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An Analysis of Polydipsia as Produced by a Multiple Schedule

Joseph J. Vaal

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AN ANALYSIS OF POLYDIPSIA
AS PRODUCED BY A MULTIPLE SCHEDULE

by

Joseph J. Vaal, Jr.

A Thesis
Submitted to the
Faculty of the Graduate
College in partial fulfillment
of the
Degree of Master of Arts

Western Michigan University
Kalamazoo, Michigan
April 1971
Polydipsia and contrast effects are two behavioral phenomena produced by manipulations of the reinforcement schedules under which the organisms are behaving. The present study created a complex situation by subjecting rats to a multiple reinforcement schedule. This situation allowed simultaneous examination of both operant and induced drinking behavior. Furthermore, this situation allowed for an examination of possible schedule interactions with respect to the induced and operant drinking behaviors.

It was expected that the results of this study would show that behavioral contrast effects could be obtained in a polydipsic situation. Even though the expected results were not obtained, it is felt that with certain procedural changes, it would be possible to study behavioral contrast with respect to polydipsic behavior.
ACKNOWLEDGEMENTS

In writing this thesis, I have benefited from the encouragement, advice, and constructive criticism of Dr. E. Wade Hitzing. I also thank the other members of my committee, Dr. David Lyon and Dr. John Renfrew. In expressing my gratitude, I am in no way divorcing myself from the sole responsibility for what is written here.

Joseph John Vaal, Jr.
VAAL, Jr., Joseph John, 1947-
AN ANALYSIS OF POLYDIPSIA AS PRODUCED BY A MULTIPLE SCHEDULE.

Western Michigan University, M.A., 1971
Psychology, experimental

University Microfilms, A XEROX Company, Ann Arbor, Michigan
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Pavlov (1927) found, while studying discrimination learning and salivary conditioning, that increases in salivation occurred to positive conditioned stimuli which were immediately preceded by stimuli associated with extinction. Pavlov labeled this effect "positive induction." Skinner (1938) observed similar changes in the rate of operant responding to discriminative stimuli during discrimination training. He called this effect "contrast."

Reynolds (1961a) termed the phenomenon observed by Skinner "behavioral contrast," and defined it as the change in rate of responding during one component of a multiple schedule in a direction away from the rate of responding generated by a procedural manipulation in the second component. When the change is an increase in the response rate, the effect is termed positive contrast, and, a decrease in response rate is referred to as negative contrast (Reynolds, 1961b).

Reynolds (1971b) observed another behavioral interaction which he called "induction," and defined it as a rate change in one component of a multiple schedule in the same direction as the rate of responding produced by a manipulation of the second component of the schedule. Positive induction refers to the increase in response of both components, while negative induction is a decrease in the response rate during both components.

There have been studies reporting behavioral contrast with a variety of subjects, response topographies, and reinforcers. Reynolds
(1961a) studied grain-reinforced key pecks in pigeons; Williams (1965) studied wheel running behavior in rats and employed intracranial brain stimulation as the reinforcer; O'Brien (1968) used money to reinforce button presses by humans; and Hitzing and Schaeffer (1968) studied lever pressing in rats reinforced with food pellets.

There have been several conditions which have been shown to be effective in the production of behavioral contrast. Reynolds (1961a, 1961b, 1961c, 1963) and Reynolds and Catania (1961) changed the absolute frequency of reinforcement in one component of a multiple schedule and produced a reliable contrast effect. Changing the absolute reinforcement frequency of one component also produces either an increase or decrease in the relative frequency of reinforcement in the constant component. One way was shown by Reynolds (1961a), by changing a mult VI-3' VI-3' to mult VI-3' EXT, created a situation in which the number of reinforcements per unit time was absolutely more in the VI component than in the EXT. Furthermore, the VI component of the mult VI-3' EXT schedule produced relatively more reinforcers than the same component of the mult VI-3' VI-3' schedule. Using this procedure, Reynolds reported a reliable positive contrast effect while holding the absolute reinforcement frequency constant.

It is not necessary to change one component to extinction in order to produce contrast effects. Reynolds (1961a) also reported that manipulations which change the absolute non-zero frequency of reinforcement in one component will produce contrast effects. As an example, a change from mult VI-1' VI-1' to VI-1' VI-1' results in a
positive contrast effect in the constant VI-1' component.

Changing the ratio requirements in one component of a multiple schedule will change the relative frequency of reinforcement, but it may be better to utilize the interval schedules (Reynolds, 1961c). Variations in the response rate can markedly alter the absolute rate of reinforcement for a given ratio schedule, and the interaction effects which result from changes in the absolute frequency of reinforcement in the manipulated component can become confounded with changes in the absolute reinforcement frequency in the constant component. By providing a relatively constant absolute frequency of reinforcement over a wide range of response rates, the interval schedules are able to overcome this problem.

The multiple schedule procedures used in these contrast studies provide experimenters with the opportunity for a new approach in the study of polydipsia. Until now, quite a bit of research has been done with schedule-induced polydipsia. However, there have not been any studies in the area of polydipsia and multiple schedules. The work on schedule-induced polydipsia will be presented below.

Falk (1961) first reported the phenomenon of schedule-induced polydipsia. Food-deprived albino rats obtained 45 mg Noyes pellets by bar-pressing on a VI-1' schedule during 3.17-hour daily sessions. During these sessions, water was constantly available to the Ss in the experimental chambers. Also, water was constantly available in the Ss' home cages. A unique drinking pattern developed on this schedule. After earning a food pellet, the rat would eat it and then typically drink approximately 0.5 ml of water. During the 3.17-hour
session, the water intake averaged 92.5 ml, or 3.43 times the pre-
experimental, 24-hour water intake level. Between sessions, al-
though water was available in the home cage, intake averaged less
than 1 ml.

By way of definition, schedule-induced polydipsia refers to the
excessive drinking behavior of a non-water deprived S. There is,
however, no one criterion as to the amount of water consumed which
determines excessive drinking. This behavior is usually produced by
providing the S with an intermittent food delivery schedule. The
development of polydipsia is not specific to only VI schedules of
reinforcement, however, and the following are three conditions nece-
sary to produce polydipsia: 1) a state of food deprivation; 2) an
intermittent schedule of food delivery; and 3) access to water follow-
ing food consumption. Most of the research on polydipsia has held
the first and third conditions constant and manipulated the food de-
ivery schedules.

In experiments employing fixed ratio (FR) schedules of reinforce-
ment, bar-pressing is reinforced according to specific ratio re-
quirements. Falk (1964) reported that FR requirements of less than
thirty did not consistently produce polydipsia. If polydipsia did
occur, it was transient in that the water intake usually returned to
baseline in less than twenty sessions. Schaeffer and Diehl (1966)
reported that when the session length is constant and the FR require-
ment is raised, the following results occur: 1) bar-press rate in-
creases; 2) total licks and water intake increases; 3) the number of
eating-followed-by-drinking combinations increases; and 4) the num-
ber of reinforcements decrease.

There are two classes of interval food delivery schedules which have been studied: those in which a response is necessary to produce a reinforcer (contingent schedules), and those in which food is delivered independently of the S's behavior (non-contingent schedules). Studies in the first class usually utilize bar-pressing as the required response. Falk (1961, 1964) and Clark (1962) reported that polydipsia is produced under VI schedules of reinforcement. Falk (1966) studied polydipsia on fixed interval (FI) schedules of reinforcement and reported that as the fixed interval was increased above 10 sec, there was a monotonic increase in water intake up to FI-90 sec for one S and FI-180 sec for the other S. Above 90 and 180 sec respectively, water intake decreased gradually to baseline values.

Using the second class of interval schedules, Falk (1964) and Reynierse (1966) both reported that polydipsia is produced with non-contingent or free variable interval food delivery schedules. Reynierse used a non-contingent VI-40 sec schedule and reported that there was a gradual acquisition phase which reached a symptom by the fourth experimental session. Segal, Oden, and Deadwyler (1965) have produced polydipsia with free fixed interval (FFI) schedules of reinforcement.

There is a third type of reinforcement schedule which has been employed in polydipsia studies, and that is the differential reinforcement of low rates (DRL). On DRL, responses are reinforced only after a minimum amount of time has passed since the last reinforcement. Segal and Holloway (1963) used DRL schedules and reported that their rats averaged over 100 ml of water during a one hour session. Using a
DRL-20 sec schedule, they observed that drinking usually occurred after a pellet was delivered and not after unreinforced bar presses.

Another group of studies relevant to the area of polydipsia are those which employed licking as the operant response. Premack (1962) and Schaeffer (1965) used the opportunity to run as a reinforcer and licking as the reinforced response. The authors reported that the Ss learned to "lick to run," but neither one reported any excessive water intake. Williams and Teitelbaum (1956) shaped rats to lick in order to avoid an electric shock. With this procedure, they reported that the Ss consumed only about 10 to 15 ml of water per hour. Koh and Teitelbaum (1961) and Segal (1965) reinforced licking with dry food pellets. Koh and Teitelbaum reported excessive drinking with their Ss, however, they did not present any quantitative data. Segal (1965) studied different patterns of drinking generated by lick-contingent reinforcement schedules. She reported instrumental response patterns with FI, FR, and DRL reinforcement schedules which were similar to typical cumulative records of those particular reinforcement schedules. Segal and Deadwyler (1964) reported a series of experiments in which licking, reinforced by the delivery of food pellets, was programmed on various schedules of reinforcement. They reported two different types of licking, which on the basis of its inter-pellet distributional properties, closely approximated other more traditional instrumental responses. One example of this first type of licking was the "scalloped" licking on FI schedules. The second type of licking which they reported was post-pellet drinking. This type of drinking occurred in sustained bursts immediately following delivery of a food pellet.
This type of licking is identical to the post-pellet licking which occurs on non-contingent food delivery schedules. Thus, the important aspect of the Segal (1965) and the Segal and Deadwyler (1964) studies is the reporting of bursts of unreinforced licking on the lick-contingent schedules after a food pellet had been delivered. Hitzing (1968) programmed licking as an instrumental response on a lick-contingent FI-60 sec schedule of food delivery. He reported that after more than twenty sessions, all four Ss stabilized at a lick rate at least four times higher than their baseline rates. Thus, it would seem that with the data presented in this section, excessive water intake in lick-contingent schedules occurs only when the reinforcer is a dry food pellet. Even though water intake is increased when rats lick to avoid electric shock (Williams and Teitelbaum, 1956), the increase is significantly lower than the increases reported in the studies using dry food pellets as reinforcers.

In the experiment described below, pellet delivery was made contingent upon licking on a mult FI FI schedule of reinforcement. This complex situation employed a contingent reinforcement schedule which allowed simultaneous examination of operant and induced drinking within the same inter-pellet interval. Experimental manipulation of the reinforcement contingencies of one component while the other component is held constant may produce behavioral contrast effects reflected by the occurrence of polydipsic drinking behavior in the Ss. Furthermore, this type of procedure allows an investigation into possible schedule interactions with respect to the operant and the induced behaviors.
METHOD

Subjects

The Ss were two experimentally naive adult male albino rats. They were maintained at approximately 80% of their ad lib body weights and housed in individual cages in a colony room with relatively constant temperature. The Ss had constant access to water in both cages and the experimental chambers, the only exception being the 24-hour water deprivation just prior to the first shaping session discussed in the procedure section.

Apparatus

The experimental chambers were two plywood boxes, with the interior part of each chamber measuring 8 3/4" wide, 14" long, and 7 1/8" from grid to ceiling. The drinking tube was placed 4" to the left of the food magazine, 1" above the cage floor, and was held in place by means of a plexiglass positioning device. The tube was positioned such that the end of the spout could be extended or withdrawn from the S's working area through a 3/8" diameter hole cut in the wall of the interior chamber. The reservoir for the drinking tube was a 100 ml glass graduated cylinder with a one-hole rubber stopper in the end. Licks were detected by means of a lickometer, the circuitry of which was designed after the Bintz and Zucker (1970) multifunction pulseforming circuit. Electronic and electromechanical devices were used to program the various experimental conditions.
Electromechanical counters, digital recorders, and Gerbrands cumulative recorders were used to record the data. The reinforcers were standard 45 mg Noyes pellets.

Procedure

Following adaption to an 80% body weight food deprivation schedule, the Ss were magazine trained using a non-contingent variable interval food delivery schedule with the intervals averaging thirty seconds in length. After this training, the Ss were deprived of water for 24 hours. The deprivation procedures were used to facilitate the shaping of the lick response during the first experimental session. The shaping procedure consisted of differentially reinforcing the Ss' successive approximations to licking the water spout. During this shaping procedure, a fixed interval contingency was employed, with the interval gradually being raised from one to five seconds (FI-1 sec to FI-5 sec).

At this point, the inter-pellet interval was gradually increased until both Ss were responding on an FI-1 min schedule. Once this was accomplished, the Ss were shifted to a multiple schedule consisting of two components during which the lick-contingent fixed-interval schedules were programmed (mult FI-1 min FI-1 min). The component in which the reinforcement schedule was manipulated was signalled by dim chamber lights during the length of the component. The second component had bright chamber lights as the external environmental cue. During each component, five reinforcers were delivered. Following
the fifth reinforcer of each component, there was a 50 sec period of time to allow the Ss to consume the fifth pellet before the time out period. The change between components was signalled by a five second time out period during which the food delivery mechanism and the chamber lights were non-functional. The sessions lasted until thirty reinforcers had been delivered during each component.

Once the rate of responding stabilized on the mult FI-1 min FI-1 min schedule, the schedule was changed to mult EXT FI-1 min. After response rate stabilization occurred under this mult EXT FI-1 min schedule, the mult FI-1 min FI-1 min schedule was reinstated. Then, after stabilization again occurred, the mult EXT FI-1 min schedule was again programmed, thus completing the systematic ABAB experimental design.
RESULTS

It should be mentioned at this point that the shorter FI values were used merely as preparation for the mult FI-1 min FI-1 min schedule, and thus, the data from these shorter values will not be presented here.

As may be seen in Figures 1 and 2, after twenty-three sessions on the mult FI-1 and FI-1 min schedule, the lick rate for both Ss stabilized at a fairly consistent rate. At this point, the schedule was shifted to mult EXT FI-1 min. The results indicate that both Ss showed a definite decline in responding during extinction (manipulated component), but showed no definite change in the rate of responding during the FI-1 min component (constant component). After a fairly stable response rate had been established for this manipulation, the conditions were changed back to a mult FI-1 min FI-1 min schedule. As would be expected, the total licks in the manipulated component returned to baseline while the number of licks in the constant component decreased slightly.

After stabilization of responding on the mult FI-1 min FI-1 min schedule, the mult EXT FI-1 min schedule was reinstated. Again, there was a decrease in total licks in the extinction component. As in the first manipulation, there was no substantial change in the rate of responding in the constant component.

Figure 3 shows the inter-pellet interval (IPI) licking distributions for both Ss during each component of all experimental conditions. The distributions during both components of the mult FI-1 min FI-1 min
Figure 1.-The total number of licks per component per session, for subject 3B3, under the four successive experimental conditions. The vertical broken lines indicate a change in the experimental conditions.
Figure 2.—The total number of licks per component per session, for subject 5B5, under the four successive experimental conditions. The vertical broken lines indicate a change in the experimental conditions.
Figure 3.—The inter-pellet interval distributions for subjects 3B3 and 5B5. The data were taken from the average number of responses during each 12 sec segment of the inter-pellet interval over the last five days of each experimental condition. The upper panels depict the distributions during the manipulated component of the two mult FI-1 min FI-1 min schedules, and the lower panels depict the distributions during the constant component of all four schedules. The numbers 1-5, along the abscissa, represent respectively the 0-12 sec, 13-24 sec, 25-36 sec, 37-48 sec, and 49-60 sec intervals of the 60 sec inter-pellet interval. The four bars above each of the five intervals show the percentage data for the four successive experimental conditions: mult FI-1 min FI-1 min, mult EXT FI-1 min, mult FI-1 min FI-1 min, and mult EXT FI-1 min.
phases show the "scalloped" distribution found on typical FI schedules.

In the constant component, it may be seen that there is no definite relative change in either the induced or operant drinking. This is reflected in the lack of difference between licking distributions during the constant component under the multi FI-1 min FI-1 min schedules and the same component during the mult EXT FI-1 min schedules. It should also be mentioned that a reversal of these experimental procedures provided a replication of the results obtained with the first experimental manipulation.

Figures 4 and 5 present a comparison of the induced and operant drinking during the constant component for all experimental conditions. This comparison was made by totaling the responses which occurred during the first 36 sec of each IPI, and, by totaling the responses which occurred during the last 24 sec of each IPI for the operant drinking. It should be stated at this point that this comparison was made to facilitate analysis of any interaction between the induced drinking and the operant drinking. It may be seen from these figures that for the constant component during the multi FI-1 min FI-1 min schedules, the rate of operant, or pre-pellet, drinking is much higher than the rate of the induced, or post-pellet, drinking. During the mult EXT FI-1 min schedules, it is interesting that the induced drinking in the constant component remains relatively low, and, that the rate of the operant drinking during the constant component is also slightly lower. A possible explanation for these results will be presented in the discussion section.

Figures 6 and 7 show the amount of water consumed during each
Figure 4.-The average number of licks during the first three intervals (post-pellet) and the last two intervals (pre-pellet) of the inter-pellet interval for the constant component of each session. The data are plotted for one experimental animal, 3B3. The vertical broken lines indicate a change in the experimental conditions.
Figure 5.—The average number of licks during the first three intervals (post-pellet) and the last two intervals (pre-pellet) of the inter-pellet interval for the constant component of each session. The data are plotted for one experimental animal, 5B5. The vertical broken lines indicate a change in the experimental conditions.
Figure 6.—The experimental session water intake values. The data presented are for subject 3B3.
Figure 7.—The experimental session water intake values. The data presented are for subject 5B5.
session. The amount of water consumed varied with the overall rate of responding. During the mult FI-1 min FI-1 min schedules, where the rates of responding for both components are relatively high, the amount of water consumed is also relatively high. When the responding in one component drops as in the EXT component, there is a noticeable drop in the amount of water consumed.
DISCUSSION

There were two purposes of this experiment. The first was to study schedule interactions on the basis of induced drinking behavior. The second purpose was to study schedule interactions by comparing operant and induced drinking behaviors. Furthermore, on the basis of previously cited contrast studies (e.g. Reynolds, 1961a), it would be assumed that the procedures employed in this study would provide a good situation for producing a reliable positive contrast effect. A different type of result like those reported by Falk (1966, 1969) and Flory (1969) stated that the degree of polydipsia is a function of the fixed-interval length between food pellets, should also indicate that the procedures used in this study would produce some reliable polydipsic drinking in the Ss.

The actual results of this study, however, do not confirm these assumptions. Reynolds (1961a, 1961b, 1961c, 1963) and Reynolds and Catania (1961) found that changing the absolute frequency of reinforcement in one component of a multiple schedule produced a positive contrast effect in the other constant component. In other words, decreasing the absolute frequency of reinforcement in one component produced an increase in the relative frequency of reinforcement in the constant component. The result of this, then, is an increase in the rate of responding in the constant component, and a decrease in the rate of responding in the manipulated component. Figures 1 and 2
show that when the mult FI-1 min FI-1 min schedules were changed to mult EXT FI-1 min thereby decreasing the absolute frequency of reinforcement in one component, that the rate of responding in the changed component did, indeed, decrease. In the constant component, however, there was not a significant change in the rate of responding even though the relative frequency of reinforcement had been increased in that component. It should be mentioned, however, that the data from one experimental, 5B5 (Figure 2), do show a slight trend toward a positive contrast effect in the last six sessions (sessions 38-43) of the first mult EXT FI-1 min phase. As can be seen in Figure 5, these last six sessions average about 200 responses higher in the rate of pre-pellet drinking than the rate of pre-pellet drinking during the same component of both the preceding and the following mult FI-1 min FI-1 min phases. Other than that particular point, the data for the two experimental animals as depicted in Figures 1 and 2, do not indicate any reliable positive contrast effects.

With regard to the polydipsia, Falk (1961) first reported schedule induced polydipsia. The food-deprived Ss obtained food on a VI-1 min schedule of reinforcement by bar-pressing. During the experimental sessions, a peculiar drinking pattern developed in that the Ss would consume substantial amounts of water immediately after the deliverance of a food pellet. In a later study, Falk (1966) obtained the same results using fixed-interval schedules of less than 90 and 180 sec.

Figures 4 and 5 present data which do not seem to support these previous findings. For both Ss, the induced, or post-pellet, drinking
remains relatively much lower than the operant, or pre-pellet, drinking in the constant component of the mult FI-1 min FI-1 min schedules. When these schedules were shifted to mult EXT FI-1 min, there was no substantial increase in the post-pellet drinking of the constant component, and, there was even a slight decrease in the pre-pellet rate of responding in the constant component. As was mentioned earlier, only one animal (5B5) gave any indication of a positive contrast effect, and that indication occurred only during six sessions. It is interesting to note in Figure 5 that animal 5B5 gives a slight indication of polydipsic drinking also in the last six sessions (sessions 38-43) of the first mult EXT FI-1 min phase. Examination of Figure 5 shows a marked increase in the rate of post-pellet responding during the constant component. Other than these six data points, there is no reliable indication of polydipsia as reflected by a marked rise in the induced, or post-pellet, drinking during the constant component of the mult EXT FI-1 min phases.

Figure 3 presents the distribution of responding during the IPI's. It can be seen that the pattern of responding during both components of the mult FI-1 min FI-1 min schedule is very much the "scalloped" pattern of responding so typical of FI schedules of reinforcement. Furthermore, when the schedule was shifted to a mult EXT FI-1 min schedule, there was no change in pattern of responding in the constant component.

Hitzing (1968) programmed licking in rats as an instrumental response on a lick-contingent fixed interval-60 sec schedule of rein-
forcement for 100 food pellets per session. Under this schedule, Hitzing reported that the Ss licked approximately 12,000 times per session. Furthermore, approximately 80% of the total licks occurred in the first 24 sec of the IPI. When Hitzing shifted the reinforcement schedule to free fixed interval-60 sec or to DRO, the animals continued licking more than 10,000 times per session. In addition, there was no significant change in the licking distribution during the five IPI intervals. The only change occurred during the DRO phase in which the IPI distributions shifted slightly to the right in that more licking was recorded in the third interval. Finally, Hitzing reported that the Ss in his study consumed between 65 and 85 ml of water per session.

The results of the study presented in this paper provide an interesting comparison with the results presented by Hitzing (1968). His Ss were licking approximately 12,000 times per session for 100 food pellets, or approximately 120 licks per pellet. The Ss in this present study varied in their licking. Animal 3B3 averaged 6,000 licks per session on the mult FI-1 min FI-1 min schedule for 60 food pellets, or approximately 100 licks per pellet. Animal 5B5, however, averaged 2,000 licks per session on the mult FI-1 min FI-1 min schedule, or only approximately 35 licks per pellet.

When a comparison is made on the basis of water consumed per pellet, the conclusion may be drawn that the Ss in Hitzing's study were licking and ingesting more water per pellet than the Ss in this study. Hitzing's Ss were consuming approximately 0.75 ml of water
per pellet, whereas the Ss in this study averaged 0.5 and 0.13 ml per pellet respectively.

In comparing the licks during the five IPI intervals, Hitzing reported that for his Ss, approximately 80% of the total licks occurred during the first two IPI intervals. In the present study, it may be seen in Figure 3 that approximately 80% of the total licks occurred in the last two IPI intervals, indicating that most of the licking in this study was operant licking.

Thus, it appears that of the two Ss in this study, only one, 3B3, approaches any polydipsic drinking as reflected by licks per pellet and ml per pellet. However, the second S, 5B5, is the only S whose pattern of induced drinking gives any indication of polydipsic drinking as shown in Figure 5, sessions 38-43.

With some changes in the experimental design, it would be possible to obtain positive contrast effects as reflected through operant drinking behavior. Since the procedures employed in this study produced a complex situation in that both induced and operant drinking could be developed in the same session, it is thought that lengthening the inter-pellet interval would more clearly separate the induced and the operant drinking. In the present study, it appears that the post-pellet drinking is not necessarily induced. Rather, it is probably an early extension of the operant, or pre-pellet drinking. This is supported by Figure 3 in that the IPI distributions are "scalloped" like those typically obtained on an FI schedule of reinforcement. Another design change would be decreasing the number of reinforcers per component and increasing the number of components, thereby giving
the Ss more frequent changes between schedules per session. This should facilitate the development of positive contrast effects.

Even though this study did not produce the expected results, it is felt that with the changes described above, it would be possible to study behavioral contrast in operant drinking behavior.


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Reynolds, G. S. "Relativity of response rate and reinforcement frequency in a multiple schedule." Journal of the Experimental Analysis of Behavior, 1961c, 4, 131-139.


