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The Effects of Session Time and Satiation

on the Form of the VI Response Function

Laura Campbell

Honors Thesis

ABSTRACT

There has been considerable recent controversy over the empirical form of the function relating response rate to reinforcement rate on Variable Interval (VI) schedules. Some theories (matching, for example) predict a monotonic relationship between response rate and reinforcement rate. Other theories (behavioral economics, for example) predict a bitonic relationship. There is empirical support for both positions. Recently, Dougan, Kuh, and Vink (in press) have shown that session length is one variable which alters the form of the function. Functions were predominantly monotonic when sessions were short (10 minutes), and predominantly bitonic when sessions were long (30 minutes), when data from the entire session were considered. However, the degree of bitonicity increased in successive 10-minute blocks within the 30-minute session, which is consistent with satiation processes. The present experiments further examined the effects of session length and satiation on the VI function. In Experiment 1, 8 rats were exposed to a ten-minute session either immediately preceding or immediately following a 20-minute time-out. Placement of the session relative to the time-out period had no effect on the form of the response function. In Experiment 2, 7 rats were exposed to a 10-minute session followed by a 20-minute time-out period. On some occasions, animals were prefed before the session. The response function was different depending on the prefeeding condition. The results are not consistent with recent demonstrations by McSweeney and her colleagues that

response rates change systematically within reinforcement sessions. The results

also suggest that satiation may play a role in the form of the VI response function.

The Effects of Session Time and Satiation on the Form of the VI Response Function

There has been considerable controversy recently over the effects of reinforcers on the responses which produce them. Traditionally, the relationship between responses and reinforcers has been described by the Law of Effect (Thorndike, 1898). According to Skinner's (1938) version of the law of effect, a response followed by a reinforcer will, by definition, always increase in frequency. Skinner's law forms the basis for more modern theories, such as the matching law (Herrnstein, 1961, 1970). According to the matching law the function relating response to reinforcement rate is monotonic: That is, response rate increases as reinforcement rate increases (see Figure 1). Several experiments have demonstrated monotonic functions on Variable Interval (VI) schedules (Catania and Reynolds, 1968; Herrnstein, 1961).

However, several recent theories make different predictions. Both behavioral economics and behavior regulation theories (Baum, 1981; Dougan, 1992; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988; Staddon, 1979; Timberlake & Peden, 1987) predict bitonic functions. Bitonic functions are defined by an increase and then decrease in response rate as a function of increases in the rate of reinforcement (refer to Figure 2). In the area of behavior economics, Hursh et al (1988), for example, found a bitonic demand function to exist in food getting responses with closed economies. Timberlake and Peden (1987) found both monotonic and bitonic functions in open as well as closed

economies. Both economic and regulatory models suggest that high response rates

will not be maintained at high reinforcement rates because they are not optimal

strategies. Perhaps this reflects "too much of a good thing": That is, food is

present in such high quantities that it would be a waste of energy to work hard.

As shown above, there is conflicting empirical evidence regarding the form

of the VI response function: Some studies have found monotonic functions while

others show bitonic functions. Research which examines the variables responsible

for the reported differences is needed. Dougan, Kuh, & Vink, (in press) have

attempted to explain these differences. They found that monotonic functions

occurred during short sessions (10 minutes), while bitonic functions occurred

during longer sessions (30 minutes). Furthermore, by dividing a 30-minute

session into 10-minute segments, Dougan et al (in press) found the first 10-minute

segment to be monotonic, the second segment to be slightly bitonic, and the third

10-minute segment to be very bitonic. Hence, monotonic functions may exist on

short sessions, but the bitonicity of the functions increases with increased session

length.

Dougan et al (in press) offered several possible explanations for the effects

of session length, one of which is behavior regulation. Regulation and economic

theories predict decreases in response rate as a result of possible anticipatory

responses (Baum, 1981; Dougan, 1992; Hursh, Raslear, Shurtleff, Bauman, &

Simmons, 1988; Staddon, 1979; Timberlake & Peden, 1987). Figure 2 shows a

bitonic curve with response rate plotted as a function of reinforcement rate. Note that on schedules that provide the highest rates of reinforcement, the rate of response is low. Anticipatory explanations suggest that early in the session the animal anticipates high rate of reinforcement late in the session resulting in low overall responding across the entire session.

Satiation is another possible explanation of the bitonic function and is, in fact, a common assumption in explaining bitonic functions. Put simply, satiation is a decrease in response rate at the end of a session as a function of reinforcement delivered earlier in the session. Satiation would not occur in a short session because an animal would be unable to obtain a high number of reinforcers in such a limited time. In longer sessions, at high reinforcement rates, however, the animal might obtain large quantities of reinforcers which could lead to satiation and the same decreased response rate as seen in Figure 2. Consequently, a monotonic function occurs in short sessions (where satiation is not a factor) and a bitonic function in long sessions (where satiation is a factor).

Although satiation may initially seem like a reasonable explanation, satiation-like results have been found in situations where satiation can be ruled out. McSweeney (McSweeney, 1992; McSweeney, Hatfield, & Allen, 1990; McSweeney and Hinson, 1992) has examined changes in responding within sessions using a wide variety of schedules, paradigms, and reinforcement rates. She found decreases in response almost universally across conditions, even in

situations where satiation can be ruled out because reinforcement rates are too low

to produce satiation.

McSweeney's results suggest that the Dougan et al (in press) results which

appear to be satiation, may in fact be due to other processes based on session time

alone. The present experiments are designed to tease apart the effects of session

time and "satiation" by isolating these variables in two experiments. Experiment

1 was designed to examine response rate as function of the duration of session.

Dougan et al (in press) found that each 10-minute segment of a 30-minute session

showed changes in the function from a monotonic curve to an increasingly bitonic

curve. However, this could be due to either satiation or to the passage of time

within the session. Experiment 1 was designed to isolate the first and last 10-

minute segments while maintaining a constant food density and thereby

determining whether there a correlation exists between time in the session and

response rate. Experiment 2 was designed to examine response rate as a function

of satiation. As shown in previous experiments, monotonic functions are found

in short sessions and also in early portions of long sessions (Dougan et al, in

press). Satiation theory predicts that monotonic functions will not be found in

longer sessions or in the later portions of longer sessions because of food earned.

Experiment 2 manipulated food density while keeping the time in session constant

by the use of a pre-session in which the animals were fed on random days. Thus,

Experiment 2 looked at possible satiation factors without the effects of time in the

session.

EXPERIMENT 1

<u>Methods</u>

<u>Subjects</u> The subjects were 8 Long Evans hooded rats, obtained from the

Illinois Wesleyan University psychology department breeding colony. Subjects

were experimentally naive and between 90 and 120 days old at the beginning of

the study. Each subject was housed individually in a hanging stainless steel cage

with free access to water in the home cage.

<u>Apparatus</u> The apparatus was a standard operant conditioning chamber for

rats, model BRS/LVE RTC-028. The chamber measured 26 cm high, 31 cm

long, and 24 cm wide with a wire mesh floor. The front and back walls were

stainless steel while the side walls and ceiling were plexiglass. The front wall

contained a 5 watt houselight centered one centimeter from the ceiling. Two

retractable bars, 2.5 cm above the floor of the cage were centered on the front

wall, each 9 cm from the closest wall. Above each bar were three stimulus lights

(white, green, and red), each 5.5 cm above the bar and 2 cm apart. Food

reinforcement was delivered in a receptacle centered at the bottom of the front

wall. The entire apparatus was enclosed in a sound attenuating chamber. All

experiments as well as data collection were controlled by an IBM PC compatible

computer connected to a MED Associates interface and running MED-PC software. This equipment was located in an adjacent room.

Procedure All subjects were maintained at 80% of their ad libitum weight. Subjects were hand shaped to press the left response lever. The experiment proper began when all animals were reliably pressing.

The subjects were exposed to eight experimental conditions as defined by four reinforcement schedules (VI7.5s, VI15s, VI30s, and VI480s) and two different time segments within the session. The order of presentation of conditions was counterbalanced to avoid any order effects. For each schedule, each subject was given access to the response lever either during the first or the last ten minutes of a thirty minute session with no access during the remaining twenty minutes. After subjects were exposed to all VI schedules on either the first or the third ten minute segment, the segment conditions were switched.

Sessions were conducted once a day, 6-7 days per week until all conditions had been completed. Each condition was in effect for fifteen days with the total experiment taking 120 days to complete. Reinforcers were 45 mg pellets (Noyes Improved Formula A). During the time-out period, when the animal had no access to the bar, the houselight remained on. The end of the session was signified when the houselight went off.

RESULTS

Response rates were calculated by dividing the number of responses in the session by the number of minutes (10). The mean response rate over the last 5 session is plotted as a function of reinforcement rate in Figure 3. As seen in Figure 3, bitonic functions were found in both first and third 10-minute blocks. However, no apparent systematic differences between first and third minute blocks were found.

Results were confirmed with a 4 X 2 within subject analysis of variance. It was found that there was a significant effect of the schedule of reinforcement ($F[3,21] = 33.34$, $p < .01$). There was no significance between the first and third blocks ($F[1,7] = .003$, $p > .05$) nor was there a significant interaction ($F[3,21] = .112$, $p > .05$).

EXPERIMENT 2

Methods

Subjects and Apparatus Subjects were 8 Long Evans rats of the same age and housed under the same conditions as those in Experiment 1. One of the 8 animals died during shaping procedures. The apparatus used in Experiment 2 was the same one used in Experiment 1.

Procedure Subjects were maintained at 80% of their ad libitum weight and hand shaped to the left response lever. The experiment proper began when all subjects were reliably pressing.

Subjects were exposed to the same four counterbalanced schedules as those in Experiment 1 (VI7.5s, VI15s, VI30s, and VI480s). For each experimental condition, each subject was first exposed to eight sessions of a baseline condition. During baseline, subjects had lever access for thirty minutes and could press the lever for food reinforcers on the VI schedule appropriate to the condition. The average number of reinforcers received for the first twenty minutes of the last five baseline sessions was calculated as the "prefeed" amount for the next step of the experiment. During the next phase, subjects were exposed to a pre-session which included eight days of a prefeed requirement and eight days of a no-prefeed requirement. These sessions were alternated pseudo-randomly so that neither pre-session condition occurred more than three times consecutively. During the pre-session, subjects were placed in a plastic tub with a wire top for twenty minutes. On prefeed days, they were given the calculated prefeed amount of Noyes pellets at the beginning of the pre-session. On non-prefeed days, the animals were placed in the plastic tub for twenty minutes without receiving any pellets. After the pre-session, subjects were placed in the operant chamber for thirty minutes. Each subject was exposed to ten minutes of access to the response lever and twenty minutes of no access. A houselight, which remained on during

the entire session, was extinguished to signal the end of the session. Subjects were then returned to their home cage.

As in Experiment 1, sessions were conducted once a day, 6-7 days per week until all conditions were completed. Each condition was in effect for 8 days of baseline and 16 days of randomly altered prefeed and non-prefeed conditions. The total experiment took 96 days to complete. Reinforcers were 45 mg pellets (Noyes Improved Formula A).

RESULTS

Response rates for the 30-minute baseline, and both 10-minute pre-session conditions were computed by dividing the number of responses in the session by the minutes in that session. Mean response rates for prefeed and non-prefeed conditions are plotted as a function of scheduled reinforcement rate in Figure 4. Note that both the prefeed and no-prefeed conditions produced bitonic functions. The prefeed function lies below the no-prefeed function at the higher reinforcement rates and further, the prefeed appears to have a sharper bitonic curve.

Statistical analysis was completed on the data shown in Figure 4. A two-way within subjects ANOVA showed that there was a significant effect of reinforcement rate ($F[3,18] = 16.19$; $p < .001$). This means that reinforcement rate did have an effect of responding (ignoring the prefeed/non-prefeed

differences). There was also a significant effect of prefeeding (F[1,6] = 7.58; p < .05), meaning that the different pre-session conditions had an effect on responding as well (ignoring reinforcement rate differences). Furthermore, there was a significant interaction between pre-session conditions and rates of reinforcement (F[3,18] = 10.31; p < .001). The interaction suggests that the overall form of the function was different depending on whether animals were prefed or not. Post-hoc tests for simple main effects of prefeeding showed that the prefeeding condition differed from the non-prefeeding condition on the VI 7.5s and VI 15s schedules, but no were no differences found in the lower reinforcement schedules.

DISCUSSION

The present experiments were designed to address the ongoing controversy over the form of the VI response function. Specifically, the two experiments attempted to separate satiation from time in session, two factors believed to be responsible for bitonic functions. Experiment 1 examined the effects of time in session while keeping reinforcement density constant. There was no significant interaction found between reinforcement rate and time in session. This suggests that time in session does not affect the VI response function independent of food density. Experiment 2 examined the effects of food density while keeping time

in session constant. There was a significant interaction between reinforcement rate and the pre-session condition. This suggests that food density does affect the shape of the VI response function, independent of time in session.

The present results extend those found by Dougan, Kuh, & Vink (in press). They found increasing bitonicity within 30-minute sessions. The present experiments suggest that this is due to food density (Exp. 2) but is not effected by time in the session (Exp. 1). When session time was manipulated as in Experiment 1, functions were not different. However, functions were different in Experiment 2 when food density was manipulated. These findings also help clarify the controversy over monotonic and bitonic functions. As mentioned above, matching law predicts monotonic functions (Catania and Reynolds, 1968; Herrnstein, 1961, 1970), while behavior regulation and behavior economic theories predict bitonic functions (Baum, 1981; Dougan, 1992; Hursh, Raslear, Shurtleff, Bauman, & Simmons, 1988; Staddon, 1979; Timberlake & Peden, 1987). The present results help refine the controversy by demonstrating one variable which apparently alters the form of the function.

These results are not consistent with the findings of McSweeney and colleagues (1990, 1992a, 1992b). McSweeney found satiation-like effects on schedules of reinforcement that produced extremely low reinforcement rates. The reinforcement received on these schedules could not possibly satiate the animal. Therefore, McSweeney suggested that factors other than food density must be

involved. In the present experiment, changes did not occur in sessions independent of food density. This evidence does not support the findings by McSweeney and further suggests that satiation may be a factor.

One completely unexpected result was the finding of bitonic functions in both experiments. Dougan et al did not find bitonic functions in any 10-minute sessions whereas the present study found bitonic functions during 10-minute sessions in both experiments. There are several possible explanations for these differences. First, the differences may be due to differences between the experimenters. Secondly, the apparati used in these two studies differed in several significant ways. First, the bars in the study by Dougan et al were further from the floor of the chamber. These bars also required greater force to fully press. These two factors together may in fact require the use of different body postures and muscles. Further, the shape of the bar in each chamber differed in possibly significant ways. The bar in the present study was narrower and extended out farther into the chamber than did the bar in the study by Dougan et al. This is important in that the shape of bar may elicit different response topographies. For example, animals in the present study appeared to engage in more "food getting" behaviors such as orienting towards the bar and chewing under the bar.

Finally, there is a difference in procedures that may also account for the differences found between this study and that by Dougan et al. In the Dougan study, the animals were in the experimental chamber only while there was access

to the bar. After each 10-minute session was over, the subject was returned to the home cage. The present experiments, on the other hand, required that the animal remain in the experimental chamber for the full 30-minute period, thereby giving the animal a 20-minute time-out.

In summary, the present experiments identified one variable that was responsible for the differences in the form of the VI response function. Future research is necessary to further delineate the mechanisms by which food density and perhaps session time alter the function. In addition, future research will be needed to determine why bitonic functions were found in 10-minute sessions in the present study, but not in the earlier Dougan et al study.

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Figure Captions

Figure 1. A hypothetical monotonic relationship between response rate and reinforcement rate.

Figure 2. A hypothetical bitonic relationship between response rate and reinforcement rate.

Figure 3. Summary of the results of Experiment 1. Mean response rate is plotted as a function of scheduled reinforcement rate, for session blocks occurring in the first and third 10 minutes of the 30-minute session.

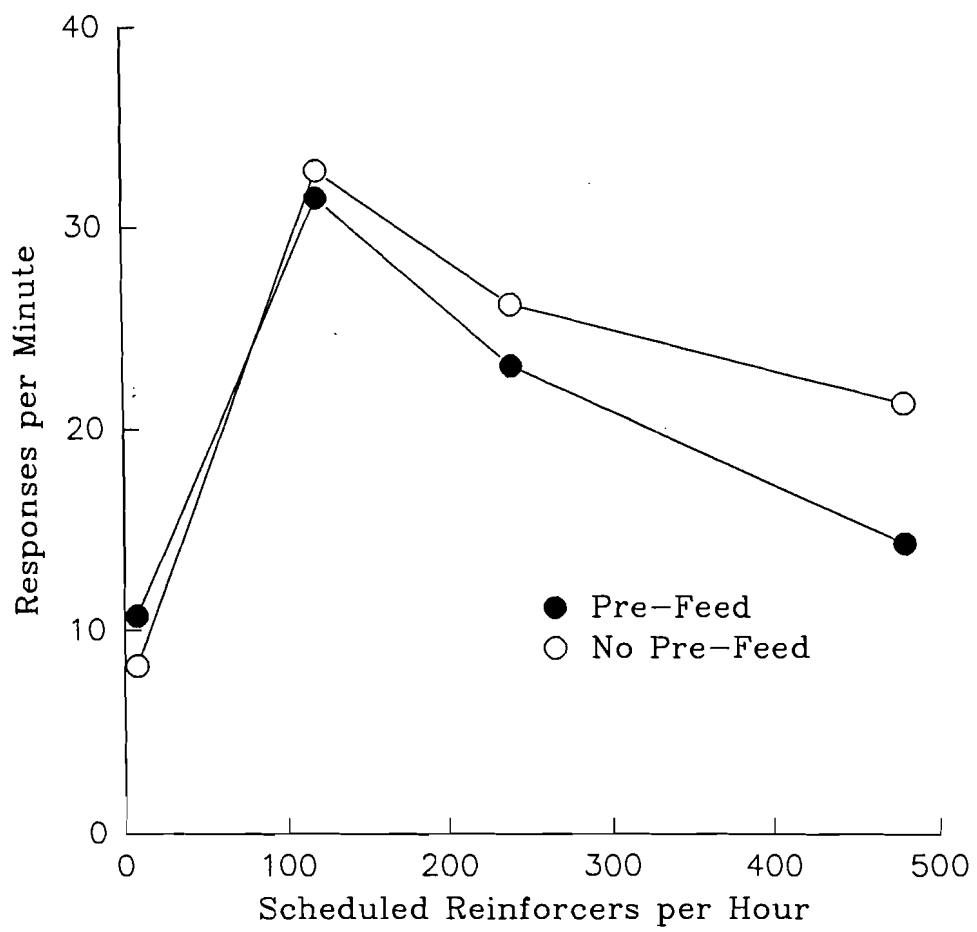Figure 4. Summary of the results of Experiment 2. Mean response rate is plotted as a function of scheduled reinforcement rate, for both the prefeed and non-prefeed conditions.
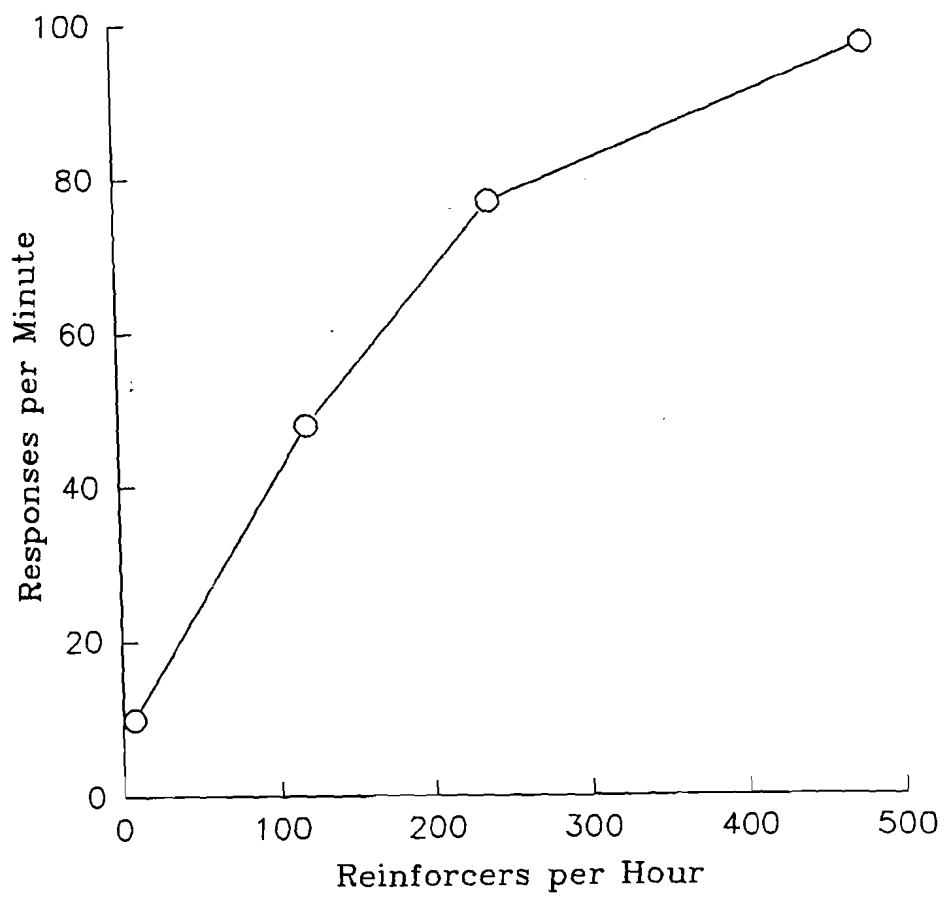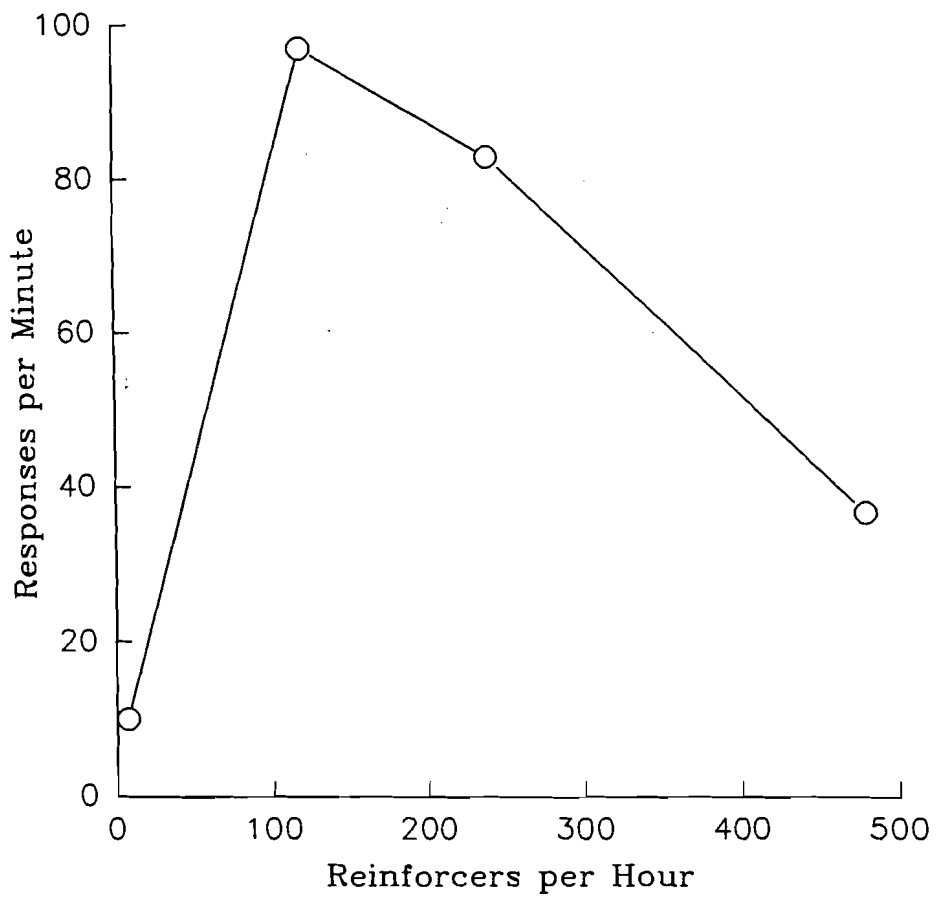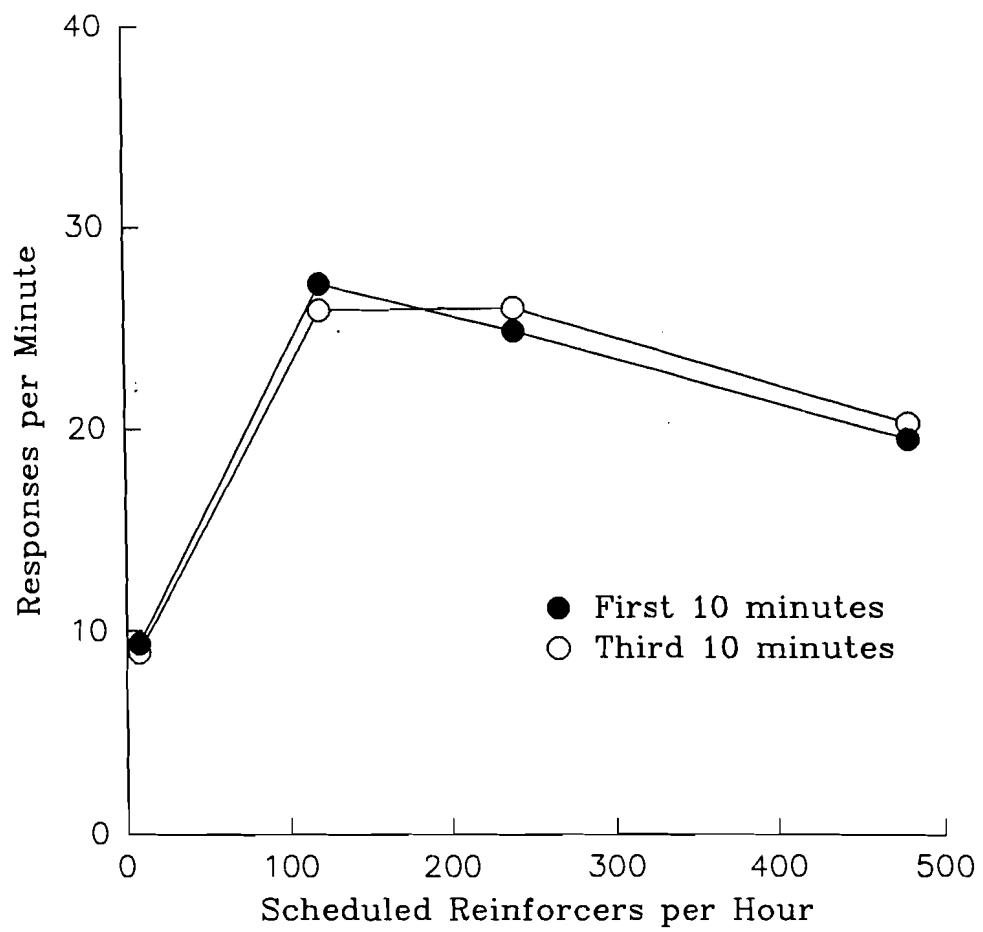
Figure 3: Results of Experiment 2