 1000 points in your score (e.g., 100,000 points = \$27.50).

It is very important that you attend every session. If you attend all scheduled sessions you will receive a bonus of \$50. If, however, you miss a session without first informing an experimenter, you will not receive this bonus, and furthermore, you will lose \$5 for missing the session. Do not touch anything on the computer or screen because this may crash the program and you will lose your points. *Press* the button, do not hit it! If you hit the button, or pull on the cables attached to it, you may damage the equipment and lose all your points.

For subjects in Experiment 2 the following text was inserted after the first sentence of the instructions above:

When a pink square is on the screen, sometimes you can add points to your score by pressing the button. If the pink square flashes and “+2000” appears in the box at the top of the screen, you have gained 2000 points.

Any questions were answered by referring subjects to the typed instructions, which were posted in subjects’ view throughout the experiment.

Screen layout. Throughout each session, subjects’ total points earned and the most recent change in score were shown in a small box at the top of the screen. Subjects pressed a mouse button to initiate each session, at which time the appropriate schedule-correlated stimuli appeared. The stimulus correlated with the avoidance schedule always was displayed on the left side of the screen. Stimuli correlated with FI schedules always were displayed on the right side of the screen. Feedback for functional responses (i.e., the flashing white box) was centered below the schedule-correlated stimuli. At the end of each session, the following message was displayed: “You can stop now <name>. You have earned <points> which is worth \$<money>”, where <name>, <points>, and <money> were replaced with the actual values.

Reinforcement. The avoidance schedule always was correlated with a green rectangle. Avoidance was scheduled on a point-loss postponement (e.g., Sidman, 1953) schedule with a response-loss (RL) interval of 10 s and a loss-loss (LL) interval of 2 s. Each avoidance response postponed point loss by 10 s. In the absence of responding, point loss occurred every 2 s. Point loss was a 75-ms flash of the green rectangle, subtraction of 150 points from the subject’s score, and a 1-s display of “-150” in the point-display box.

Fixed-interval schedules for which timeout was the reinforcer were correlated with a red rectangle. On these schedules, a response after the expiration of an inter-reinforcement interval was followed by a 30-s timeout period during which the screen was blank and responses had no programmed consequences.

The fixed-interval schedule for which point gain was the reinforcer was correlated with a pink rectangle. On that schedule, the first response after the expiration of an interval was followed by point gain. Point gain was a 75-ms flash of the pink rectangle, addition of 2000 points to the subject's score, and a 1-s display of "+2000" in the point-display box.

Experimental conditions. With a few exceptions, all sessions were 28-min in duration. Sessions in the Multiple-Schedule condition lasted for 24.5 min. Sessions in all conditions except Multiple-Schedule were 27-min long for H206. Subjects remained in Point-Gain, Timeout-from-Avoidance, and Avoidance-and-Point-Gain conditions for at least eight sessions and until post-reinforcement pause and quarter life (described below) met the stability criteria described at the end of this section.

For the Avoidance-Only condition, subjects responded on the avoidance schedule for the entire session. Subjects remained in the Avoidance-Only condition until they received few or no point losses in the second half of a session. All subjects completed the Avoidance-Only condition within 2 sessions.

For the Multiple-Schedule condition, the avoidance schedule was in effect for 3 min, followed by a response-independent timeout (30 s). A session was composed of seven 3.5-min cycles of alternating avoidance and timeout components. Subjects remained in the Multiple-Schedule condition until they made fewer than 2% of total responses during the timeout component for at least one session. All subjects completed the Multiple-Schedule condition within 5 sessions.

During the Point-Gain condition, an FI 240-s schedule was in effect for the entire session. The reinforcer was point gain as described above.

For the Timeout-from-Avoidance condition, timeout reinforcers were scheduled on

FI with intervals that ranged from 30 s to 480 s. Avoidance was scheduled concurrently with the FI schedule. The green (i.e., avoidance) and red (i.e., timeout) rectangles both remained on the screen except during timeout, but responses were only effective for one schedule at a time. That is, each response was applied to only one (i.e., the effective) schedule. The rectangle correlated with the effective schedule was larger (8 cm X 8 cm) than the rectangle correlated with the ineffective schedule (3 cm X 3 cm). Subjects changed the effective schedule by moving the mouse cursor into the smaller rectangle and clicking the left button (changeover response), which made the smaller rectangle larger and the larger rectangle smaller. Following each changeover response, the mouse cursor was returned to the center of the screen. Time continued to lapse for both the avoidance and FI schedules when they were ineffective. That is, subjects could lose points when the green (i.e., avoidance) rectangle was smaller, and the FI continued to elapse when the red (i.e., timeout) rectangle was smaller. During timeout (i.e., when no rectangles were on the screen), timing for both schedules was suspended.

In the Avoidance-and-Point-Gain condition, avoidance was presented concurrently with point gain. Effective schedules and changeover responses operated as described for Timeout-from-Avoidance.

Data Analysis

Dependent measures. Response rate, post-reinforcement pause, quarter life, index of curvature, latency to reinforcement, and relative cumulative responses were analyzed. Response rate was calculated by dividing the number of responses during FI components by the total session time excluding timeout. Post-reinforcement pause was calculated for each interval except the first, then mean post-reinforcement pause was calculated for each session. The quarter life for each session was calculated by first assigning each FI response for a session to 1 of 10 bins

according to its time within the interval. For example, if a response occurred 30 s into an interval on FI 240 s, it would be placed in the second bin (i.e., each bin is 1/10 or 24 s of the interval; 30 s is in the second 24-s bin). Responses were accumulated in bins throughout the session, then quarter life was defined as the time within an interval at which 25% of the responses had occurred. Interpolation was used when necessary. Index of curvature was calculated for each session with the procedure described by Fry, Kelleher, and Cook (1960). Figure 3 shows an example of an index-of-curvature analysis. Index of curvature is a measure of the area between the cumulative-response curve that would be produced if responses were made at a constant rate (straight line in Figure 3) and the cumulative-response curve obtained (curved line in Figure 3). Larger indices of curvature (hatched area in Figure 3) correspond to a more concave cumulative-response curve.

Quantitative interval types. Classifying each interval according to the response pattern suggested by Hyten and Madden (1993) is a useful analysis of FI responding. Using visual criteria to classify intervals, however, is labor intensive and imprecise. Consequently, response patterns reported below were classified according to the following quantitative criteria. All intervals with fewer than three responses were labeled terminal-minimum patterns. Remaining intervals were classified according to two parameters: post-reinforcement-pause length relative to interval length, and the difference in time required for the first half and the second half of total responses in the interval. Figures 4 to 6 illustrate this analysis. Figure 4 shows a sample interval analysis for hypothetical curves that would be classified as constant-rate and break-run. Horizontal dashed lines mark half the total number of responses in the interval. Vertical dashed lines show the time at which half of the responses had been made. For intervals with an odd number of responses, the middle response was the median. For intervals with an even number of

Figure 3. Hypothetical data showing the area measured by Index of Curvature.

Figure 4. Hypothetical data showing examples of the quantitative Constant and Break-Run response patterns.

Figure 5. Hypothetical data showing examples of the quantitative Scallop and No-Pause Scallop response patterns.

Figure 6. Hypothetical data showing examples of the quantitative Other response pattern.

responses, the middle response was interpolated. Dot-dash lines connect the middle response to the first and last responses. Slopes of the dot-dash lines are used to determine response pattern. For example, if the slopes of the two dot-dash lines are similar (i.e., slope of Line 1 is $\leq \pm 20\%$ of the slope of Line 2), responding is defined as constant-rate. Because both constant-rate and break-run patterns have relatively constant slopes after the first response, the length of the post-reinforcement pause determines whether an interval is classified as constant-rate or break-run. For present purposes, if the first response was made after 25% of the interval had elapsed, the pattern was labeled break-run.

Figure 5 shows the interval analysis for scallop and no-pause-scallop patterns. In both panels, the slope of the dot-dash line from the first to middle response is less than the slope of the line from the middle to the last response (i.e., slope of Line 1 < 80% of the slope of Line 2). In the top panel, the pause is less than 25% of the interval length, so this interval is classified as a no-pause scallop. The interval in the bottom panel is classified as a scallop.

Figure 6 shows an interval classified as other because the slope of the first dot-dash line is greater than the slope of the second dot-dash line (i.e., slope of Line 1 > 120% of the slope of Line 2).

With the exception of the first interval in each session (which did not have a post-reinforcement pause), responding in every interval was classified into one of the pattern categories described above. The proportion of each type of interval across FI value and reinforcer conditions is reported below.

Stability criteria. Responding was operationally defined as stable when both mean post-reinforcement pause (PRP) and quarter life (QL) had a mean difference of 0.10 or less over eight sessions. That is, responding was stable when the mean PRP and QL of the first four

sessions and the mean of the last four sessions did not differ by more than 10%.

CHAPTER 3: Experiment 1

Experiment 1 had two purposes: to determine whether timeout from avoidance of point loss is a reinforcer for humans, and to assess the pattern of responding for timeout on various fixed-interval schedules.

Method

Subjects

H206, H212, and H213 were subjects.

Procedure

Subjects completed the Avoidance-Only and Multiple-Schedule conditions, then responded on Timeout-from-Avoidance with timeout scheduled on various FI parameters. Table 1 shows the sequence of conditions. The first timeout of the first session in the Timeout-from-Avoidance condition immediately followed the first response on FI. A similar procedure has been used to train rats to respond for timeout from avoidance (e.g., Courtney & Perone, 1992). In Courtney and Perone's procedure, timeout initially was available after one response, then the schedule was changed to VI with a mean interval that gradually increased to the terminal schedule. In the present procedure it was important that subjects not have a history of responding on any schedule other than FI (cf. Weiner, 1969). Pilot data with the present procedure, however, showed that FI responding extinguished if subjects did not obtain a reinforcer early in the session. The single timeout available on FR 1 provided sufficient reinforcement to prevent extinction of FI responding, without allowing a pattern of responding to develop for a schedule other than FI (i.e., one response does not make a pattern.).

Subjects were given 10,000 points at the beginning of each session, and any points that had not been lost during the session were added to the subject's point total.

Table 1

Experiment 1: Sequence of Conditions, Number of Sessions in Each Condition, and Median Response Rates and Semi-Quartile Ranges (SQR).

Subject	Condition	FI	# Sessions	Median Rate (SQR)	
				AV	FI
H206	Avoidance	--	1	--	--
	Mult	--	3	--	--
	TOAV	30	11	20.34 (1.54)	2.98 (0.11)
		120	26	25.42 (1.42)	0.45 (0.15)
		240	8	25.70 (1.05)	0.40 (0.18)
		480	9	18.33 (0.76)	0.69 (0.11)
		60	16	20.88 (0.60)	0.35 (0.05)
		480	10	21.23 (0.41)	0.29 (0.08)
		60	10	25.73 (1.04)	0.30 (0.03)
H212	Avoidance	--	1	--	--
	Mult	--	3	--	--
	TOAV	30	18	8.41 (0.35)	2.50 (0.54)
		60	8	7.77 (0.25)	3.40 (0.26)
		120	9	7.20 (0.30)	0.80 (0.21)
		240	11	7.51 (0.43)	0.70 (0.24)
		480	18	7.17 (0.21)	0.30 (0.15)
		60	15	7.63 (0.44)	0.90 (0.09)
		480	34	6.66 (0.07)	0.20 (0.07)

(Table continues)

Table 1 (cont.)

Subject	Condition	FI	# Sessions	Median Rate (SQR)	
				AV	FI
H213	Avoidance	--	2	--	--
	Mult	--	5	--	--
	TOAV	30	15	20.24 (6.66)	51.40 (4.61)
		60	19	70.09 (8.65)	20.40 (7.10)
		120	12	40.05 (7.74)	5.10 (4.63)
		240	9	17.79 (1.82)	5.00 (2.25)
		480	17	22.30 (1.99)	4.45 (2.29)
		60	12	59.89 (5.06)	3.80 (1.18)

Note. Avoidance is the Avoidance-Only condition; Mult is the Multiple-Schedule condition; TOAV is Timeout-from-Avoidance conditions.

Following each timeout, the avoidance schedule always was the effective schedule. That is, the green (i.e., avoidance) rectangle always was larger when the stimuli reappeared after a timeout.

Results

Unless otherwise noted, all data reported in this section are from the FI component of the Timeout-from-Avoidance condition.

Following the *Timeout from Avoidance* section, common dependent measures (i.e., response rate and PRP) are reported to show their parametric functions across FI value. Response rate and PRP are compared with data from animals and other humans to see whether timeout from avoidance functions similarly to other reinforcers for responding on FI. Then, other measures (i.e., quarter life, index of curvature, and latency to reinforcement) are reported to show the patterns of subjects' responding on FI. Finally, quantitative interval types are reported to determine whether they accurately represent response patterns.

Timeout from Avoidance

Table 2 shows the total number of timeouts, percent of available timeouts, total number of point losses, rate of point loss, and effort per minute during avoidance for all conditions and subjects. Effort was defined as the time integral of force of responding (e.g., Notterman & Mintz, 1965). Because point-loss frequency and effort both were zero during timeout, the point-loss and effort data shown in Table 2 also show respective reductions in point-loss frequency and effort from timein to timeout. All subjects responded for timeout. With few exceptions (e.g., H206), more than 80% of available timeouts were obtained in each condition. H206 received the fewest total point losses (15), H212 received an intermediate number (108), and H213 received the most losses (896).

Table 2

Experiment 1: Number (#TOs) and Percent of Available Timeouts (%TOs) Obtained,
Number (#Losses) and Frequency of Losses (Loss/Min), and Avoidance Effort per
Minute (Eff/Min).

Subject	FI	#TOs	%TOs	#Losses	Loss/Min	Eff/Min
H206	30	183	88	0	0.00	1823261
	120	56	70	0	0.00	3270619
	240	36	90	0	0.00	4088604
	480	24	100	7	0.03	1692621
	60	64	47	5	0.03	3313504
	480	21	88	2	0.01	3073609
	60	56	41	1	0.01	3096384
H212	30	203	94	15	0.12	497445
	60	136	94	26	0.17	422511
	120	81	92	0	0.00	598935
	240	43	90	14	0.07	558741
	480	23	96	6	0.03	493632
	60	128	89	1	0.01	472353
	480	19	79	46	0.21	430638

(Table continues)

Table 2 (cont.)

Subject	FI	#TOs	%TOs	#Losses	Loss/Min	Eff/Min
H213	30	213	99	506	4.31	389429
	60	133	92	73	0.46	2028358
	120	76	86	94	0.51	1505294
	240	40	83	48	0.24	1197187
	480	23	96	154	0.72	1607171
	60	130	90	21	0.13	2741300

To assess what factors controlled responding for timeout on FI, Pearson correlations were calculated for FI response rate, percent of timeouts obtained, avoidance response rate, avoidance effort, and point-loss frequency. FI response rate and percent of timeouts obtained are indices of responding on FI. Avoidance response rate and effort are indices of effort reduction. Point-loss frequency is an index of loss-frequency reduction. Those latter three variables are potential sources of reinforcement for responding that produces timeout (e.g., Courtney & Perone, 1992).

The only significant correlation was between response rate on FI and point-loss frequency ($r[19] = 0.92$, $p < .01$), but that correlation was due entirely to one outlier (H213, FI 30 s). When that data point was removed from the analysis, there were no significant correlations. This result suggests that neither responding on FI nor percent of timeouts obtained were related to either point loss or effort reduction. It is clear that timeout from avoidance was a reinforcer. What is not clear is why.

Parametric Functions

Response rate. Figure 7 shows median responses per minute across FI values for all three subjects. The horizontal axis has a log scale. Error bars show the semi-quartile range for the eight stable sessions of each condition. Numbers near data points show the ordinal number of that condition (e.g., for H206, FI 60-s was the 5th and 7th condition in the sequence). For two subjects (H206 and H213), response rates were highest on FI 30. For the third subject (H212), response rate was highest on FI 60. For two subjects (H206 and H212), response rates were lowest on FI 480. For H206, however, response rates during both FI 60-s conditions (0.35 and 0.30, respectively) were similar to response rate on FI 480 s (0.29). For each FI value that was determined twice (i.e., FI 60 for all subjects plus FI 480 for H206 and H212), response rate was lower on the second determination (see Table 1 for medians and semi-quartile ranges). In

Figure 7. Experiment 1. Median responses per minute across FI values. Error bars show semi-quartile ranges; numbers near data points indicate the order of conditions. Note that x-axes are on a log scale, and the y-axis scale is different for H213.

addition, H213's response rate decreased across successive conditions, including the redetermination of FI 60 s. Those data suggest that response rate decreases with successive FI conditions. Figure 7 shows little evidence of a reliable relation between FI value and response rate. This could be interpreted as a lack of sensitivity to changes in the FI parameter, but subsequent analyses show that such an interpretation is incorrect.

The lower panel of Figure 8 (drawn from data shown in Lowe, Harzem, and Bagshaw, 1978), shows response rates across FI values for rats (triangles) and humans (squares) in two experimental groups. In one group (binary clock), pressing one button briefly illuminated a "clock" which indicated whether points were available for pressing a second button. In the other group (digital clock), presses on one button briefly illuminated a digital clock which showed the time that had elapsed since points were last earned for pressing the second button. Points became available on the second button after intervals without responding that ranged from 10 s to 360 s, and were only available for a limited time (i.e., DRL with limited hold of $1/15^{\text{th}}$ the schedule value). Filled squares in Figure 8 show mean response rates for subjects in the digital-clock group; open squares show mean response rates for subjects in the binary-clock group. Lowe et al. mentioned that the function relating response rate to schedule value for the digital-clock group is similar to the functions for rats, whereas the response-rate function for the binary-clock group is not.

Figure 9 shows median response rates for subjects H206, H212, and H213 with FI value on a linear scale (as used in Lowe, Harzem, & Bagshaw, 1978). The shape of the functions is more similar to corresponding functions obtained with rats and humans in Lowe, Harzem, and Bagshaw's (1978) digital-clock group than to the corresponding binary-clock group. That is, with timeout from avoidance as the reinforcer, present parametric response-rate functions are

Figure 8. Mean responses per minute and post-reinforcement pause for rats and humans drawn from data in Lowe, Harzem, and Bagshaw (1978).

Figure 9. Experiment 1. Median responses per minute on a linear scale.

qualitatively similar to those reported for rats with food reinforcers, and for humans responding for points on one observing task with a limited-hold contingency.

Running rate. Running rate (response rate excluding the post-reinforcement pause) often is more sensitive to changes in experimental variables than is overall response rate (e.g., Dukich & Lee, 1973; Schneider, 1969). In Lowe (1979), power functions relating running rate to schedule value were reported for rats, pigeons, and humans under various experimental conditions. With the exception of the binary-clock group, rats' and humans' running rates in Lowe (1979) are similarly described by a power function with a negative slope (R^2 from 83% to 99%). Figure 10 shows the same analysis for the present subjects. With the exception of a weak, nonsignificant, relation between running rate and FI value for H212, there are no consistent patterns. Running rate was constant in all but the second FI-480 condition for H206, and in all conditions except FI 30 and FI 480 for H213. Although the present response-rate functions (Figure 9) are similar to those obtained with rats, there is no consistent relation between running rate and FI value (Figure 10).

Post-reinforcement pause. Figure 11 shows median post-reinforcement pause (PRP) across FI value. For all subjects, PRP increased with FI value. In contrast to running-rate data, PRP results suggest that responding was well differentiated across FI value. Figure 12 shows PRP as a proportion of interval length. Data points above the dotted line show that subjects paused for a period longer than the FI interval. Subject H212 paused for approximately the same proportion of the interval for all FI values. Both H206 and H213 showed an increase, then a decrease in relative PRP across FI values.

The top panel of Figure 8 shows functions relating PRP to FI value for rats (diamonds) from Lowe's laboratory, and for humans in the binary-clock (open squares) and digital-clock

Figure 10. Experiment 1. Median running rate. X-axes are on a log scale; note the different y-axis scales. Lines show power functions.

Figure 11. Experiment 1. Median post-reinforcement pause (s). X-axes are on a log scale; note the different y-axis scales.

Figure 12. Experiment 1. Median post-reinforcement pause divided by FI value X-axes are on a log scale; note the different y-axis scales. Dotted lines show relative PRP equal to FI value.

(filled squares) groups. Pausing of rats and humans in the digital-clock group was negatively accelerated across FI value, whereas pausing of humans in the binary-clock group increased linearly with FI. Figure 13 shows the results of that analysis for the present subjects. A log function describes pausing well (minimum $\underline{R}^2 = 0.89$, $p < 0.01$) for all subjects. Pausing of H206 and H213 is negatively accelerated, whereas pausing of H212 is linear. Compared with data shown in Figure 8 from subjects in the digital-clock group and rats, functions for H206 and H213 are steeper. H212's function resembles that of subjects in the binary-clock group.

Figure 14 shows the present PRP data fit to power functions on log-log coordinates (as in Lowe, 1979). Pausing of all subjects is well described by the power function, as are the data for rats, pigeons, and humans in Lowe (1979; $\underline{R}^2$ from 0.98 to 0.99). It is interesting to note that the pausing for H212 was most similar to rats and humans in the digital-clock group with one analysis (Figure 14), but least similar to rats and humans in the digital-clock group with another analysis (Figure 13). Because H212's data have the best fit with one analysis but the worst fit with another, those analyses cannot be equivalent.

Regardless of their similarity to functions from animals and other human subjects, the present functions relating PRP to FI value are clear and reliable, which suggests sensitivity to changing FI parameters.

Measures of Response Patterns

Previous analyses showed the parametric relations of response rate and PRP to FI value. In the next section, response patterns on FI are described.

Quarter life and index of curvature. Figure 15 shows median quarter life relative to FI length. Data points near the dotted line ($QL = 0.25$) indicate constant-rate responding, whereas quarter lives near 1 indicate terminal-minimum responding. With the exception of

Figure 13. Experiment 1. Median post-reinforcement pause (s) on a linear X-axis Note the different y-axis scales.

Figure 14. Experiment 1. Median post-reinforcement pause (s). X-axes are on a log scale; note the different y-axis scales. Lines are power functions.

Figure 15. Experiment 1. Median quarter life divided by FI value. X-axes are on a log scale; note the different y-axis scale for H212. Dotted lines show quarter life equal to 0.25.

quarter lives near 0.25 for H213 at FI 30 and for H212 at FI 480, most responses were made near the end of the interval, regardless of FI value.

Figure 16 shows median index of curvature (IOC). As with quarter life, larger IOCs indicate a greater proportion of responses at the end of the interval, and lower IOCs indicate constant-rate responding. Index-of-curvature data are similar to quarter life: with the exception of two conditions, responding occurred near the end of intervals.

Latency to reinforcer. Scalloped response patterns on FI usually are correlated with a short latency to reinforcement: when subjects respond at high rates near the end of an interval, reinforcers are consumed soon after they become available, and reinforcement rate approaches the maximum possible. In contrast, the terminal-minimum patterns produced by humans often result in longer latencies to reinforcement and, consequently, lower overall reinforcement rates. If timeout from avoidance is more like food for hungry animals than are points, it should produce short latencies to reinforcement. Figure 17 shows latency to reinforcement across FI values. For H206, latency to reinforcement decreased systematically from FI 60 to FI 480. For H213, latency increased systematically from FI 30 to FI 480. For H212, latency was low and undifferentiated for FI values except 480. For two subjects (H212 and H213), FI 480 had the longest latency to reinforcement. The implications of latency to reinforcement for the reinforcing value of timeout are discussed in the *General Discussion*.

Relative cumulative responses. Figures 18 to 20 show cumulative responses during FI intervals for Subjects H206, H212, and H213, respectively. For each condition, FI intervals were divided into tenths. All responses from the stable eight sessions were assigned to the tenth of the interval in which they occurred. Responses in each interval tenth were expressed as a proportion of the total responses in the interval, and the proportion of responses in each interval tenth were cumulated across the interval. The tenth interval is indicated by a vertical, dotted line

Figure 16. Experiment 1. Median index of curvature. X-axes are on a log scale.

Figure 17. Experiment 1. Median latency to consuming reinforcers (s). X-axes are on a log scale; note the different y-axis scales.

Figure 18. Experiment 1. Relative cumulative responses (%) in each FI condition for H206.

Figure 19. Experiment 1. Relative cumulative responses (%) in each FI condition for H212.

H213

Figure 20. Experiment 1. Relative cumulative responses (%) in each FI condition for H213.

on each panel of the figures. Responses in the 11th portion of the interval (i.e., to the right of the dotted line) were made after the interval had elapsed. It should be noted that one response had to occur in the 11th portion of every interval to obtain the reinforcer. Curves with a sharp increase in responses in the last (11th) portion of the interval illustrate a large proportion of terminal-minimum responding. See Figure 18, Panels FI 60 a and FI 60 b for examples of terminal-minimum responding. Figure 20, Panel FI 30 shows an example of constant-rate responding. Many of these panels show some degree of scallop, particularly FI 240 in Figures 19 and 20, FI 120 in Figure 20, and FI 480 a and FI 480 b in Figure 18.

Note that the curves shown in Figures 18 to 20 represent total responding across eight sessions. Cumulative response curves that show a scalloped pattern could result without a single scallop interval in any of the eight sessions. These data are shown for comparison with other aggregated data (e.g., Barnes & Keenan, 1993), and with results reported below from the analysis of intervals classified by quantitative criteria.

Quantitative response patterns. Figure 21 shows the proportion of each interval type across FI values according to the quantitative criteria described above. Terminal-minimum patterns were the most common for all subjects and FI values. With the exception of FI 30 for H213, there was little evidence of constant-rate patterns, and virtually no no-pause scallops. For subjects H212 and H213, the largest proportion of scallop intervals occurred on FI 240. For H206, the largest proportion of scallop intervals occurred on FI 480.

The prevalence of terminal-minimum patterns, and the relative absence of constant-rate patterns, is similar to Weiner's (1969) results when subjects lost a point after every response. This suggests that the large response-force requirement used in the present procedure had similar effects on responding as did response cost.

Figure 21. Experiment 1. Proportion of intervals categorized by response pattern in each FI condition. “TM” = terminal minimum; “CON” = constant rate; “BR” = break-run; “NPS” = no-pause scallop; “SC” = scallop; “OTH” = other.

The summary of interval types is in accord with other dependent measures. For example, response rates that decrease with increasing FI values and post-reinforcement pausing that approximates the FI value imply mostly terminal-minimum response patterns. High quarter lives and indices of curvature also imply terminal-minimum patterns. Although response patterns inferred from response rate, PRP, quarter life, and index of curvature are based on aggregated data (i.e., medians), the quantitative-interval analysis is not. With the quantitative-interval analysis, response patterns of intervals that were not terminal-minimum also are identified, whereas they may have been averaged with the other dependent measures.

Order of Conditions

For several of the dependent variables discussed above, responding may have changed with successive conditions. To assess such a putative order effect, Spearman correlations were calculated for each dependent measure (i.e., response rate, latency to reinforcement, index of curvature, relative PRP, and relative quarter life) with both FI value and condition number. Although there were strong correlations between response rate and condition number for all three subjects (H206, -0.86; H212, -0.75; H213, -1.0), a sign test (Siegel, 1956) showed that condition number did not predict responding better than did FI value.

Summary

Overall, the present experiment showed that timeout from avoidance of point loss is a reinforcer for human subjects, even with very small to zero reductions in point-loss frequency. Post-reinforcement pausing reliably increased with FI value for all subjects. Relations between FI value and response rate were less reliable, and no relations were apparent for latency to reinforcement, relative quarter life, and index of curvature. When compared with data from rats and pigeons, post-reinforcement pausing had similar power functions, overall response rate was

qualitatively similar, and running rate was not at all similar.

Although cumulative-response curves showed some evidence of scalloped intervals, most intervals had terminal-minimum patterns. This is consistent with the finding that PRP increased with FI value, and response rate decreased with FI value. Subjects waited for most of the interval then made only a few responses. The overall conclusion, therefore, is that human subjects in the present study responded differentially to different FI schedules, although their patterns of responding did not change much across conditions.

Discussion

Parametric FI Functions

Subjects in the present study showed pausing across FI value that is similar to animals and some humans (cf. Figures 8, 13, and 14). In addition, the function relating overall response rate to FI value was similar to those found with animals (e.g., Lowe, Harzem, & Bagshaw, 1978). In general, the present subjects responded less than did other subjects. One reason for less responding may be the greater response-force requirement (see Notterman & Mintz, 1965, for details of the relation between response effort and rate.). Operant responses generally are easier for most human subjects, including those in Lowe, Harzem, & Bagshaw (1978), than they are for animals. Although it is difficult to compare directly the effort required for responding of animals and humans, animals' responding probably is more effortful. Hence, the response-force requirement may explain why present subjects responded less than did those in Lowe's studies (e.g., Lowe, 1979; Lowe, Harzem, & Bagshaw, 1978), but it does not explain why there was less responding relative to animal subjects.

Another reason why present subjects may have responded less than those in Lowe, Harzem, and Bagshaw (1978) is present subjects' greater experience responding on each

FI schedule. Subjects in Lowe et al. only participated for 3 to 9 sessions, whereas present subjects had more sessions (see Table 1), particularly in the first FI condition. Before their responding met the stability requirement, subjects responded more on FI, and often showed scalloped intervals during the first sessions following a change in FI conditions.

Scallops

An interesting finding is that the present data (Figures 9, 13 and 14) fit the parametric functions well compared with Lowe's corresponding analyses (Figure 8 and Lowe, 1979) despite the present absence of scalloped intervals (Figure 21). What does this imply for the study of responding on FI schedules? First, scallops are not synonymous with sensitivity. That different animal data were used for comparison with humans in Lowe (1979) and Lowe, Harzem, and Bagshaw (1978) suggests that the standard pattern of responding on FI may not be a simple issue for subjects of any species. For example, if the responding of animals on FI had a standard pattern, why were data from different subjects used as a standard for comparison with humans in in Lowe (1979) and Lowe, Harzem, and Bagshaw (1978)? A simple answer is that there is no standard pattern for animals responding on FI. Even though authors generally have reported that animals produce scalloped intervals on FI, a reexamination of the data shows various response patterns actually occurred (e.g., Cumming & Schoenfeld, 1958; Ferster & Skinner, 1957), and that the break-run pattern describes animals' responding better than does the scalloped pattern (Schneider, 1969). For animals and humans, reports of responding based solely on cumulative records are open to wide ranges of interpretation and generalization. The individual scallop, it seems, is not as typical as has been suggested.

CHAPTER 4: Experiment 2

The purpose of the second study was to compare point gain and timeout from avoidance as reinforcers for humans responding on FI. The Avoidance-and-Point-Gain condition was used to control for the relative contributions to FI response patterns of concurrent activity and reinforcer type.

The FI 240-s schedule was used in this experiment for several reasons: (a) Based on data from Experiment 1, the only schedule that seemed inappropriate was FI 30-s; (b) Either FI 240-s or FI 480-s was more desirable because it seemed less likely that subjects could accurately time longer intervals; and (c) FI 240-s was chosen over FI 480-s because only two intervals per session would have been analyzed with FI 480-s, and for two subjects in Experiment 1, FI 480-s had the longest latency to reinforcement.

Method

Subjects

H217, H218, and H219 were the subjects.

Procedure

In this experiment, point gain and timeout always were scheduled on FI 240-s. The sequence of conditions is shown in Table 3.

Because subjects earned points during conditions with point gain, they were not given 10,000 points at the beginning of Timeout-from-Avoidance sessions. Instead, point losses were deducted from subjects' point totals (i.e., the points they earned during Point-Gain conditions). The magnitude of point gain (2,000 points) was chosen so that average hourly earnings in Experiments 1 and 2 would be approximately equal.

Because presentation of point gain was instantaneous, the FI schedule remained effective

Table 3

Experiment 2: Sequence of Conditions, Number of Sessions in Each Condition, Median Response Rates and Semi-Quartile Ranges (SQR), and Percent of Reinforcers Obtained in FI (% FI Rein).

Subject	Condition	# Sessions	Median Rate (SQR)		
			AV	FI	% FI Rein
H217	Point Gain	10	--	1.68 (0.29)	100
	Avoidance	1	--	--	--
	Av and Point Gain	9	11.23 (2.45)	0.96 (0.14)	100
	Point Gain	8	--	0.81 (0.19)	100
	Mult	1	--	--	--
	TOAV	9	11.60 (0.14)	0.82 (0.14)	100
	Point Gain	8	--	0.75 (0.17)	100
H218	Point Gain	28	--	6.75 (0.95)	100
	Avoidance	1	--	--	--
	Mult	1	--	--	--
	TOAV	16	11.51 (1.10)	0.33 (0.07)	83
	Point Gain	10	--	6.00 (0.73)	100
	Av and Point Gain	9	12.67 (0.87)	0.75 (0.13)	100
	Point Gain	8	--	3.52 (0.49)	100

(Table continues)

Table 3 (cont.)

Subject	Condition	# Sessions	Median Rate (SQR)		
			AV	FI%	FI Rein
H219	Point Gain	14	--	3.90 (0.43)	100
	Avoidance	1	--	--	--
	Av and Point Gain	17	12.68 (1.63)	1.76 (0.32)	96
	Point Gain	10	--	2.44 (0.09)	100
	Mult	2	--	--	--
	TOAV	24	12.07 (1.61)	0.35 (0.08)	77
	Point Gain	10	--	2.19 (0.20)	100

following each reinforcer. Data from a pilot subject suggested that this minor procedural change produced responding that was no different from responding when the avoidance schedule remained effective following reinforcement (i.e., as in Experiment 1).

Because subjects were exposed to FI 240 in the first Point-Gain condition, the FR-1 contingency for the first timeout was not implemented in this experiment.

Results

Response Rate and PRP

In this section, there is a description of response rates and post-reinforcement pausing, response patterns across conditions, then the contribution of avoidance responding to patterns on FI .

Response rate. Figure 22 shows median response rate across the stable 8 sessions for each condition. Data labeled “G” refer to Point-Gain conditions, “AG” is Avoidance-and-Point-Gain, and “AT” refers to Timeout-from-Avoidance conditions. Error bars show semi-quartile ranges for the 8 stable sessions.

For all subjects, response rate was highest in the first condition. Thereafter, response rates across conditions showed two general patterns. For H217, responding in subsequent conditions was lower than in the first condition, and did not vary across the remaining conditions. For H218 and H219, however, response rate decreased across successive Point-Gain (G) conditions. Response rate was higher in Point-Gain conditions than in the two conditions with a concurrent avoidance response (AG and AT). Furthermore, response rate in Avoidance-and-Point-Gain (AG) was higher than in Timeout-from-Avoidance (AT). This pattern of responding across conditions was found even though Timeout-from-Avoidance was the second condition for H218 and the fourth condition for H219.

Figure 22. Experiment 2. Median responses per minute on FI 240. “G1”, “G2”, and “G3” = point gain conditions; “AG” = avoidance and point gain conditions; “AT” = timeout from avoidance conditions. Note the different y-axis scales.

Post-reinforcement pause. Figure 23 shows median post-reinforcement pausing for all subjects. Pausing is expressed relative to FI length, so a PRP of 1.0 represents a post-reinforcement pause of 240 s. Subject H217 paused for nearly the entire interval in all conditions. Post-reinforcement pauses were slightly longer in his final Point-Gain condition (G3), than in the other conditions. For H218, pausing in Point-Gain (G) conditions was similar, and shorter than in concurrent conditions (AG and AT). Pausing was longer in Timeout-from-Avoidance (AT) conditions than in Avoidance-and-Point-Gain conditions (AG). H219 had a similar pattern of pausing. Both H218 and H219 paused for nearly the entire interval in Timeout-from-Avoidance conditions (AT). For H218, pausing was a little longer in Avoidance-and-Point-Gain (146 s) than in Point-Gain conditions (127 s, 115 s, 103 s). For H219, however, there was a larger difference between pausing in Point-Gain conditions (17 s, 29 s, 34 s, respectively) and Avoidance-and-Point-Gain (115 s).

Measures of Response Patterns

Subjects' patterns of responding on FI are described in the following sections.

Quarter life and index of curvature. Figure 24 shows median quarter life for all three subjects. Virtually all of H217's responding was at the end of the interval across all conditions (i.e., QL was close to 1.0). H218 also had similar quarter lives across conditions, indicating that most responding was near the ends of intervals. Quarter life was highest for H218 in the Timeout-from-Avoidance (AT) condition. For H219, quarter life was near 0.25 for Point-Gain (G) conditions, indicating constant-rate responding. Quarter life was higher in the Avoidance-and-Point-Gain condition, and highest in Timeout-from-Avoidance, indicating responding that was mostly restricted to the end of the interval. Figure 25 shows median index of curvature. The pattern of IOC across conditions is the same as for quarter life.

Figure 23. Experiment 2. Median post-reinforcement pause (PRP) divided by FI value (i.e., 240). Dotted lines show relative PRP = 1.0 (i.e., 240 s).

Figure 24. Experiment 2. Median quarter life (QL) divided by FI value (i.e., 240). Dotted lines show QL = 0.25 (i.e., 60 s).

Figure 25. Experiment 2. Median index of curvature.

Latency to reinforcement. Figure 26 shows median latency to reinforcement. H217 had short latencies to reinforcement (i.e., less than 6 s) in all conditions, with the shortest latencies in the first and last Point-Gain conditions (G1 and G3). The patterns of latency for H218 and H219 were similar to the patterns found with other dependent measures: latency was similar and shortest in Point-Gain conditions, longer in Avoidance-and-Point-Gain, and longest in Timeout-from-Avoidance. Both H218 and H219 obtained a timeout about 45-50 s after it became available. As a result of their long latencies, H218 and H219 only obtained 83% and 77% of available timeouts, respectively, whereas they obtained 100% (H218) and 96% (H219) of available reinforcers in the Avoidance-and-Point-Gain condition, and both earned 100% of reinforcers in all Point-Gain conditions. See Table 3 for the percent of reinforcers obtained in all conditions.

Subjects might be expected to have longer latencies to reinforcement when they respond on two concurrent responses because there are more responses between which subjects' time is allocated. H217's responding showed the pattern that might be expected (i.e., similar latencies in AG and AT that were different from latencies in G) if the concurrent response were the only factor affecting latencies across conditions. The large reliable differences between latency to reinforcement during AG and AT shown by H218 and H219, however, suggest that there is some difference between point-gain and timeout reinforcers.

Relative cumulative responses. Figures 27 to 29 show relative cumulative responding for H217, H218, and H219, respectively. These curves were constructed in the same way as Figures 18 to 20. As suggested by his other data, H217 responded similarly in all conditions. Cumulative-response curves show that H217 made the largest proportion of responses during the last 24 s of the interval, as indicated by the steepest portion of the curve between interval tenths

Figure 26. Experiment 2. Median latency to reinforcement (s). Note the different y-axis scales.

Figure 27. Experiment 2. Relative cumulative responses (%) in each FI condition for H217.

Figure 28. Experiment 2. Relative cumulative responses (%) in each FI condition for H218.

Figure 29. Experiment 2. Relative cumulative responses (%) in each FI condition for H219.

9 and 10 (i.e., just to the left of the dotted line) for each condition. When virtually all responses occurred in the 10th interval (as in G3), the most likely response pattern is break-run. When several responses occurred before the steep increase in responding during the tenth interval (e.g., as in G2 and AT), the pattern might be considered a scallop with a sharp acceleration. H217's cumulative response curves show the same overall pattern of responding as his index of curvature (Figure 25). A high index of curvature is associated with a steep curve later in the interval (as in G1, AG, G2, and AT), and a slightly higher index of curvature is associated with fewer responses prior to the steep acceleration at the end of the interval (as in G3).

Figure 28 shows cumulative responding for H218. In all three Point-Gain (G) conditions, there is evidence of a scalloped pattern with no post-reinforcement pausing. The shallow portion of the curve between interval tenths 10 and 11 (to the right of the dotted line) indicates very little terminal-minimum responding in Point-Gain conditions. In contrast, the steep portion of the curve in the 11th interval tenth (to the right of the dotted line) of the Timeout-from-Avoidance condition shows that about 60% of responses occurred after the end of the interval, which suggests a preponderance of terminal-minimum responding. During the Avoidance-and-Point-Gain condition, H218 paused for a shorter time than in Timeout-from-Avoidance, which is consistent with data on post-reinforcement pausing (Figure 23), and responses were more evenly distributed in time from interval tenths 5 to 10, suggesting a break-run pattern. About 30% of responses in the Avoidance-and-Point-Gain condition occurred in the 11th interval, suggesting there were some terminal-minimum intervals, but fewer than in the Timeout-from-Avoidance condition.

Figure 29 shows cumulative responding for H219. Responding had a constant-rate pattern in all three Point-Gain conditions, as illustrated by the constant slope of the line from the

beginning to the end of the interval. There was a slight acceleration in proportion of responses from interval tenths 4 to 9 and again from 9 to 10 in the Avoidance-and-Point-Gain condition. About 45% of responses in Timeout-from-Avoidance occurred during the 11th interval tenth (i.e., to the right of the dotted line), suggesting terminal-minimum responding. About 40% of responses occurred between the 6th and 10th interval tenths, however, suggesting break-run or scallop patterns as well.

Quantitative interval types. Figure 30 shows the proportion of each quantitative interval type across conditions. Most of H217's intervals had terminal-minimum or scallop intervals. H217 had no constant-rate intervals, few no-pause scallops, and a moderate proportion of break-run intervals. The largest proportion of scallop and break-run intervals occurred in the Point-Gain conditions (gray bars), and the largest proportion of terminal-minimum intervals occurred in AG and AT (hatched bars). There appeared to be a trade-off between break-run and terminal-minimum intervals from Point-Gain to conditions with a concurrent avoidance response (hatched bars). Because H217 showed no difference in post-reinforcement pausing across conditions, and because any interval with fewer than three responses was classified as terminal-minimum regardless of pausing, this trade off of interval types could reflect fewer responses in the concurrent conditions, even though the overall pattern of responding was the same. This interpretation is supported by H217's similar relative cumulative response curves in all conditions (see Figure 27).

Point-Gain conditions (gray bars) consisted mostly of scallop and no-pause scallop intervals for H218, but she had fewer scallops in the Avoidance-and-Point-Gain (upward hatches) condition, and the fewest scallops during Timeout-from-Avoidance (downward hatches). There were few constant-rate intervals in H218's third Point-Gain condition, but none

Figure 30. Experiment 2. Proportion of intervals categorized by response pattern in each FI condition. “TM” = terminal minimum; “CON” = constant rate; “BR” = break-run; “NPS” = no-pause scallop; “SC” = scallop; “OTH” = other.

in the other conditions. Timeout-from-Avoidance was characterized by mostly terminal-minimum intervals, and Avoidance-and-Point-Gain had about equal proportions of terminal-minimum and break-run patterns, and a smaller proportion of scallop intervals. Overall, H218's responding was shifted toward the end of the interval in both concurrent conditions (AG and AT), with a complete shift (i.e., to terminal-minimum patterns) in Timeout-from-Avoidance.

For H219, responding also was shifted toward the end of the interval in the concurrent conditions, with the greater shift occurring during Timeout-from-Avoidance. This pattern is illustrated by the large proportion of constant-rate and no-pause scallop intervals (both of which involve short PRPs) during Point-Gain conditions, and an increase in break-run and scallop intervals, which involve larger PRPs, during the Avoidance-and-Point-Gain condition. Finally, Nearly all intervals were terminal-minimum during Timeout-from-Avoidance, indicating maximum pausing and the largest shift in responding toward the end of the interval. Intervals with fewer than three responses (i.e., terminal-minimum intervals) only occurred during Timeout-from-Avoidance for H219.

Inter-response times. Another way to assess subjects' patterns of responding across conditions is to analyze the time between successive responses, or inter-response times (IRT). Some authors have suggested that FI responding is composed of short and long IRTs, and changes in response patterns on FI schedules result from changes in the proportions of short and long IRTs rather than changes in response topography (e.g., Branch & Gollub, 1974; Gentry, Weiss, & Laties, 1983; Schneider, 1969). For example, responding on FI could consist of long IRTs early in the interval, followed by a transition to short IRTs during the interval. The transition from long to short IRTs does not happen at exactly the same time in every interval, and scallops may be an artifact of averaging different times of transition from long to short IRTs.

According to this view, IRTs that are intermediate between long and short are relatively infrequent. This proposition was assessed with the present data.

Figures 31 to 33 show the frequency of IRTs in the stable eight sessions of each condition. Each bar represents IRTs within a 2-s range, and any IRTs longer 250 s were included in the last bar on the figures (i.e., they were counted as IRTs of 250 s). For H217 (Figure 31), there were a few IRTs of intermediate length, but most were either short or long. In all conditions, most responses had IRTs of 2 s or less (shown by the first, tallest bar in each panel), with virtually all responses having IRTs of 20 s or less. The proportion of long IRTs increased throughout the five conditions, but there is little difference in IRT distributions across conditions. This pattern of IRTs is consistent with other data from H217: he responded similarly in all conditions.

Figure 32 shows the same IRT distributions for H218. In all three G conditions, most IRTs were 2 s or less. In G1 and G2, all IRTs were 20 s or less. There was a slight lengthening of short IRTs with successive Point-Gain conditions. In the concurrent conditions (AT and AG), there was a distinct shift in IRT distribution. The most obvious change was an increase in the variability of IRTs. In the Avoidance-and-Point-Gain condition (AG), more IRTs are in the short half of the distribution (i.e., less than 120 s) than in the longer half of the distribution, whereas the opposite is true of IRTs in the Timeout-from-Avoidance condition (AT). In particular, most responses in AT were 240 s or longer, indicating terminal-minimum responding, and no IRTs were shorter than 40 s. Overall, the concurrent conditions changed H218's responding on FI from short, consistent IRTs to intermediate and long, but more variable IRTs.

Figure 33 shows IRT distributions for H219. In Point-Gain conditions (G1-G3), all IRTs were on the short half of the distribution, with the most frequent IRT at about 10 s during G1,

Figure 31. Experiment 2. Relative frequency of inter-response times (IRT) in each FI condition for H217. Each bar represents a 2-s range of IRTs.

Figure 32. Experiment 2. Relative frequency of inter-response times (IRT) in each FI condition for H218. Each bar represents a 2-s range of IRTs.

Figure 33. Experiment 2. Relative frequency of inter-response times (IRT) in each FI condition for H219. Each bar represents a 2-s range of IRTs.

and at about 20 s during G2 and G3. The range of IRTs increased with successive Point-Gain conditions, so that the longest IRTs in G3 were about 80 s, whereas all IRTs during G1 were shorter than 40 s. In concurrent conditions (AG and AT), IRTs were more variable. As for H218, IRTs were more variable in AG than in G conditions, and most variable in AT. Also like H218, more IRTs were in the short half of the distribution during AG, and in the long half during AT. Unlike H218, however, H219 showed an increase from nearly 0% (in G conditions) to almost 40% (in AG) of responses with IRTs shorter than 2 s. Although H219's IRTs were more variable than H218's during Point-Gain conditions, IRT variability and proportion of longer IRTs increased in both concurrent conditions for H219. For all three subjects, the fewest short IRTs occurred in the Timeout-from-Avoidance condition.

The IRT distributions in Figures 31-33 show the proportion of each IRT that occurred across conditions, but they do not show the temporal patterning of particular IRTs. Figures 34 to 37 show the mean IRT for each ordinal response position (e.g., 1st response, 2nd, etc.) for a representative Point-Gain condition (G2) and both concurrent conditions (AG and AT) for each subject (Figures 34-36), and for the mean of all three subjects (Figure 37). A mean scallop pattern would be illustrated by long IRTs for the first response in an interval, followed by progressively shorter IRTs throughout the interval. For H217 (Figure 34), the first response in each condition has a long IRT (more than 200 s), followed by an IRT of approximately 20 s, then similar short IRTs throughout the remainder of the interval. In all conditions, H217's patterns of IRTs suggest a break-run pattern with a time of transition between break and run (i.e., between long and short IRTs) that varied little over intervals. In addition, H217 made a similar number of responses in each interval in all conditions (i.e., 12 in G2, 13 in AG, and 11 in AT).

Figure 34. Experiment 2. Mean inter-response times as a function of the ordinal position of responses for a representative point-gain condition (G2), and the two conditions with a concurrent avoidance response (AG and AT), for H217.

Figure 35. Experiment 2. Mean inter-response times as a function of the ordinal position of responses for a representative point-gain condition (G2), and the two conditions with a concurrent avoidance response (AG and AT), for H218.

Figure 36. Experiment 2. Mean inter-response times as a function of the ordinal position of responses for a representative point-gain condition (G2), and the two conditions with a concurrent avoidance response (AG and AT), for H219.

Figure 37. Experiment 2. Mean inter-response times as a function of the ordinal position of responses for a representative point-gain condition (G2), and the two conditions with a concurrent avoidance response (AG and AT). Data show means for all three subjects.

For H218 (Figure 35), mean IRTs also suggest a break-run pattern with a consistent transition time during G2. H218 made few responses in both concurrent conditions (AG and AT) compared with her Point-Gain conditions. Mean IRTs from the Avoidance-and-Point-Gain condition resemble a scalloped pattern without the high, terminal response rate. That is, the mean IRT of the first response is long, followed by progressively shorter IRTs, but, whereas a scallop would end with a series of short IRTs, H218's intervals ended with two or three intermediate (approximately 40 s) IRTs. Inter-response times during Timeout-from-Avoidance show few responses, and a longer IRT for the first response in an interval (i.e., longer PRP) than the other conditions.

Figure 36 shows mean IRTs for H219. In condition G2, constant IRTs around 20 s to 30 s reflect his constant-rate responding during Point-Gain conditions. During Avoidance-and-Point-Gain, mean IRTs suggest three phases throughout the interval: One response with a long IRT, followed by approximately 12 responses with intermediate IRTs (20-40 s), followed by several responses with short IRTs. This pattern might be characterized as a scallop with a less gradual transition from low to high response rates. Inter-response times during Timeout-from-Avoidance resemble a scallop without a high, terminal response rate.

To assess the proposition that scallops only occur when data are averaged, Figure 37 shows Mean IRTs averaged across subjects. These mean data suggest break-run patterns in all three conditions, with decreasingly abrupt transitions from long to short IRTs across conditions G2, AG, and AT. Although the IRTs in Figure 37 do not represent prototypical scallops with gradually accelerating response rates (i.e., gradually decreasing IRTs), they are more similar to scallop patterns than are any of the IRT data shown for individual subjects in Figures 34-36.

Figure 38 shows the Mean IRTs for all subjects from AG and AT conditions plotted as cumulative response curves. That is, the horizontal axis shows time and the vertical axis shows cumulative responses. If the mean IRTs from Figure 37 were from one interval of one subject, his cumulative record would look like Figure 38. Both mean cumulative response curves resemble scallops despite there being virtually no evidence of scalloped intervals for any individual subject.

Avoidance Responding

Concurrent activity has affected FI response patterns in previous studies (e.g., Barnes & Keenan, 1993; Laties & Weiss, 1963), and effects of the concurrent response have been replicated with the present data. Consequently, differences in responding during Avoidance-and-Point-Gain, and Timeout-from-Avoidance conditions could be explained by differences in concurrent avoidance responding.

Figure 39 shows median avoidance response rates for all three subjects during the Timeout-from-Avoidance and Avoidance-and-Point-Gain conditions. All three subjects in both the AG and AT conditions responded at approximately the same rate on avoidance (10-15 responses per minute). Avoidance response rate could remain constant while response topography changed, resulting in more time or effort spent on responding on the avoidance schedule, which could affect response rate on the concurrent FI similarly to changes in response rate. The duration and force of avoidance responses, however, did not change across the concurrent conditions.

Together, these data suggest that differences in responding on avoidance cannot account for the general differences in responding on FI between H217 and the other subjects. In addition, concurrent responding on avoidance is not sufficient to account for differences in responding

Figure 38. Experiment 2. Mean inter-response times for all subjects during AG and AT conditions expressed as cumulative response curves.

Figure 39. Experiment 2. Median responses per minute during the avoidance component of AG and AT conditions.

during AG and AT conditions for H218 and H219.

Summary

Overall, avoidance scheduled concurrently with FI resulted in lower FI response rates, longer post-reinforcement pauses, and a shift in responding toward the end of the interval. In addition, IRTs generally were longer and more variable. Response rates were lowest, pauses were longest, and the largest proportion of terminal-minimum intervals occurred during Timeout-from-Avoidance. Despite a lack of intervals with scalloped patterns, a cumulative-response curve showing mean responding of all subjects resembled scallops in the concurrent conditions, suggesting that response patterns on FI may be misleading when expressed as means.

In addition, latency to consume the reinforcer was longest in Timeout-from-Avoidance conditions. Differences in responding between Avoidance-and-Point-Gain and Timeout-from-Avoidance conditions cannot be attributed to differences in the rate or topography of avoidance responding, so may be due to different reinforcer types. In particular, the present point gain seems to be a more powerful reinforcer than the present timeout from avoidance.

CHAPTER 5: General Discussion

The main purposes of the present experiments were to determine (a) whether timeout from avoidance is a reinforcer for humans, (b) whether timeout from avoidance produces sensitive responding on FI, and (c) how responding on FI differs when the reinforcer is points or timeout from avoidance. Present results show that timeout from avoidance is a reinforcer which produces sensitive responding on FI, but that it is less valuable than points with the present procedure. These results and their implications are discussed more fully below.

Timeout from Avoidance

Subjects responded for timeout from avoidance of point loss when timeout was scheduled on FI, suggesting that timeout is a reinforcer for humans. In only one condition (H206, FI 480), however, were all available timeouts obtained. This was probably a consequence of long latencies to reinforcement in many conditions.

Details of the Present Procedure

Avoidance schedule. Perhaps some timeouts were not obtained because subjects allocated a disproportionate amount of time to the avoidance schedule. In other words, subjects did not respond as much on FI because they were too busy avoiding point loss. In an early version of the present procedure, avoidance was scheduled on VC 30-s with a minimum inter-loss interval of 5 s. On that schedule, subjects responded as if all losses were scheduled after the shortest interval (i.e., with at most a few seconds between successive responses). Because inter-loss intervals were short, and because responding did not postpone point losses on the VC 30-s schedule, there was a high probability that subjects would lose points while the FI schedule was in effect, and that may have resulted in less responding on FI. To allow more equitable allocation of responding across the two alternatives, the avoidance schedule was changed to an RL 10-s

point-loss postponement schedule. Every response on this schedule always was followed by 10 s without point loss. That 10 s could be allocated to the FI schedule. There was no such guaranteed period of safety from point loss on VC 30-s. Following the change to RL, subjects allocated larger proportions of responding to the FI schedule, and there was evidence of more responding on FI. In Experiment 1, H206 obtained 100% of timeouts during her first FI 480 condition. Although she received few losses during that condition (7), she received fewer in all other conditions. That H206 received the most losses during the same condition in which she obtained the most timeouts suggests that it may be difficult to allocate responses across the FI and avoidance schedules so that all losses are avoided and all FI reinforcers are obtained. Results from Experiment 2, however, do not support that proposition. H217 obtained 100% of timeouts during both conditions that required allocation of responding across FI and avoidance schedules (AG and AT). In addition, H218 obtained 100% of available point reinforcers during the Avoidance-and-Point-Gain condition. Fewer reinforcers were obtained in the other conditions with concurrent avoidance, but the range of obtained reinforcers varied despite avoidance responding that was similar across conditions and subjects. Consequently, it does not seem likely that responding on the RL 10-s schedule precluded responding on the concurrent FI alternative.

Magnitude of timeout. Perhaps subjects did not obtain all available timeouts because timeout magnitude (i.e., length) was too small. Although pilot results showed no difference between the proportion of 30-s and 60-s timeouts that were obtained, it is possible that timeout must be longer than 60 s to be reinforcing. With the session and FI lengths used in the present experiments, however, longer timeout durations would have been impractical.

Motivation. Perhaps subjects did not obtain all available timeouts because the avoidance schedule was not sufficiently aversive. That possibility also was tested with the pilot subject who

received different timeout lengths. On FI 60-s, the force requirement on the avoidance schedule was 30 N, 45 N, then 30 N. There was no difference in the number of timeouts obtained across conditions. The range of force requirements tested may not have been sufficient to affect aversiveness of the avoidance schedule, but virtually all subjects tested with an avoidance-force requirement of 30 N reported that pressing the button was difficult.

The pilot subject who was given timeout-duration and force-requirement variations reported that timeouts “weren’t much of a break” because she had to start responding again as soon as the timeout finished to avoid losing any points. That comment highlights one difference between the present Timeout-from-Avoidance procedure and those normally used with animals. With the present procedure, subjects were required to attend to the monitor to determine whether they were in timeout. If they leaned back in their chairs or closed their eyes during a timeout, they might miss the return to timein and thereby lose points. In contrast, timeout for rats generally is correlated with auditory and visual stimuli (e.g., white noise and houselight offset). Rats in timeout need not look at the work panel to avoid missing the return to timein. For this reason, future studies on timeout from avoidance with humans should use an auditory stimulus to signal the beginning and end of timeout.

Even if the nature of the stimuli correlated with timeout resulted in fewer timeouts being obtained, that does not explain why different percentages of available timeouts were obtained in different FI conditions.

Timeout from Avoidance as a Reinforcer

The most obvious difference between conditions in Experiment 1 was the FI length (i.e., the length of time before a timeout became available). There was no consistent relation between the percentage of timeouts obtained and FI value. For H206, the most timeouts (100%) were

obtained on FI 480-s, the second most (88%) on FI 480-s and FI 30-s, and the fewest (41% and 47%) on FI 60-s. For H212, both the most and the fewest timeouts were obtained on FI 480-s, and the second most on FI 30-s and FI 60-s. For H213, the conditions with the most timeouts (99% and 96%) were FI 30-s and FI 480-s, respectively. In Experiment 2, percent of timeouts obtained on FI 240-s ranged from 77% to 100%. Some factor other than FI schedule must account for the differences in timeouts obtained across conditions. These analyses are best suited to parametric data, so the following discussion is focused on data from Experiment 1.

Shock – frequency reduction. Some authors have found that rats' responding on avoidance schedules is maintained by reductions in the frequency of shock when they press the lever, relative to when they do not press the lever (e.g., de Villiers, 1974; Herrnstein & Hineline, 1966). The reductions in shock frequency said to have maintained responding in those studies ranged from 0.6 to 3.6 shocks per minute and from 3 to 9 shocks per minute, respectively. Other authors have reported that responding for timeout was maintained when shock frequency was reduced from timein to timeout by less than 0.3 shocks per minute (Perone & Galizio, 1987), and by 0.05 to 2.54 shocks per minute (Courtney & Perone, 1992). In Experiment 1, the reduction in point-loss frequency from timein to timeout ranged from 0.0 to 4.31 losses per minute, but there was no correlation between the percent of timeouts obtained or FI response rate and point-loss frequency reduction.

Effort reduction. As an alternative to shock-frequency reduction as a reinforcer for timeout from avoidance, Courtney and Perone (1992) showed that responding for timeout was sensitive to reductions in the effort (expressed as avoidance response rate) required by responding on the avoidance schedule. Although avoidance effort per minute, avoidance response rate, FI response rate, and percent of timeouts obtained in Experiment 1 appeared

sufficiently variable to permit correlations, none were found. This result is surprising considering the support for the notion that responding for timeout is maintained by reductions in the effort of responding on avoidance. There are a few possible explanations for this apparent absence of results.

First, although response rate on VI has been a valid index of the reinforcing value of timeout (e.g., Courtney & Perone, 1992), response rate on FI may not be as suitable for several reasons: (a) FI response rate generally decreased across conditions, suggesting that it was affected by factors other than specific schedule conditions; (b) although FI response rate decreased across successive conditions, the magnitude of change in response rate generally was small, suggesting that it may not be sufficiently sensitive to reflect changes in reinforcer value; (c) stability was assessed on PRP and quarter life, not on response rate which may not have been at steady-state; and (d) FI response rate and percent of timeouts obtained were not correlated. Response rate on FI and percent of timeouts obtained both have face validity as indices of the value of timeout, but their low correlation suggests that measuring value in this situation is not straightforward.

Second, the present effort measures may not be appropriate. Although the time integral of force is a valid measure of physical effort, it may not capture with humans all that is captured by measures of effort (i.e., response rate) with animals. For example, attending to the screen to see when timeouts end also may involve effort. If so, the effort-reduction analyses reported above would be inaccurate. The first step in remedying this potential problem is to use a timeout that is correlated with stimuli other than those on screen. Then, if reductions in the time integral of force still do not account for timeout responding, that measure should be discarded.

Reinforcing Value of Timeout and Points

Although it is a difficult construct to define and measure, some evaluation of the relative reinforcing value of points and timeout should be made here. Because the concurrent avoidance response affects responding, the best comparison of the reinforcers' value that can be made is between the AG and AT conditions in Experiment 2.

One measure of reinforcing value that has face validity is the percent of available reinforcers that were obtained in different conditions. These data are shown in Table 3. Fewer than 100% of available reinforcers were obtained in only three conditions, two of which were Timeout-from-Avoidance (H218 and H219), and the third was Avoidance-and-Point-Gain (H219). For H218 and H219, one could conclude that timeout was less valuable than points, and for H217, the two were equally valuable.

Another measure of value could be post-reinforcement pausing. For example, it has been found that PRP decreases with increases in the magnitude of the upcoming reinforcer (e.g., Baron, Mikorski, & Schlund, 1992; Perone & Courtney, 1992), which suggests that PRP could be an index of reinforcer value. With this measure (see Figure 23), timeout and points were equally valuable for H217, and points were more valuable than timeout for H218 and H219.

Reinforcer value decreases with increased delays to reinforcement (e.g., Richards, Mitchell, de Wit, & Seiden, 1997). When latencies to reinforcement are longer, the delay to reinforcement also is longer, so latency to reinforcement might be associated with reinforcer value. According to this view, points and timeout were equally valuable for H217, and points were more valuable than timeout for H218 and H219 (see Figure 27). Regardless of what measure is used as an index of reinforcer value, the results are the same: Timeout was less valuable than points in the present procedure.

What factors might account for the relative lack of value of timeout? The pilot manipulations of timeout described above suggest that timeout length and avoidance-schedule force requirement are not viable candidates. In Experiment 2, the same FI schedule was used in all conditions, and timeout still was less valuable than point gain, which suggests that its value was not related to different FI parameters. Subjects H218 and H219 received the Timeout-from-Avoidance condition in a counterbalanced order and had similar results, which suggests that value was not related to the order of the timeout condition. Together, these data suggest that PRP and latency to reinforcement were longer, and fewer reinforcers were obtained in Timeout-from-Avoidance because timeout is a less valuable reinforcer than is point gain.

Positive versus negative reinforcement. Perhaps timeout is less valuable than points because negative reinforcers in general are less valuable than positive reinforcers. This issue is not simple, however. First, the defining characteristics of positive and negative reinforcers are not clear. For example, is timeout from avoidance a negative reinforcer because it is escape from the avoidance schedule, or is it a positive reinforcer because it is the presentation of a shock-free, effort-free period? Studies with rats (Galizio & Allen, 1991; Galizio & Liborio, 1995; Galizio & Perone, 1987) suggest that timeout from avoidance is a positive reinforcer. For example, cocaine affected responding maintained by timeout from avoidance differently from responding maintained by avoidance. Furthermore, morphine, alcohol, and benzodiazepines all had effects on responding for timeout that were similar to their effects on responding for food.

Even if it were easy to classify timeout from avoidance as a positive or negative reinforcer, it is not clear that the two reinforcer types have different effects. For example, Logue and de Villiers (1978) trained rats on variable cycle (VC) shock-cancellation schedules (similar to VI schedules of food reinforcement), and found that shocks avoided closely conformed to

Herrnstein's (1970) matching equation. Logue and de Villiers reported sensitivity parameters (i.e., a was .82 to 1.32) that are within the range of those reported with positive reinforcement (a from .52 to 1.36; de Villiers, 1977). In addition, there is evidence that positive and negative reinforcement are mediated by the same brain structures (e.g., Gray, 1991). Given the nature of data comparing positive and negative reinforcement, it seems better to compare reinforcers based on their specific properties rather than their positive or negative classification.

Other properties of reinforcers. One specific property of timeout and point reinforcers is their magnitudes. Perhaps timeout from avoidance and point gain were not similarly valuable because their magnitudes were not comparable. For example, maybe a 30-s timeout from avoidance is less valuable than 2,000 points. This proposition could be tested with a titration procedure. For example, subjects could choose between timeout and point reinforcers, and the magnitude of one reinforcer could be adjusted until subjects choose both reinforcers equally often. Of course, the concurrent avoidance schedule that is required by the timeout-from-avoidance reinforcer would complicate the comparison.

It is interesting to note that Verhave (1962) initially concluded that timeout from avoidance was a weak reinforcer for rats. Subsequent procedural changes (e.g., Baron, DeWaard, & Lipson, 1977; Courtney & Perone, 1992; Dewaard, Galizio, & Baron, 1979; Perone & Galizio, 1987) have shown that timeout is more valuable than had been thought originally. The present procedure may be analogous to Verhave's procedure, and future modifications may find that timeout from avoidance is more valuable for humans than is suggested by the present data. For example, the present procedure may not have been sufficiently sensitive to show the full value of timeout from avoidance as a reinforcer. In general, response rate is not the best measure of reinforcer value because of the various factors which affect it (e.g., Herrnstein, 1964). Those

problems may be compounded by the additional complexity of humans' responding on FI, including response patterns that are not steady between reinforcers, and the concurrent avoidance schedule.

A choice procedure may provide a more sensitive measure of reinforcer value (e.g., Grace & Nevin, 1997; Grace, Schwendiman, & Nevin, 1998). The consumability of reinforcers already is an important variable in self-control and impulsivity procedures (e.g., Hyten et al., 1994). Perhaps that is a more appropriate paradigm in which to investigate the effectiveness of timeout from avoidance. With rats as subjects, the effectiveness of timeout from avoidance as a reinforcer also has been assessed with progressive-ratio procedures (e.g., Baron, 1991), resistance to extinction, and the generalized matching equation (Courtney & Perone, 1992). Similar procedures could be arranged for human subjects.

Finally, the present procedure may not have been based on optimal parameters of timeout. Although a comprehensive investigation of the properties of timeout from avoidance was not the focus of the present project, a thorough parametric investigation seems warranted considering the present data showing that humans respond for timeout from avoidance. The length of timeout, its schedule, and various features of the avoidance schedule including effort and rate of responding, and intensity of the aversive stimulus should be manipulated over a wide range of values to determine the most effective parameters with human subjects.

In conclusion, the present experiments are merely the first in what should be a series of experiments designed to gain a better understanding of timeout from avoidance as a reinforcer with human subjects, how it compares with other reinforcers, and its implications for human-operant research.

Responding of Humans on FI

Sensitivity

One goal of the present project was to show sensitivity of responding on FI to changes in schedule value when timeout from avoidance was the reinforcer. A second goal was to determine whether timeout produced better evidence of sensitivity than did points as reinforcers.

Consequently, to judge the results, sensitivity must be operationally defined. One commonly used definition of sensitivity with human subjects is the degree to which responding is similar to that of animal subjects under similar conditions. Comparison of humans' and animals' responding is important for drawing conclusions about the breadth and limitations of specific variables, and about the principles of behavior in general. In the present project, animal-like response patterns on FI were sought to rule out the proposition that human and animal response patterns are controlled by different variables (e.g., Lowe, 1979). For the purposes of Experiment 2, response patterns of animals could be considered the standard for comparison with response patterns of humans. Such a comparison, however, should not be used as the only definition of sensitivity of the responding of humans to experimental variables. In many ways, response patterns common with humans (e.g., terminal-minimum) could be considered evidence of better sensitivity than scalloped intervals. What pattern of responding could be more adaptive or efficient than waiting until the end of an interval, then making one or two responses? Although responding of humans on FI has not been consistent within or across studies, data from animal subjects also have been inconsistent both within and across species (e.g., Lowe & Harzem, 1977; Perone et al., 1987). It seems arbitrary that response patterns of animals should be considered the standard for humans, rather than the other way around.

A more useful definition of sensitivity is changes in responding following changes in

experimental conditions. With that definition, present subjects generally were sensitive to changing FI parameters and to different reinforcer conditions. With respect to the second purpose of these experiments, timeout did not produce more scallop and break-run intervals than did points.

Variables Affecting FI Performance

Based on the present data, reinforcer type and concurrent tasks both affect responding on FI, though the question of how and why they do so remains unanswered.

Some authors (e.g., Barnes & Keenan, 1993; Laties & Weiss, 1963; Lowe, 1979) have suggested that the effects of concurrent responses depend on whether they distract human subjects from counting or timing the interval. Lowe (1979) even suggested that distracting humans from counting was necessary for producing scalloped intervals. It is assumed that, if subjects wait until the end of the interval before responding (i.e., as with terminal–minimum patterns), then they must be timing or counting the interval. This conclusion is primarily based on subjects' reports (e.g., Lowe, 1979; Laties & Weiss, 1963; Barnes & Keenan, 1993). Only one present subject (H217) reported explicit counting of intervals, but if terminal-minimum patterns are interpreted as evidence of counting, then the preponderance of such intervals in the AG and AT conditions suggests that the concurrent task (i.e., the avoidance schedule) helped rather than hindered subjects' counting.

Unfortunately, it is not clear which concurrent tasks distract, and it may be difficult to experimentally manipulate such an abstract variable as distractibility. The effort of the concurrent response may be related to the effects of a concurrent response on FI responding. If subjects must exert more effort toward the concurrent response, perhaps they will be more distracted from counting the FI, thereby resulting in response patterns more like those produced

by animals (i.e., break-run or scallops). The concurrent avoidance response in the present procedure required more physical effort than most operant responses used with humans, yet subjects did not show evidence of being distracted from counting the FI. The concurrent response for subjects in Laties and Weiss (1963) was subtracting numbers, which could be considered a cognitively effortful response, and those subjects showed terminal-minimum and constant-rate patterns, neither of which was interpreted as evidence of distraction from counting the FI. In Barnes and Keenan (1993), the concurrent response was watching television, which is not physically or cognitively effortful, yet those subjects showed some scalloped intervals, which often is interpreted as evidence of distraction from counting the FI. The only clear conclusion from existing data is that it is unclear how a concurrent response affects responding on FI. As elusive and vague as it is, distracting humans from counting seems to be important, and therefore warrants further investigation.

That it is so difficult to distract humans from counting, and the apparent necessity of attempting to do so, raise an interesting question. Should human-operant research be focused on producing procedures and results that are more like those found with animals, controlling for or eliminating variables such as counting and instructions, and interpreting results according to their similarity to those produced by animals? Alternatively, should the focus of human-operant research be on variables such as counting and instructions, other topics which take into account the effects of counting and instructions, and interpreting results according to whether they change reliably with experimental conditions?

Both tactics probably would help the development of a more complete science of behavior. If humans are made to respond like animals, and if animals are made to respond like humans, then the generality of fundamental principles can be identified. Meanwhile, if relations

between independent and dependent variables can be established, and if those relations are different for different species or subjects, but reliable within species or subjects, then the limitations of certain principles can be identified. Together, the generalities and limitations will help define the science of behavior, and further the understanding of why organisms behave as they do.

Although both these general approaches to human-operant research are important, neither can be ultimately successful without the other, and without standardized procedures.

Methodological Issues

Relative to procedures used with animals, those used with humans are widely variable, and have achieved little standardization across laboratories and preparations.

Stability

Sidman (1960) argued that the ultimate test of a stability criterion is whether it produces reliable data. Data from human-operant experiments often are not reliable (e.g., Buskist et al., 1981; Buskist et al., 1980; Matthews et al., 1977), yet relatively lax – if any – stability criteria are the norm. For example, in studies by Lowe and colleagues (e.g., Lowe, Harzem, & Bagshaw, 1978; Harzem, Lowe, & Bagshaw, 1979), performance of humans on FI was “judged as stable” or “judged as stable over 3 sessions”, and the bases for judgement of stability were not reported. Across two experiments (Lowe, Harzem, & Bagshaw, 1978; Harzemet al., 1978), most conditions lasted from 4 to 6 sessions, several lasted 3 sessions, one condition lasted 7, one 8, and a third 9 sessions. Contrast that with the present experiments, in which only 4 of the 35 conditions lasted the minimum 8 sessions, and the longest condition took 35 sessions to become stable (see Tables 1 and 3 for numbers of session in each condition). Perhaps previous results from humans on FI were based on behavior in transition.

Examples of criteria for changing conditions in other studies include 50 reinforcers (Lippman & Meyer, 1967), at least one and usually two sessions (Zeiler & Kelley, 1969), no directional trends in, or similar shape of cumulative records for at least four consecutive sessions (Bennett, Miller, & Buskist, 1984; Buskist et al., 1980), and less than 15% variation in mean response rate over three sessions (Buskist & Miller, 1986). Stability was not mentioned, or criteria were not reported in some studies (e.g., Buskist et al., 1981; Decasper & Zeiler, 1972; Terrell, Bennett, Buskist, & Williams, 1986).

As an example of the different conclusions when stability criteria are applied across different numbers of sessions, the present stability criterion (mean difference for PRP and $QL \leq 0.1$) was applied to data across three sessions for some of H213's conditions. For the FI 30-s condition, 10 sessions were required before PRP and QL were stable across 3 sessions (i.e., the number of sessions assessed in many studies), whereas it took 15 sessions to meet the criterion across 8 sessions (i.e., the number of sessions assessed in the present experiments). Cumulative records from the stable 3 sessions look similar to cumulative records from the 8 stable sessions: Both show constant-rate responding. For H213's next condition (FI 60), 5 sessions were required for PRP and QL to be stable across 3 sessions, and 19 sessions were required to be stable across 8 sessions. Cumulative records of the stable 3 sessions showed constant-rate responding, but cumulative records of the stable 8 sessions showed terminal-minimum and break-run patterns.

This reanalysis shows that using even the same stability criterion over a small number of sessions results in fewer sessions before the criterion is reached. Furthermore, the resultant stable behavior can be different when different numbers of sessions are used to assess stability.

Perhaps the most disturbing feature of the stability criteria used in many human-operant

studies is the frequency of their absence. In a recent survey of studies reported in the *Journal of the Experimental Analysis of Behavior* that used human subjects (Rehfeldt & Ghezzi, 1996), 46% of studies between 1958 and 1995 reported stability criteria, and of those, only 30% were statistical (i.e., not based on visual inspection or mastery). The few studies with humans responding on FI cited above show that even statistical stability criteria can be relatively lax (e.g., when applied to only a few sessions).

If results reported in human-operant experiments are to become more reliable across subjects, studies, and laboratories, then stringent stability criteria must be used routinely. Comparisons with data from animals, and generalizations about behavior of humans are futile until only steady-state behavior is being studied.

Dependent Measures

Standardizing human-operant procedures also requires using dependent measures that can be compared across studies. Hyten and Madden's (1993) review shows that, although descriptions of humans' responding on FI have changed over time, the data have not. When only cumulative records are reported, as was common until recently, descriptions of those records can vary widely. For example, according to the description of data in Matthews et al. (1977), the consummatory response produced schedule sensitivity of humans responding on VR and VI schedules, whereas the cumulative records show that the results are more equivocal. In addition, several of the present analyses showed how averaging data across sessions or subjects can produce "artifactual scallops" (see also Baron & Leinenweber, 1994). Consequently, whether a particular experiment produces scalloped patterns can depend on how the data are analyzed and how the cumulative records are interpreted. It would be difficult for any consistency to emerge among data analyzed with such subjective measures.

The present quantitative analysis of interval types presents a promising alternative to cumulative records and average-response curves. With this quantitative analysis, each interval is evaluated individually – so there is no averaging of response pattern – and intervals are categorized objectively according to quantitative parameters, so there is no possibility of different interpretations of response patterns as there is with cumulative records. Finally, when the proportion of each interval type is summarized, the result provides a sensitive depiction of the pattern of responding on FI. The specific parameters used to define each interval type in the present analysis were chosen arbitrarily, and may be refined in the future, but the results obtained are in accord with other measures, suggesting that the present parameters are appropriate.

Quantitative analyses of intervals should not replace other dependent measures such as response rate, post-reinforcement pause, and IRT frequencies. Instead, quantitative interval analyses should replace cumulative records as the primary means of describing response patterns across conditions. This alternative analysis will allow reliable descriptions of responding which can be compared across subjects, experiments, and laboratories. Such quantitative comparisons are a necessary - though not sufficient – step to discovering the degree to which humans are sensitive to experimental variables, and the degree to which the responding of humans and animals are controlled similarly. Only by striving to answer such fundamental questions will the experimental analysis of human behavior progress sufficiently to be applied successfully to the ever increasing problems of society.

References

- Azrin, N. H. (1958). Some effects of noise on human behavior. Journal of the Experimental Analysis of Behavior, 1, 183-200.
- Barnes, D., & Keenan, M. (1989). Instructed human fixed-interval performance: The effects of the experimental setting. The Psychological Record, 39, 351-364.
- Barnes, D., & Keenan, M. (1993). Concurrent activities and instructed human fixed-interval performance. Journal of the Experimental Analysis of Behavior, 59, 501-520.
- Baron, A. (1991). Avoidance and punishment. In I. H. Iversen & K. A. Lattal (Eds.), Techniques in the behavioral and neural sciences: Vol. 6. Experimental analysis of behavior: Part 1 (pp. 87-134). Amsterdam: Elsevier.
- Baron, A., & Galizio, M. (1976). Clock control of human performance on avoidance and fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 26, 165-180.
- Baron, A., & Kaufman, A. (1966). Human, free-operant avoidance of "time out" from monetary reinforcement. Journal of the Experimental Analysis of Behavior, 9, 557-565.
- Baron, A., & Kaufman, A. (1968). Facilitation and suppression of human loss-avoidance by signaled, unavoidable loss. Journal of the Experimental Analysis of Behavior, 11, 177-185.
- Baron, A., & Leinenweber, A. (1994). Molecular and molar analyses of fixed-interval performance. Journal of the Experimental Analysis of Behavior, 61, 11-18.
- Baron, A., & Perone, M. (1982). The place of the human subject in the operant laboratory. The Behavior Analyst, 5, 143-158.
- Baron, A., DeWaard, R. J., & Lipson, J. (1977). Increased reinforcement when timeout from avoidance includes access to a safe place. Journal of the Experimental Analysis of Behavior, 27, 479-494.
- Baron, A., Kaufman, A., & Stauber, K. A. (1969). Effects of instructions and reinforcement-feedback on human operant behavior maintained by fixed-interval reinforcement. Journal of the Experimental Analysis of Behavior, 12, 701-712.
- Baron, A., Mikorski, J., & Schlund, M. (1992). Reinforcement magnitude and pausing on progressive-ratio schedules. Journal of the Experimental Analysis of Behavior, 58, 377-388.
- Baron, A., Perone, M., & Galizio, M. (1991). Analyzing the reinforcement process at the human level: Can application and behavioristic interpretation replace laboratory research? The Behavior Analyst, 14, 95-105.

- Baum, W. M. (1974). On two types of deviation from the matching law: Bias and undermatching. Journal of the Experimental Analysis of Behavior, 22, 231-242.
- Bennett, R. H., Miller, Jr., H. L., & Buskist, W. F. (1984). Human performance on modified fixed-interval schedules. The Psychological Record, 34, 99-114.
- Bentall, R. P., Lowe, C. F., & Beasty, A. (1985). The role of verbal behavior in human learning: II. Developmental differences. Journal of the Experimental Analysis of Behavior, 43, 165-181.
- Branch, M. N., & Gollub, L. R. (1974). A detailed analysis of the effects of d-amphetamine on behavior under fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 21, 519-539.
- Buskist, W. F., & Miller, J. R. (1986). Interactions between rules and contingencies in the control of human fixed-interval performance. The Psychological Record, 36, 109-116.
- Buskist, W. F., Bennett, R. H., & Miller, H. L., Jr. (1981). Effects of instructional constraints on human fixed-interval performance. Journal of the Experimental Analysis of Behavior, 35, 217-225.
- Buskist, W. F., Miller, H. L., Jr., & Bennett, R. H. (1980). Fixed-interval performance in humans: Sensitivity to temporal parameters when food is the reinforcer. The Psychological Record, 30, 111-121.
- Buskist, W. F., Morgan, D., & Barry, A. (1983). Interspecies generality and human behavior: An addendum to Baron and Perone. The Behavior Analyst, 6, 107-108.
- Courtney, K., & Perone, M. (1992). Reductions in shock frequency and response effort as factors in reinforcement by timeout from avoidance. Journal of the Experimental Analysis of Behavior, 58, 485-496.
- Crosbie, J. (1998). Negative reinforcement and punishment. In K. A. Lattal & M. Perone (Eds.), Handbook of human operant behavior research methods. New York: Plenum.
- Cumming, W. W., & Schoenfeld, W. N. (1958). Behavior under extended exposure to a high-valued fixed-interval reinforcement schedule. Journal of the Experimental Analysis of Behavior, 1, 245-263.
- de Villiers, P. A. (1974). The law of effect and avoidance: A quantitative relationship between response rate and shock-frequency reduction. Journal of the Experimental Analysis of Behavior, 21, 223-235.
- de Villiers, P. A. (1977). Choice in concurrent schedules and a quantitative formulation of the law of effect. In W. K. Honig & J. E. R. Staddon (Eds.), Handbook of operant behavior, (pp. 233-287). Englewood Cliffs, NJ: Prentice-Hall.

- DeCasper, A. J., & Zeiler, M. D. (1972). Steady-state behavior in children: A method and some data. Journal of Experimental Child Psychology, 13, 231-239.
- DeWaard, R. J., Galizio, M., & Baron, A. (1979). Chained schedules of avoidance: reinforcement within and by avoidance situations. Journal of the Experimental Analysis of Behavior, 32, 399-407.
- Dukich, T. D., & Lee, A. E. (1973). A comparison of measures of responding under fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 20, 281-290.
- Ferster, C. B., & Skinner, B. F. (1957). Schedules of reinforcement. New York: Appleton-Century-Crofts.
- Findley, J. D., & Ames, L. L. (1965). A note on timeout from avoidance with the chimpanzee. Journal of the Experimental Analysis of Behavior, 8, 419-423.
- Flora, S. R., & Pavlik, W. B. (1992). Human self-control and the density of reinforcement. Journal of the Experimental Analysis of Behavior, 57, 201-208.
- Fry, W., Kelleher, R. T., & Cook, L. (1960). A mathematical index of performance on fixed-interval schedules of reinforcement. Journal of the Experimental Analysis of Behavior, 3, 193-199.
- Galizio, M. (1979). Contingency-shaped and rule-governed behavior: Instructional control of human loss avoidance. Journal of the Experimental Analysis of Behavior, 31, 53-70.
- Galizio, M., & Allen, A. R. (1991). Variable-ratio schedules of timeout from avoidance: Effects of d-amphetamine and morphine. Journal of the Experimental Analysis of Behavior, 56, 193-203.
- Galizio, M., & Liborio, M. O. (1995). The effects of cocaine of behavior maintained by timeout from avoidance. Journal of the Experimental Analysis of Behavior, 63, 19-32.
- Galizio, M., & Perone, M. (1987). Variable-interval schedules of timeout from avoidance: Effects of chlordiazepoxide, CGS 8216, morphine, and naltrexone. Journal of the Experimental Analysis of Behavior, 47, 115-126.
- Gentry, G. D., Weiss, B., & Laties, V. G. (1983). The micro analysis of fixed-interval responding. Journal of the Experimental Analysis of Behavior, 39, 327-343.
- Gollub, L. R. (1964). The relations among measures of performance on fixed interval schedules. Journal of the Experimental Analysis of Behavior, 7, 337-343.
- Grace, R. C., & Nevin, J. A. (1997). On the relation between preference and resistance to change. Journal of the Experimental Analysis of Behavior, 67, 43-66.

- Grace, R. C., Schwendiman, J. D., & Nevin, J. A. (1998). Effects of unsignaled delay of reinforcement on preference and resistance to change. Journal of the Experimental Analysis of Behavior, 69, 247-262.
- Gray, J. A. (1991). The psychology of fear and stress. New York: Cambridge University Press.
- Harzem, P., Lowe, C. F., & Bagshaw, M. (1978). Verbal control in human operant behavior. The Psychological Record, 28, 405-423.
- Herrnstein, R. J. (1970). On the law of effect. Journal of the Experimental Analysis of Behavior, 13, 243-266.
- Herrnstein, R. J. (1964). Secondary reinforcement and the rate of primary reinforcement. Journal of the Experimental Analysis of Behavior, 7, 27-36.
- Herrnstein, R. J. (1969). Method and theory in the study of avoidance. Psychological Review, 76, 49-69.
- Herrnstein, R. J., & Hineline, P. N. (1966). Negative reinforcement as shock-frequency reduction. Journal of the Experimental Analysis of Behavior, 9, 421-430.
- Holland, J. G. (1958). Human vigilance. Science, 128, 61-67.
- Hyten, C., & Madden, G. J. (1993). The scallop in human fixed-interval research: A review of problems and data description. The Psychological Record, 43, 471-500.
- Hyten, C., Madden, G. J., & Field, D. P. (1994). Exchange delays and impulsive choice in adult humans. Journal of the Experimental Analysis of Behavior, 62, 225-233.
- King, G. R., & Logue, A. W. (1990). Human's sensitivity to variation in reinforcer amount: Effects of the method of reinforcer delivery. Journal of the Experimental Analysis of Behavior, 53, 33-45.
- Laties, V. G., & Weiss, B. (1963). Effects of a concurrent task on fixed-interval responding in humans. Journal of the Experimental Analysis of Behavior, 6, 431-436.
- Lippman, L. G., & Meyer, M. E. (1967). Fixed-interval performance as related to instructions and to subjects' verbalizations of the contingency. Bulletin of the Psychonomic Society, 8, 135-136.
- Lippman, L. G., Leander, J. D., & Meyer, M. E. (1970). Human fixed-interval performance as related to response effortfulness and to initial point. The Journal of General Psychology, 82, 57-61.
- Logue, A. W., & de Villiers, P. A. (1978). Matching in concurrent variable-interval avoidance schedules. Journal of the Experimental Analysis of Behavior, 29, 61-66.

- Logue, A. W., & Pena-Correal, T. E. (1984). Responding during reinforcement delay in a self-control paradigm. Journal of the Experimental Analysis of Behavior, 41, 267-277.
- Logue, A. W., Pena-Correal, T. E., Rodriguez, M., & Kabela, E. (1986). Self-control in adult humans: Variation in positive reinforcer amount and delay. Journal of the Experimental Analysis of Behavior, 46, 159-173.
- Lowe, C. F. (1979). Determinants of human operant behavior. In M. D. Zeiler & P. Harzem (Eds.), Advances in analysis of behavior: Vol. 1. Reinforcement and the organization of behavior (pp. 159-192). Chichester, England: Wiley.
- Lowe, C. F., & Harzem, P. (1977). Species differences in the temporal control of behavior. Journal of the Experimental Analysis of Behavior, 28, 189-201.
- Lowe, C. F., Beasty, A., & Bentall, R. P. (1983). The role of verbal behavior in human learning: Infant performance on fixed-interval schedules. Journal of the Experimental Analysis of Behavior, 39, 157-164.
- Lowe, C. F., Harzem, P., & Bagshaw, P. (1978). Species differences in temporal control of behavior II: Human performance. Journal of the Experimental Analysis of Behavior, 29, 351-361.
- Lowe, C. F., Harzem, P., & Hughes, S. (1978). Determinants of operant behavior in humans: Some differences from animals. Quarterly Journal of Psychology, 30, 373-386.
- Madden, G. J. (1995). Effects of observing schedule-correlated stimuli and reinforcers on human sensitivity to concurrent variable-interval schedules of reinforcement. Unpublished doctoral dissertation. West Virginia University, Morgantown, WV.
- Madden, G. J., Chase, P. N., & Joyce, J. H. (1998). Making sense of sensitivity in the human operant literature. The Behavior Analyst, 21, 1-12.
- Matthews, B. A., Catania, A. C., & Shimoff, E. (1985). Effects of uninstructed verbal behavior on nonverbal responding: Contingency descriptions versus performance descriptions. Journal of the Experimental Analysis of Behavior, 43, 155-164.
- Matthews, B. A., Shimoff, E., Catania, A. C., & Sagvolden, T. (1977). Uninstructed human responding: Sensitivity to ratio and interval contingencies. Journal of the Experimental Analysis of Behavior, 27, 453-467.
- Mazur, J. E., & Logue, A. W. (1978). Choice in a "self-control" paradigm: Effects of a fading procedure. Journal of the Experimental Analysis of Behavior, 30, 11-17.
- Navarick, D. J. (1982). Negative reinforcement and choice in humans. Learning and Motivation, 13, 361-377.
- Navarick, D. J. (1996). Choice in humans: Techniques for enhancing sensitivity to reinforcement immediacy. The Psychological Record, 46, 539-554.

- Notterman, J. M., & Mintz, D. E. (1965). Dynamics of Response. New York: John Wiley & Sons.
- Perone, M., & Courtney, K. (1992). Fixed-ratio pausing: Joint effects of past reinforcer magnitude and stimuli correlated with upcoming magnitude. Journal of the Experimental Analysis of Behavior, *57*, 33-46.
- Perone, M., & Galizio, M. (1987). Variable-interval schedules of timeout from avoidance. Journal of the Experimental Analysis of Behavior, *47*, 97-113.
- Perone, M., Galizio, M., & Baron, A. (1987) Schedule control of human and animal behavior: How different? Experimental Analysis of Human Behavior Bulletin, *5*, 24-30.
- Pouthas, V., Droit, S., Jacquet, A. -Y., & Wearden, J. H. (1990). Temporal differentiation of response duration in children of different ages: Developmental changes in relations between verbal and nonverbal behavior. Journal of the Experimental Analysis of Behavior, *53*, 21-31.
- Rehfeldt, R. A., & Ghezzi, P. M. (1996). The steady-state strategy in human operant research: How stable are we? Experimental Analysis of Human Behavior Bulletin, *14*, 23-25.
- Richards, J. B., Mitchell, S. H., de Wit, H., & Seiden, L. S. (1997). Determination of discount functions in rats with an adjusting-amount procedure. Journal of the Experimental Analysis of Behavior, *67*, 353-366.
- Rosenfarb, I. S., Newland, M. C., Brannon, S. E., & Howey, D. S. (1992). Effects of self-generated rules on the development of schedule-controlled behavior. Journal of the Experimental Analysis of Behavior, *58*, 107-121.
- Schneider, B. A. (1969). A two-state analysis of fixed-interval responding in the pigeon. Journal of the Experimental Analysis of Behavior, *12*, 677-687.
- Schroeder, S. R., & Holland, J. G. (1968). Operant control of eye movements. Journal of Applied Behavior Analysis, *1*, 161-166.
- Seigel, S. (1956). Nonparametric statistics for the behavioral sciences. Tokyo: McGraw-Hill Kogakusha.
- Sidman, M. (1953). Avoidance conditioning with brief shock and no exteroceptive warning signal. Science, *118*, 157-158.
- Sidman, M. (1960). Tactics of scientific research: Evaluating experimental data in psychology. Boston, MA: Author's Cooperative.
- Sidman, M. (1962). Timeout from avoidance as a reinforcer: A study of response interaction. Journal of the Experimental Analysis of Behavior, *5*, 423-434.
- Skinner, B. F. (1953). Science and human behavior. New York: Macmillan.

- Skinner, B. F. (1957). Verbal Behavior. New York: Appleton-Century-Crofts.
- Skinner, B. F. (1969). Contingencies of reinforcement. New York: Appleton-Century-Crofts.
- Solnick, J. V., Kannenberg, C. H., Eckerman, D. A., & Waller, M. B. (1980). An experimental analysis of impulsivity and impulse control in humans. Learning and Motivation, 11, 61-77.
- Terrell, D. J., Bennett, R. H., Buskist, W., & Williams, R. A. (1986). Effects of orienting instructions on human fixed-interval performance. Bulletin of the Psychonomic Society, 24, 107-109.
- Verhave, T. (1962). The functional properties of a timeout from an avoidance schedule. Journal of the Experimental Analysis of Behavior, 5, 391-422.
- Weiner, H. (1962). Some effects of response cost on human operant behavior. Journal of the Experimental Analysis of Behavior, 5, 201-208.
- Weiner, H. (1963). Response cost and the aversive control of human operant behavior. Journal of the Experimental Analysis of Behavior, 6, 415-421.
- Weiner, H. (1964a). Conditioning history and human fixed-interval performance. Journal of the Experimental Analysis of Behavior, 7, 383-385
- Weiner, H. (1964b). Conditioning history and human fixed-interval performance. Journal of the Experimental Analysis of Behavior, 7, 383-385.
- Weiner, H. (1965a). Conditioning history and maladaptive human operant behavior. Psychological Reports, 17, 935-942.
- Weiner, H. (1965b). Real and imagined cost effects upon human fixed-interval responding. Psychological Reports, 17, 659-662.
- Weiner, H. (1969). Controlling human fixed-interval performance. Journal of the Experimental Analysis of Behavior, 12, 349-373.
- Weiner, H. (1972). Controlling human fixed-interval responding with fixed-ratio responding or differential reinforcement of low rate responding in mixed schedules. Psychonomic Science, 26, 191-192.
- Weiner, H. (1983). Some thoughts on discrepant human-animal performances under schedules of reinforcement. The Psychological Record, 33, 521-532.
- Zeiler, M. D., & Kelley, C. A. (1969). Fixed-ratio and fixed-interval schedules of cartoon presentation. Journal of Experimental Child Psychology, 8, 306-313.