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INVESTIGATION OF TWO PARAMETERS THAT ESTABLISH SELF-CONTROLLED EATING IN THE PIGEON

by

GUADALUPE COLL

A dissertation submitted to the Graduate Faculty in Psychology in partial fulfillment of the requirements for the degree of Doctor of Philosophy, The City University of New York.

1983

This manuscript has been read and accepted for the Graduate Faculty in Psychology in satisfaction of the dissertation requirement for the degree of Doctor in Philosophy.

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date — Chairman of Examining Committee

9/14/83 — Herbert D. Saltzstein
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Abstract

INVESTIGATION OF TWO PARAMETERS THAT ESTABLISH SELF-CONTROLLED EATING IN THE PIGEON

by

Guadalupe Coll

Advisor: Professor William N. Schoenfeld

The acquisition and maintenance of self-control were studied using a trial by trial procedure as described by Cole et al., 1982. A trial consisted of two hopper presentations and one intertrial interval (ITI). The hopper (SR1) was presented for an assigned criterion time, at the end of which, if the animal had not approached SR1, the house light came on and SR1 was removed. A key-peck on the center key produced a second presentation of the hopper (SR2) and the bird was then allowed to eat from it for three seconds. A trial was correct if the bird did not approach SR1. A subject's approach to SR1 caused its immediate removal and SR2 was cancelled.

Two parameters of this procedure were investigated:

A) The probability that the presentation of SR2 would require a key-peck after a criterion wait. Six probabilities were investigated: 1.000, 0.750, 0.500, 0.250, 0.125, and 0.000.

B) The probability of reinforcement (SR2). Six values were investigated; 1.000, 0.500, 0.375, 0.250, 0.125, and 0.000.

A group of six pigeons was randomly assigned to each one of these six values for each variable. Training was considered complete after five consecutive sessions with at least 80% correct trials at SR1 of 10 seconds. The group at probability of 1.000 was divided into two subgroups to study the effects of gradually decreasing the probabilities of variables A and B.

When variable A was investigated only at P=1.000 all subjects reached the acquisition criterion. However, once the behavior has been acquired, the key-peck could be eliminated completely and the behavior was maintained.

A decrease in the probability of variable B to a value of 0.250 brought about a decrease in the number of subjects acquiring self-control.

It was concluded that although reinforcement is both necessary and sufficient to maintain self-controlled behavior, it may be insufficient to establish it. An intervening response (key-peck) is required during acquisition to transform a partially successful procedure

into one that is reliable for all subjects.

The success of the present procedure was compared to that of other self-control studies.

To my mother, brother, and sisters

I wish to express my deepest gratitude to Drs. William N. Schoenfeld and Brett K. Cole for making this work possible.

I also want to thank the members of my committee for their stimulating questions, especially Dr. Charles A. Catania for his thorough editorial work and valuable suggestions. I would like to thank my friends Barry Stern for his excellent work in proof reading the final copies of this paper and for his encouragement and patience, and Gene Fisch for his assistance in statistical matters and for his willingness to help. My appreciation goes to John Leong and Andy Rothman from the Computer Center at Queens College for the help provided in using the computer facilites, and to Mike Takano for his assistance in using the word processor. I also want to thank Dr. Daniel I. Sverdlik whose computer program was used in developing the Figures.

My special gratitude to Dr. William N. Schoenfeld for his support and encouragement when times were difficult.

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Introduction

The present study developed from a discussion of "self-control", and a series of experiments, reported by Cole, Coll, and Schoenfeld (1982). The study of self-control at the onset of those experiments presented several problems.

The first problem consisted of identifying or defining the behavioral pattern that would be taken as characterizing self-control. In the usage of Cole et al., the fact that a reinforcer is presented, but that the subject refrains from taking it until some prescribed period of time has elapsed, is what distinguishes self-control from other behaviors. Thus, for instance, in dealing with self-controlled eating it could be said that a subject has been brought to self-control if, when its eating response has earlier been well established, it refrains from eating in the presence of food for some prescribed period of time. This case has been called "brute-force" self-control by Rachlin (1974) and has been exemplified by him as: "When the temptation is offered, it is simply refused. The martini is turned down at the party, the bakery is passed without a purchase, the dessert is pushed away, etc." However, it seems correct to say that not all the behavioral characteristics of these examples are shared by other examples of self-control.

Thus, pushing the dessert away is a different response than simply not taking the dessert. Not only are they different, but the contingencies necessary to establish these two behaviors also may be quite different. For instance, although punishment might be used to train a subject to refrain from taking the reinforcer, it seems unlikely that via punishment alone a subject could be brought to approach the reinforcer, take it in its hands, and then push it away. At the least, even if by circuitous training the latter sequence of responses could be experimentally established by punishment, it could be confidently predicted that it would be a long and relatively inefficient route for establishing such self-control. However, in both of these examples, i.e., pushing the dessert away and simply not taking the dessert, the absence of the response of taking the dessert is sufficient to qualify the behavior as self-controlled; describing anything else the subject does obscures this designation.

Other researches have conceptualized self-control as a paradigm of choice (Mischel, 1966, Rachlin, 1974, Brigham, 1978, and Fantino and Logan, 1979). Within this framework, self-control consists of making a reponse that leads to a larger but delayed reinforcer, instead of making a different response that leads to a smaller but immediate reinforcer. For convenience, this latter paradigm will be referred to here as the "choice paradigm", while the earlier will be referred to as the "self-control paradigm".

In both paradigms, the subjects have to wait for the reinforcer, but there is a basic difference between the paradigms in the conditions that prevail while the period of waiting takes place. In the self-control paradigm, the subject waits in the presence of the reinforcer; in the choice procedure, the reinforcer is absent during the waiting period. Because the subject is supposed to refrain in the presence of the reinforcer the study of self-control faces a second problem: how to prevent a subject from taking the reinforcer once it has been presented to him. In the traditional procedures of the laboratory, the reinforcer is presented by the experimenter if the subject makes a specified response. But once the reinforcer is presented, assuming the reinforcer is food, the sequence of eating after the reinforcer presentation is taken for granted; this sequence, already established before the experiment begins, is the foundation upon which control over other behavior is later established. For the latter purpose, the procedure would be inadequate if the subject were not to take the reinforcer reliably. In the customary experimental situation, the experimenter makes sure (as a prerequisite for any further training) that the subject will take the reinforcer (say, food or water) whenever it is offered. To establish self-control after such training however, the problem to be solved is how a subject who is ready to eat can be taught not to eat when food is available. There is little in present behavior theory that anticipates this question. Instead, it is expected and routinely predicted that if food is presented when the subject is ready to eat, it will eat. For the experimental study of self-control, the problem is to find a procedure that will make the subject refrain from taking the food. In a prototypical example of self-control, a child is told by his mother that he may take the candy bar she is leaving on top of the piano if he practices for one hour. After the mother leaves, the child practices for one hour, takes the candy bar, and eats it (Cole et al., 1982). In this example the taking of the candy bar after the practice has elapsed is not a sufficient contingency to explain the earlier "refrainment" (Cole et al.) of the child. The candy bar may be the reinforcer maintaining the behavior, but the problem is how refrainment in the presence of the reinforcer was acquired in the first place so that it could thereafter be reinforced and maintained. In other terms, perhaps, it should be asked how refrainment can be "shaped".

One obvious possibility for developing refrainment is the use of positive punishment. In an experimental situation using pigeons as subjects, for instance, electric shock may be used as a punisher if the subject approaches the food. Although this interesting alternative deserves investigation, the experiments reported by Cole et al. took a different route. In these experiments the withdrawal of the food was used to prevent the bird from reaching the food and no extra stimulus was added to the situation.

The details of the procedure of Cole et al. are as follows: After shaping the key-peck response and several sessions under a Regular Reinforcement schedule (CRF) a trial-by-trial procedure was introduced. The hopper was presented twice in each trial. In the first presentation on any trial, the bird was required not to approach the hopper for a prescribed period of time. If the non-approach requirement was fulfilled, the hopper was withdrawn. A key-peck was then required for the hopper to be presented a second time allowing the bird to eat for 3 sec. A few seconds later another trial began. If, on any trial, the bird approached the hopper on its first presentation of the trial before the requisite time had elapsed, the hopper was immediately withdrawn, the second presentation was cancelled, and a few seconds later a new trial began. Thus, a key-peck was required in every trial on which the non-approach criterion was met before the hopper was presented for the second time. Key-pecks at other times had no programmed consequences except during the interval between trials when they postponed the next trial for a few additional seconds. The duration of the non-approach requirement (called hereinafter the "criterion waiting time"), and therefore the duration of the first hopper presentation, was gradually increased starting at 1 sec. Eight pigeons were exposed to this procedure. Although there were individual differences in the number of trials, and in the number and size of steps by which the criterion waiting time was lengthened, all subjects reached a criterion of 15 sec waiting time with at least 80% correct trials.

This succesful experiment was done manually (the presentations and withdrawals of the hopper, the timing of the intervals, the observation of the subjects, etc., was done by the experimenter), and therefore a more automated experiment was designed to improve procedural reliability. The first step was automatically to detect the pigeon's head entering the opening of the hopper. This was accomplished by means of a photo-cell. In the manual procedure, the experimenter had needed something by which to distinguish food presentations which were followed by eating from those which were not, and for this purpose the key-peck had been introduced as a required pre-eating response. Once the photo-cell was installed, however, this intruded key-peck was deemed obsolete and therefore eliminated.

Thereafter, a second concern was to investigate some parameters of the manual procedure, and a total of eight experiments were conducted with this purpose. In the first of these experiments, seven pigeons with different experimental histories were used, and the temporal distance between the first and second hopper presentations was selected as the experimental target. The two hopper presentations were spaced within a 60 sec cycle. The second presentation (SR2) always occurred at the end of the cycle and the subject was allowed to eat from it. The first presentation in the cycle (SR1) was presented at three different locations for different animals: at 0-3 sec (for one bird), at 30-33 sec (for two birds), and at 57-60 sec (for four birds) into the cycle. If the subject approached the hopper on its first presentation in the cycle, the hopper was immediately withdrawn, the second presentation was cancelled, and at the end of the 60 sec cycle a new one started again. All seven animals failed to reach the criterion waiting time, including those exposed to the 57-60 sec temporal placement, which was equivalent to the earlier manual procedure in terms of the temporal distance between SR1 and SR2. The failure to replicate the earlier success obtained with the manual procedure, focused the next experimental efforts on pin-pointing the variable(s) that had led to that success.

In the next five experiments, the following manipulations were performed on the procedure outlined in experiment 1: a) in experiment 2, the presentation of SR2 was made independent of the subject's waiting during SR1; b) the cycle duration was manipulated in different experiments. The values investigated were: 6 sec in experiment 3, 15 sec in experiment 4, and 4 and 20 sec in experiment 6; c) in experiment 5 the hopper presentation was reduced to one per cycle. In the presence of the hopper, the subject was required to refrain from approaching it for 1, 2, or 3 sec. If it did refrain, the hopper remained for 3 more seconds during which time the subject was allowed to eat. An external cue (house light) signalled to the subject the onset of the eating time. Some of these manipulations improved the performance of two subjects, one to 65% and the other to as high as 95%, but none of these experiments were succesful in bringing all animals to criterion performance.

Experiment 7 was the final attempt to recover the degree of accuracy and reliability across subjects obtained by the manual procedure. In this experiment, the hopper was presented twice in a trial and an "extra" key-peck was reintroduced as a requirement for the presentation of SR2 after the criterion waiting time during SR1 was met. With the introduction of the key-peck, the cycle duration became variable (i.e., depended on the animal), and the ITI had to be specified instead of the cycle duration. All ten animals reached the waiting criterion at 3 sec with over 80% correct trials. Half of the subjects were exposed to the procedure with a 1 sec ITI, and the other half with a 17 sec ITI. There were no obvious differences between them in the final "self-controlled" performance.

This dramatic result following the introduction of the key-peck was extended in experiment 8 by increasing the criterion waiting time. Once again, individual differences appeared in the rate of progress. The longest criterion waiting time reached was 49 sec by one subject at the time this series of experiments ended. The increase in the waiting criterion was done gradually (by 1 to 3 second steps) at the lowest SR1 durations, but once a subject reached SR1=20 sec, increases were made in 10 sec steps. In some cases, taking such large steps sufficiently disrupted the behavior to require re-training at the shortest duration before extending the criterion waiting period again.

With the re-discovery of a successful procedure for establishing reliable refrainment from eating, two pieces of information were uncovered at the same time which were important considerations in arriving at the final experimental design and procedure described in the present experiments: a) the size of the intertrial interval (within the range studied) did not have any obvious effect on the acquisition of self-controlled eating; b) a gradual increase, or "extensive shaping", of the criterion waiting time was needed to prevent disruption of previously acquired self-control. Because of these two findings, the ITI in the present study was set at 1 sec, and the step size used to increase the criterion waiting time was fixed at 1 sec for all animals.

The newly observed importance of this "extra" key-peck -that is, its role in the successful acquisition of the self-controlled behavior we were dealing with- seemed to call for further study, and became a central question of the experiment reported here. This "extra" response, interpolated or intruded into the response (not eating - eating) sequence, seems to facilitate, and perhaps even be necessary, for the acquisition of reliable refrainment from eating. There have been earlier reports of improvement in discrimination performance produced by such an intervening response (Verhave and Mabry, 1966; Cumming, 1966; and Wykoff, 1952), but the reasons for such improvement in performance remain obscure. In the present study two variables were investigated. The first was a parameter of the situation involving this intervening key-peck: the probability that the reinforcer (SR2 presentation) would actually require a key-peck after a correct criterion wait. The second variable was the traditional parameter of intermittency of reinforcement: the probability that the reinforcer (SR2) would occur after a correct criterion wait plus an "extra" key-peck. While investigating the second variable, the key-peck was a necessary but not sufficient requirement for reinforcement.

Method

Subjects

Sixty six female adult White Carneaux experimentally naive pigeons were maintained at 80% (+ - 20 grams) of their free-feeding weights. Water and grit were available at all times in their home cages.

Apparatus

Three Lehigh Valley pigeon test chambers model 132-02 containing three milky translucent response keys were employed. The transillumination of the three keys provided for the

overall illumination of the chamber. Throughout the experiment only the center key was operative. External cues were provided by the house light located above the center key. A photocell was mounted at the opening of the hopper to record the pigeon's head reaching for the grain; with the photocell positioned between the panel and the hopper, the latter was separated from the panel by 3/4 in. A ventilating fan provided a constant masking noise.

Solid state equipment was used for programming, and data were recorded on printing counters and totalizing counters.

Procedure

Preliminary training: After the birds had reached about 80% of their free-feeding weights, the key-peck response was trained by means of a "punchboard" placed within the animal's living cage (Cumming, 1955). The punchboard consisted of flakeboard 1/2 in thick, 8 1//2 inches wide and 11 inches high. It had nine 1 in diameter depressions 5/6 in deep arranged in three rows of three each. One metal sheet, 1/16 in thick, 8 1/2 inches wide and 11 inches high had 1 in diameter holes over the flakeboard depressions when the sheet was placed and fastened atop the flakeboard. The daily allowance of grain necessary to maintain the bird's 80% weight was distributed within the nine depressions on the flakeboard. One facing sheet of onion skin paper lay over the flakeboard between it and the metal sheet . This punchboard was left in the living cage until the pigeon obtained all of the grain by tearing through the paper. For the first presentation, some of the holes were torn out by the experimenter so that the grain was exposed to the pigeon. It was occasionally necessary to continue the punchboard training for more than four days until the pigeons were obtaining all of the grain within a few minutes of the presentation of the punchboard.

Magazine training: One of the three experimental chambers was used for magazine training and key peck training. Because of time limitations imposed by the number of animals used, all birds did not begin training at the same time. However, once a particular animal began magazine training, it was run every day, seven days a week, until all stages of training were completed for this animal.

During magazine training, the three keys were covered with opaque tape and the house light was on continuously. The hopper was operated at random intervals averaging 40 seconds (T=20 seconds, P=.5). The hopper remained in the up position for a pre-specified period which was timed only while the animal's head was interrupting the photocell beam. This pre-specified period was initially 12 seconds and it was gradually reduced to 4 seconds. It was rarely necessary to prolong this training beyond one session of 60 hopper presentations. By the end of this training, birds were readily eating from the hopper.

Key peck training: This began immediately after magazine training. The center key was uncovered, and both the center key and the house light were on continuously throughout the session. Thirty reinforcers were delivered by a CRF schedule, each reinforcer duration being 3 seconds.

The key-pecking response was quickly established in 51 of the birds. The remaining 15 birds were key peck trained by the method of successive approximations (Keller and Schoenfeld, 1950).

Following this initial key peck training, all birds were given seven additional CRF sessions during which all three keys were uncovered. The three keys and the house light were on throughout these sessions, in each of which sixty reinforcers were delivered.

Self-control training: The self-control training began immediately following the key peck training.

General procedure.- A trial by trial procedure was used with the three key lights on continuously. Each trial consisted of two hopper presentations and one intertrial interval (ITI). A session began with an ITI at the end of which the hopper was presented (SR1) for an assigned criterion time. At the end of this criterion time, if the animal had not approached SR1, the house light came on and SR1 was removed. A trial was considered "correct" if the bird did not approach SR1. A key peck on the center key produced a second presentation of the hopper (SR2) and the bird was then allowed to eat from it. Key pecks at any other time were recorded but had no programmed consequences. SR2 and the house light stayed on until the bird approached SR2, and both continued for three more seconds after the approach.

The reader should know that throughout this procedure SR1 was presented but not available (i.e. it was removed before the subject could reach the food). SR2 on the other hand, was presented and the subject was allowed to eat it.

If the bird approached the opening of the hopper instead of pecking at the key when the house light was on, the SR2 presentation was cancelled, the house light went off, and the next ITI began, but the trial was considered "correct", i.e., the bird had successfully waited for the criterion time.

A subject's approach to SR1 caused its immediate removal. The timing of the criterion time continued, however, at the end of which the next ITI began. This was counted as an "incorrect" trial.

Within this general procedure, two variables were investigated:

A) The probability of reinforcement (SR2) after the subject had waited out the assigned criterion time (a "correct" trial) and had pecked the key. Six probabilities were investigated: 1.000, 0.500, 0.375, 0.250, 0.125, and 0.000.

B) The probability of response requirement, that is, the probability that the presentation of SR2 would require a key-peck after a criterion wait. Six probabilities were investigated: 1.000, 0.750, 0.500, 0.250, 0.125, and 0.000.

One group of six animals was randomly assigned to each one of these values immediately after key-peck training was completed. For any value of one variable, the probability for the other variable was kept constant at 1.000. At probability of 1.000, both variables were at the same probability, and the resulting procedure was the same whichever variable was being explored. Only one group was necessary to explore this value, and therefore a total of 11 groups, and not 12, were needed.

When the probability was less than 1.000, the procedural details changed only for those trials in which the variable was programmed not to occur. These changes were as follows: (a) when, at probability less than 1.000, SR2 was not scheduled to occur after a criterion wait and subsequent peck, the peck following the criterion wait turned the house light off and began the next ITI. (b) when, at probability less than 1.000, SR2 was scheduled not to require a key peck, the house light and the hopper came on following the wait independently of the key peck. The time between the offset of SR1 and the onset of SR2 was equal to the minimum time (between .3 and .4 sec) necessary for the excursion of the hopper going down and up again.

For all values of the two variables, SR1 duration was set to 1 second at the outset of the self-control training, and it was gradually increased to 10 seconds in 1 second steps. When SR1 was 1 second, the ITI was 4 seconds, and as SR1 increased up to 3 seconds the ITI was reduced accordingly down to 1 second and stayed at this value througout the rest of the training.

The criterion to move from one SR1 duration to the next was 80% correct trials in one 50 trial session. At any probability value, training was considered complete after five consecutive sessions with at least 80% correct trials at SR1 of 10 seconds.

After reaching this performance level, the group at probability of 1.000 (the baseline group) was divided into two subgroups of three birds each. For one group, the probability of SR2 after a criterion wait and key peck was gradually decreased; for the other group, the probability that SR2 would require a key peck after a criterion wait was gradually decreased. The sequence of probabilities for both groups was the following: .500, .250, .125, .0625, .03125, and 0.000. SR1 was kept at 10 seconds throughout the sequence. The criterion to move from one probability value to the next was that of 80% correct trials in seven consecutive sessions of 50 trials each.

At any probability less than 1.000, training was terminated if after a total of 1900 trials a bird had not reached 80% correct trials in one session with SR1 of 1 second. The probability was then increased to 1.000 and the two criteria described above were applied. If, after this second probe, a bird did not complete the training, five sessions were given with a CRF schedule, followed by a third probe with probability set at 1.000, and with the two criteria mentioned above in force. Whether training was completed or not, all training terminated after this third probe.

Results

Table 1 presents the proportion of animals at each probability value (P) that reached and sustained the criterion of 80% correct trials at SR1 duration of 10 sec for five consecutive sessions. The upper half of the Table presents the probability of reinforcement variable and the bottom half presents data obtained using the probability of response requirement variable.

For the probability of reinforcement variable, all of the animals in the groups exposed to probability values of 1.000, 0.500, and 0.375 reached criterion on the 1st probe. At probability of 0.250, only half of the animals reached criterion, and, from this P value down, the proportion of animals who reached criterion was a decreasing function of P.

For the probability of response requirement variable, probability of 1.000 is the only value at which all six animals reached criterion on the 1st probe. The group at probability value of 1.000 is the same in both halves of Table 1.

At the start of the experiment, the probabilities for both variables (i.e., the probability of reinforcement and the probability of response requirement variables) were planned to be the same, i.e., 1.000, 0.500, 0.250, 0.125,

Table 1.- Proportion of animals that reached 80% correct at SR1=10 sec on the first, second, and third probes (segments 1, 2, and 3, respectively). The last column presents the accumulated proportion of animals who reached criterion over the course of the three probes. The denominator in each proportion represents the number of animals exposed to a given probability value.

TABLE 1

PROBABILITY OF REINFORCEMENT

First Probe		Second Probe		Third Probe		
P	Proportion of subjects	P	Proportion of subjects	P	Proportion of subjects	Total
1.000	6/6					6/6
0.500	6/6					
0.375	6/6					
0.250	3/6	1.000	2/3	1.000	1/1	6/6
0.125	1/6	1.000	5/5			6/6
0.000	0/6	1.000	6/6			6/6

PROBABILITY OF RESPONSE REQUIREMENT

First Probe		Second Probe		Third Probe		
P	Proportion of subjects	P	Proportion of subjects	P	Proportion of subjects	Total
1.000	6/6					6/6
0.750	2/6	1.000	0/4	1.000	0/4	2/6
0.500	3/6	1.000	0/3	1.000	0/3	3/6
0.250	3/6	1.000	0/3	1.000	0/3	3/6
0.125	0/6	1.000	2/6	1.000	1/4	3/6
0.000	3/6	1.000	0/2	1.000	0/2	3/6

and 0.000. However, data obtained from the 1st probe at these probability values showed that the lowest probability at which all animals reached criterion was not the same for both variables. These values were 0.500 for probability of reinforcement and 1.000 for probability of response requirement.

To approximate more closely the lowest probability value necessary for all animals to reach criterion, a group at probability 0.375 was included for the probability of reinforcement variable, and a group at probability 0.750 for the probability of response requirement variable. From the data presented in Table 1 these values should be found somewhere between 0.375 and 0.250 for the probability of reinforcement variable, and between 1.000 and 0.750 for the probability of response requirement variable.

Fourteen out of the 30 animals exposed to reinforcement probability values less than 1.000 did not reach criterion on the 1st probe. For these animals, probability was increased to 1.000 on the second probe. Thirteen out of the 14 animals reached criterion on this second probe. The remaining animal, exposed to probability of 0.250 on the 1st probe, reached criterion on the 3rd probe which consisted of five added sessions on CRF after which the probability 1.000 was introduced again.

For the probability of response requirement variable, 11 out of the 30 animals exposed to probability values less than 1.000 reached criterion on the 1st probe. As a rule, animals who did not reach the final criterion at SR1=10 sec, did not reach 80% correct at SR1=1 sec. One exception was animal 69 from the group at probability of 0.000 who reached 80% correct at SR1=7 sec, but failed to meet the criterion at 8 sec. All training was terminated for this animal after 1900 trials in SR1=8 sec. Of the remaining 18 animals, only two reached criterion when exposed to probability of 1.000 on the 2nd probe. Only one of the remaining 16 animals reached criterion with the 3rd probe. The total number of animals who had reached criterion by the end of the 3rd probe was 30 out of 30 for the probability of reinforcement variable, and only 14 out of 30 for the probability of response requirement.

First Probe:

Figures 1 and 2 present the mean number of trials at each SR1 duration for the probability of reinforcement variable and for the probability of response requirement variable. Each point represents the number of trials to reach the criterion of at least 80% correct trials on a single session for each SR1 duration. All figures in which the number of trials is plotted include the trials of the session in which the 80% correct criterion was met. Each

Figure 1.- Mean number of trials to reach 80% correct at each SR1 duration under the reinforcement probability variable. The diamonds represent the group (N=6) exposed to P=1.0 (baseline group) which is replicated in each panel for comparison purposes. The triangles represent the group exposed to the P value indicated on top of each panel. The N represents the number of subjects from which the means for the triangles was computed.

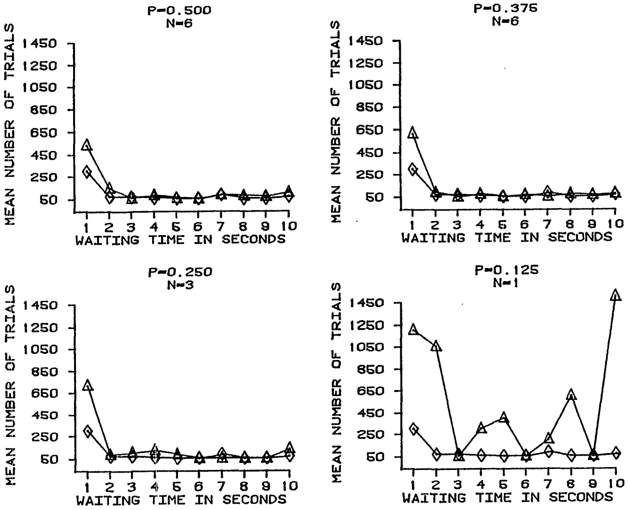
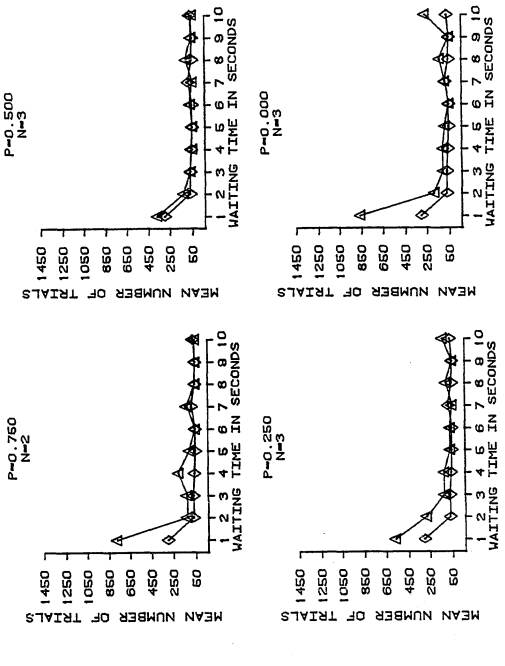

P=0.500
N=6
P=0.375
N=6
P=0.250
N=3
P=0.125
N=1
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1 2 3 4 5 6 7 8 9 10
WAITING TIME IN SECONDS

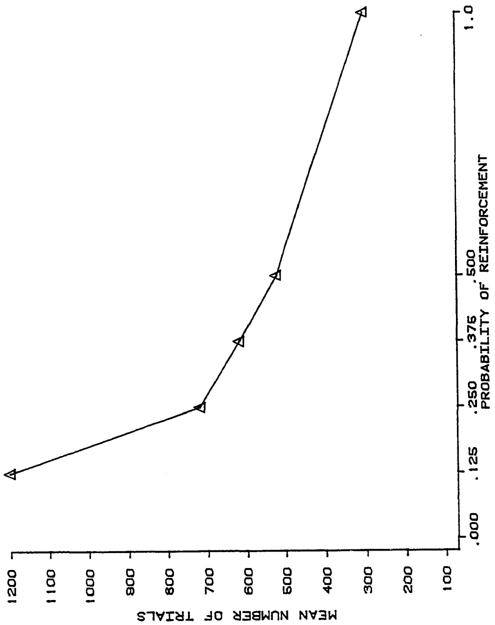
Figure 2.- Mean number of trials to reach 80% correct at each SR1 duration under the response requirement probability variable. The diamonds represent the group (N=6) exposed to P=1.0 (baseline group) which is replicated in each panel for comparison purposes. The triangles represent the group exposed to the P value indicated on top of each panel. The N represents the number of subjects from which the means for the triangles was computed.


P=0.000
N=3
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1 2 3 4 5 6 7 8 9 10
WAITING TIME IN SECONDS
P=0.250
N=3
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1 2 3 4 5 6 7 8 9 10
WAITING TIME IN SECONDS
P=0.500
N=3
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1 2 3 4 5 6 7 8 9 10
WAITING TIME IN SECONDS
P=0.750
N=2
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1 2 3 4 5 6 7 8 9 10
WAITING TIME IN SECONDS

panel represents a different probability value. Only animals who reached the 10 sec criterion waiting time on SR1 are included in these Figures. Therefore, the N from which these means are computed are not necessarily the same for each panel. The N for the baseline group is 6 and since it is unchanging it is not shown in the Figures. The N shown on top of each panel applies to the other function in the panel. No data are presented for reinforcement probability of 0.000, nor for the response requirement probability of 0.125, since no animal reached the final criterion at these probability values.

For the probability of reinforcement variable, at all values of P except 0.125, the number of trials to reach criterion was greater at SR1=1 sec than at any other SR1 duration. When SR1 was 1 sec, the number of trials increased as P decreased (See Figure 3). When SR1 was greater than 1 sec, there were no differences in the number of trials as a function of P. At any given P value, increments in SR1 duration beyond 2 seconds did not change the number of trials necessary to reach the criterion, except at probability 0.125. However, the changes in the number of trials as a function of SR1 duration for P of 0.125 were not systematic. The number of trials required by the single animal at this probability value was greater than that for any other single animal at any P value for SR1

Figure 3.- Mean number of trials to reach 80% correct at SR1=1 sec as a function of the reinforcement probability value. The number of subjects from which these means were computed differs for the different P values, and they correspond to the N presented in Figure 1 for each P value.


MEAN NUMBER OF TRIALS
100
200
300
400
500
600
700
800
900
1000
1100
1200
PROBABILITY OF REINFORCEMENT
.000
.125
.250
.375
.500
1.0

durations of 2, 5, 8, and 10 sec.

For the probability of response requirement variable, the number of trials to criterion was greater at SR1=1 sec than at any other SR1 duration for all values of P. As was found with the probability of reinforcement variable, increments in SR1 duration beyond 2 sec did not change the number of trials necessary to reach the criterion for any of the P values. When the response requirement probability was manipulated, there were no systematic changes in the number of trials at SR1=1 sec or at any other SR1 duration (see Figure 4).

In Figures 5 and 6 the total number of trials accumulated throughout training to reach criterion at SR1=10 sec was plotted as a function of P. When compared to the functions shown in Figures 3 and 4 there was no change in the trend noted for either of the two variables at SR1=1 sec. For the probability of reinforcement variable there is an increase in the number of trials as P decreases. For the probability of response requirement variable there is no systematic change as a function of P.

Figures 7 and 8 show the obtained percent correct for the probability of reinforcement variable and the probability of response requirement variable, respectively. The data represented by the diamonds are the means for the five consecutive sessions at SR1=10 sec in which the

Figure 4.- Mean number of trials to reach 80% correct at SR1=1 sec as a function of the response requirement probability value. The number of subjects from which these means were computed differs for the different P values, and they correspond to the N presented in Figure 1 for each P value.

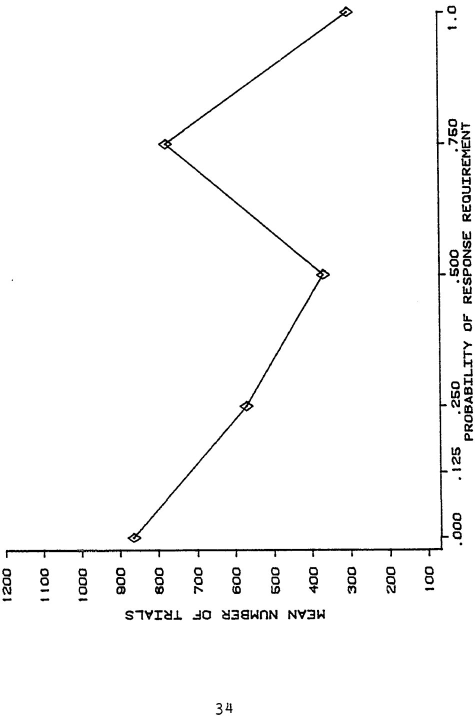

1200
1100
1000
900
800
700
600
500
400
300
200
100
MEAN NUMBER OF TRIALS
.000
.125
.250
.500
.750
1.0
PROBABILITY OF RESPONSE REQUIREMENT

Figure 5.- Mean number of trials accumulated over the ten SR1 durations under the reinforcement probability variable. The number of subjects from which these means were computed differs for different P values, and they correspond to the N presented in Figure 1 for each value of P.

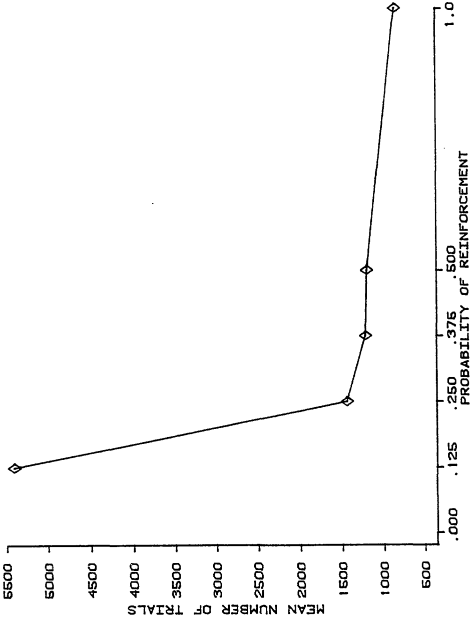

MEAN NUMBER OF TRIALS
5500
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
.000
.125
.250
.375
.500
1.0
PROBABILITY OF REINFORCEMENT

Figure 6.- Mean number of trials accumulated over the ten SR1 durations under the response requirement probability variable. The number of subjects from which these means were computed differs for different P values, and they correspond to the N presented in Figure 1 for each value of P.

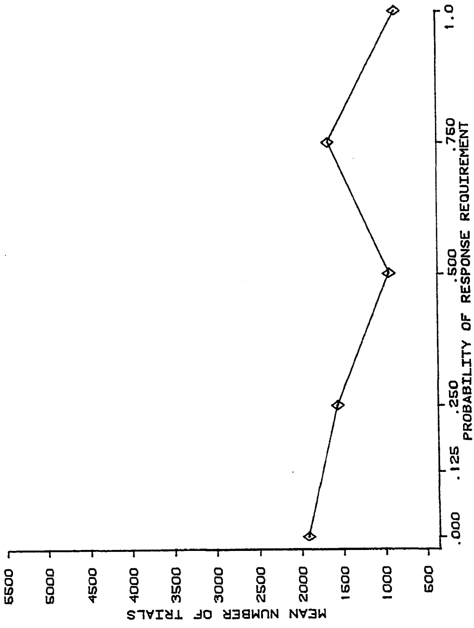

MEAN NUMBER OF TRIALS
500
1000
1500
2000
2500
3000
3500
4000
4500
5000
5500
PROBABILITY OF RESPONSE REQUIREMENT
.000
.125
.250
.500
.750
1.0

Figure 7.- Grand means of individual means for the percent correct obtained under the different reinforcement probabilities. Only animals that reached the 80% correct criterion at SR1=10 sec were included in this Figure. Diamonds represent the means at SR1=10 sec and triangles represent the means at SR1=1 sec (see text for further explanation). The line at 80% represents the 80% correct criterion established by the experimenter.

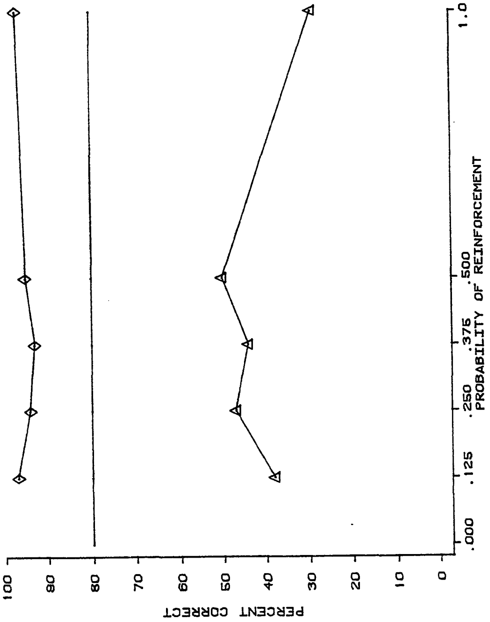
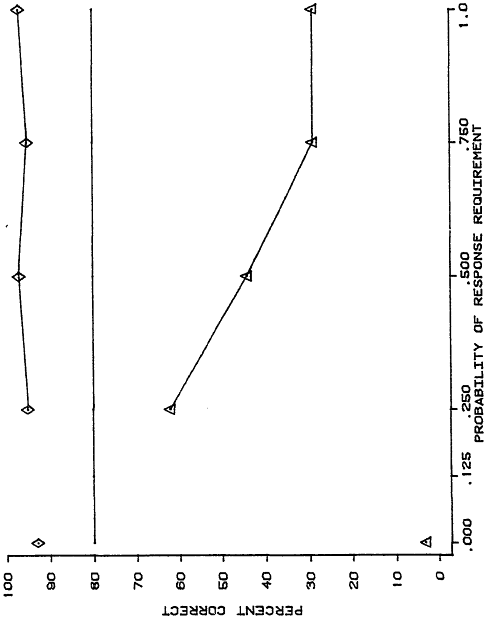

PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
PROBABILITY OF REINFORCEMENT
.000
.125
.250
.375
.500
1.0

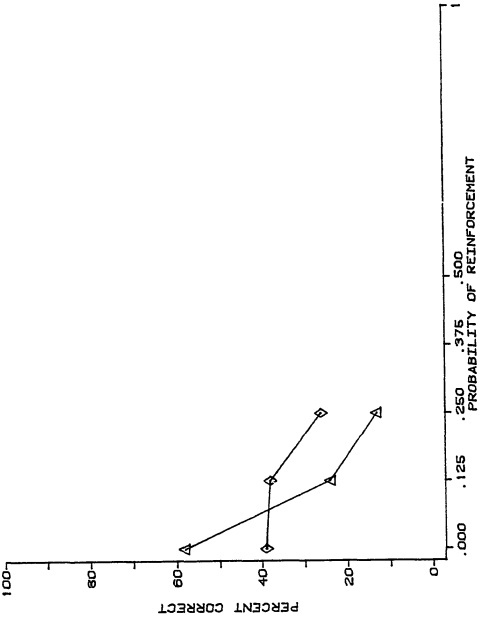
Figure 8.- Grand means of individual means for the percent correct obtained under the different response requirement probabilities. Only animals that reached the 80% correct criterion at SR1=10 sec were included in this Figure. Diamonds represent the means at SR1=10 sec and triangles represent the means at SR1=1 sec (see text for further explanation). The line at 80% represents the 80% correct criterion established by the experimenter.


PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
.000
.125
.250
.500
.750
1.0
PROBABILITY OF RESPONSE REQUIREMENT

criterion of at least 80% correct was met. The reason for presenting these data is to show that the obtained percent correct was higher than the 80% criterion. The data represented by the triangles are the means for the first sessions at SR1=1 sec before the animal reached the 80% criterion. Thus, if an animal reached the 80% criterion in the second session at SR1=1 sec, only the data from the first session were included for this animal. If, on the other hand, it took an animal more than five sessions to reach the 80% criterion at SR1=1 sec, only the first five sessions were included in the computation of the mean. The functions for SR1=10 sec in both Figures show no change in the percent correct with changes in P, and higher-than-criterion percent correct at all values of P. The functions for SR1=1 sec in both Figures 7 and 8 are well below the percent correct at SR1=10 sec. The magnitude of the change in the percent correct from the beginning (at SR1=1 sec) to the end of the training (at SR1=10 sec) is large for both variables. There are no data points at P=0.000 for the probability of reinforcement variable (Figure 7), nor at P=0.125 for the probability of response requirement (Figure 8), because none of the animals from these two probability groups reached the 80% criterion.

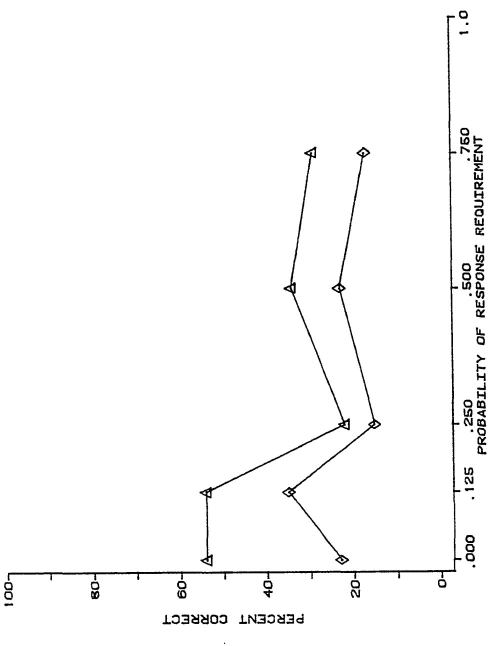
Figures 9 and 10 represent the mean percent correct for the probability of reinforcement variable and for the

Figure 9.- Means for the percent correct obtained under the different reinforcement probabilities for animals who did not reach the 80% criterion even at SR1=1 sec. Each point represents the grand mean of individual means for the first 5 sessions (diamonds), and for the last 5 sessions (triangles) on SR1=1 sec.



PERCENT CORRECT
100
80
60
40
20
0
.000
.125
.250
.375
.500
PROBABILITY OF REINFORCEMENT

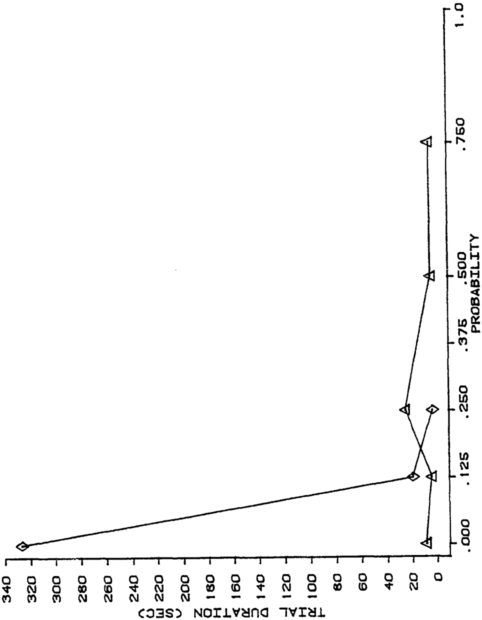
Figure 10.- Means for the percent correct obtained under the different reinforcement probabilities for animals who did not reach the 80% criterion even at SR1=1 sec. Each point represents the grand mean of individual means for the first 5 sessions (diamonds), and for the last 5 sessions (triangles) on SR1=1 sec.


PERCENT CORRECT
100
80
60
40
20
0
.000
.125
.250
.500
.750
1.0
PROBABILITY OF RESPONSE REQUIREMENT

probability of response requirement variable, for animals who did not meet the criterion of 80% correct even when they remained at SR1=1 sec for 1900 trials. There is a decrease in the percent correct for the probability of reinforcement variable from the first five sessions (diamonds) to the last five sessions (triangles) for two out of the three probability values. At P=0.000, there was an increase in the percent correct almost twice the size of the decrease for the other two P values. The percent correct increased as P decreased, especially for the function which shows the last five sessions. While the probability of reinforcement variable deteriorates with exposure to the procedure (except for P=0.000), the response requirement variable shows an improvement from the first to the last five sessions at all values of P.

Figure 11 shows the average trial duration for the last five sessions of the first probe, for the probability of reinforcement (diamonds) and response requirement variables (triangles). SR1 duration was subtracted from the original measures to make these two functions comparable to data presented below from other SR1 durations. The main effects of decreasing the probability of reinforcement to 0.000 were not only that all animals failed to reach the criterion (see Table 1), but also that trial duration increased from a few seconds at other P values to several minutes at P=0.000.

Figure 11.- Average trial duration for the last five sessions for the probability of reinforcement (diamonds) and response requirement variables (triangles). Each point represents the grand mean for all animals who did not reach the 80% criterion at SR1=1 sec on the first probe (see text for further explanation).

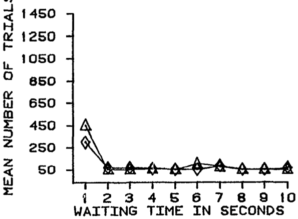

TRIAL DURATION (SEC)
340
320
300
280
260
240
220
200
180
160
140
120
100
80
60
40
20
0
PROBABILITY
.000
.125
.250
.375
.500
.750
1.0

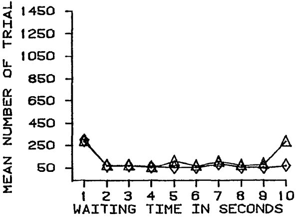
The animals could increase trial duration by increasing the key-peck latency after the offset of SR1, or by increasing the eating latency to the onset of SR2. Since at P=0.000 there was no reinforcement (SR2), the increase in trial duration was due to an increase in the key-peck latency to SR1, a well-known effect of extinction. Moreover, the improvement shown by animals at P=0.00 in the percent correct from the beginning to the end of training can be accounted for by the general effects of extinction, and need not be attributed to a real effect of the self-control training. The effect of manipulating the probability of response requirement variable was not as striking as that of the probability of reinforcement variable. However, there was an increase in the average trial duration at P=.250.

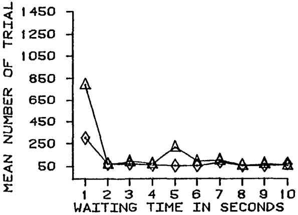
Second and Third Probes:

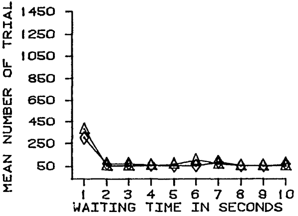
Figure 12 represents the mean number of trials at each SR1 duration when the probability of reinforcement variable was in effect. Judging from the overlap of the two functions in each panel, failure to reach criterion under probabilities of reinforcement (P less than 1.000 in the first probe, or P equal to 1.000 in the second probe) seems to have little or no effect on subsequent training at P=1.00 in the second and third probe. The only statistically significant difference between any two corresponding points

Figure 12.- Mean number of trials to reach 80% correct at each SR1 duration under the reinforcement probability variable. The function for the baseline group at P=1.00 (diamonds) is reproduced in each panel for comparison purposes; the N for this function is 6. The triangles represent the function for animals who reached criterion at P=1.00 on the second probe. N represents the number of animals from which the means for this function were computed. The bottom right panel presents the function for the only animal that did not reach criterion on the second probe. P represents the probability values to which these animals were exposed on the first probe.


P=0.250, 2ND PROBE
N=2


P=0.125, 2ND PROBE
N=5


P=0.0, 2ND PROBE
N=6

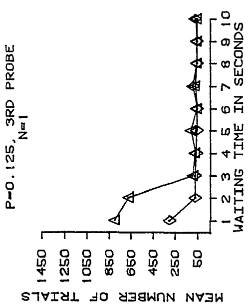

P=0.250, 3RD PROBE
N=1

in the two functions is at SR1=1 sec in the second probe after P=0.000 (t=2.784, df=10, p<.02).

Figure 13 represents the mean number of trials at each SR1 duration for the response requirement variable. The functions for the groups under the probability of reinforcement variable in the second and third probes were almost identical to the function under P=1.000 in the first probe. The functions for the groups under the probability of response requirement variable in the second and third probes, however, were different from the function under P=1.00 in the first probe: the function for the second probe was significantly higher than the first probe at SR1=1 sec (t=2.755, df=6, p<.04) and at SR1=2 sec (t=3.839, df=6, p<.01); and the function for the third probe was significantly higher than the first probe at SR1=1 sec (t=3.689, df=7, p<.01) and at SR1=2 sec (t=3.404, df=7, p<.02).

Figure 14 shows the obtained percent correct for the probability of reinforcement variable in the second probe for the last five sessions at SR1=10 sec (diamonds), and for the sessions at SR1=1 sec (triangles), that preceded reaching the 80% criterion. At SR1=10 sec, all groups showed approximately the same level of performance independently of the P value to which they were exposed in the first probe. At SR1=1 sec, however, the lower the P,

Figure 13.- Mean number of trials to reach 80% correct at each SR1 duration under the response requirement variable. The function for the baseline group at P=1.00 (diamonds) is reproduced in each panel for comparison purposes; the N for this function is 6. The triangles represent the function for animals who reached criterion at P=1.00 on the second probe (left panel) and on the third probe (right panel. N represents the number of animals from which the means for this function were computed. P represents the probability values to which these animals were exposed on the first probe.


P=0.125, 3RD PROBE
N=1
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1
2
3
4
5
6
7
8
9
10
WAITING TIME IN SECONDS

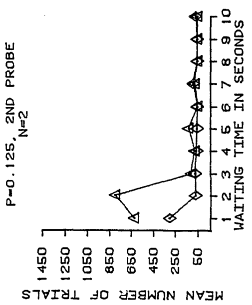
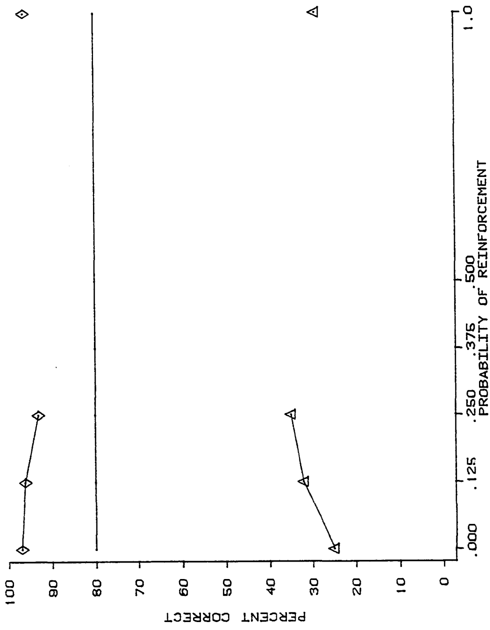

P=0.125, 2ND PROBE
N=2
MEAN NUMBER OF TRIALS
1450
1250
1050
850
650
450
250
50
1
2
3
4
5
6
7
8
9
10
WAITING TIME IN SECONDS

Figure 14.- Grand means of individual means for the percent correct obtained on the second probe. The data points shown here were all obtained under P=1.00. Thus, the values on the abscissa represent the reinforcement probability to which the groups were exposed on the first probe. The separated points under P=1.00 represent the baseline group and are included in this Figure for comparison purposes. Diamonds represent the means at SR1=10 sec and triangles represent the means at SR1=1 sec. These data were computed in a manner similar to that of Figures 7 and 8 (see text). The line at 80% represents the 80% correct criterion established by the experimenter.


PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
.000
.125
.250
.375
.500
1.0
PROBABILITY OF REINFORCEMENT

the lower the percent correct. There are no major differences in percent correct at SR1=1 sec and SR1=10 sec between animals exposed to P=1.000 initially (baseline group) and those exposed to P=1.000 after unsuccessful training under P values less than 1.000.

The single animal who required a third probe at P=1.000 increased on that probe approximately 30% from the beginning of training at SR1 1 sec (60% correct) to the end of training at SR1=10 sec (91% correct).

Data from animals exposed to the probability of response requirement variable are not graphed because all animals failed to reach criterion during both the second and the third probes except for some of the animals with a history at P=.125. Two of these animals reached criterion in the second probe, improving from a mean of 60% in the first sessions to a mean of 96% in the last five sessions. One animal reached criterion in the third probe improving from 64% correct in the first sessions to 98% in the last five.

Among the animals who reached the final 80% criterion there are no major differences in the percent correct obtained at SR1=10 sec between the probability of reinforcement and the probability of response requirement variables; nor between different values of any of the two variables; nor among the first, second, and third probes.

Figures 15 and 16 show the percent correct for animals who did not reach criterion on the second and third probes, respectively, with the probability of response requirement variable. There was no systematic change in either curve in either Figure as a function of the P values used in the first probe. While in the first probe there was an improvement from the first to the last sessions, in the second and third probes no systematic change was found.

Baseline Group:

Figures 17 and 18 represent the percent correct for the baseline group. Figure 17 shows the percent correct for the three animals exposed to several probabilities of reinforcement, and Figure 18 shows the percent correct for the three animals exposed to several probabilities of response requirement. The percent correct obtained is somewhat higher for the probability of response requirement variable than for the probability of reinforcement variable, but there is no systematic change as a function of P for either of the two variables.

In the first probe for the groups under the probability of reinforcement variable, 100% of the animals reached the 80% criterion at P=.375 and higher P values. At values lower than .375, the number of animals reaching the criterion was a decreasing function of P. For the baseline

Figure 15.- Grand means of individual means for the percent correct obtained for animals who did not reach the 80% criterion even at SR1=1 sec on the second probe. The data points shown here were all obtained under P=1.00. Thus, the values on the abscissa represent the response requirement probability to which the groups were exposed on the first probe. Diamonds represent means for the first 5 sessions, and triangles represent means for the last 5 sessions on SR1=1 sec.

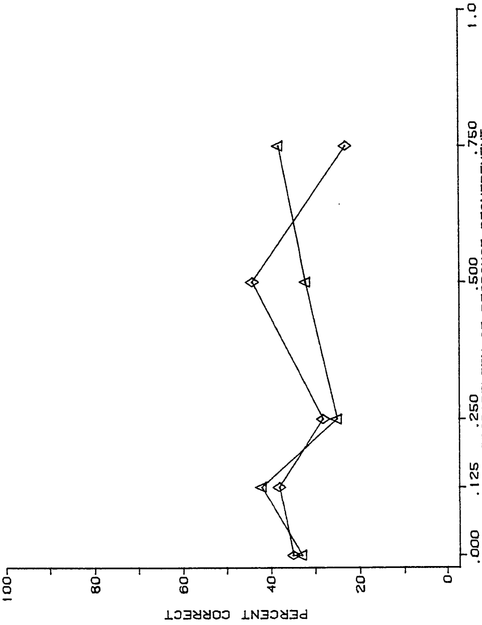

PERCENT CORRECT
100
80
60
40
20
0
.000
.125
.250
.500
.750
1.0
PROBABILITY OF RESPONSE REQUIREMENT

Figure 16.- Grand means of individual means for the percent correct obtained for animals who did not reach the 80% criterion even at SR1=1 sec on the third probe. The data points shown here were all obtained under P=1.00. Thus, the values on the abscissa represent the response requirement probability to which the groups were exposed on the first probe. Diamonds represent means for the first 5 sessions, and triangles represent means for the last 5 sessions on SR1=1 sec.

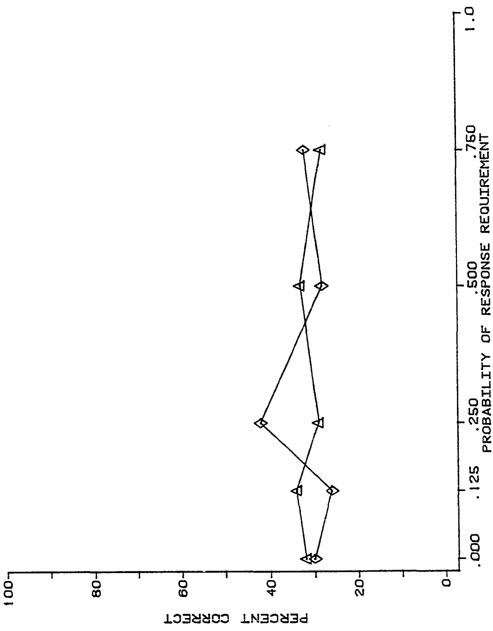

PERCENT CORRECT
100
80
60
40
20
0
.000
.125
.250
.500
.750
1.0
PROBABILITY OF RESPONSE REQUIREMENT

Figure 17.- Grand means of individual means for the percent correct obtained by the baseline group exposed to the different reinforcement probabilities. Each point is the mean for the first five of seven consecutive sessions after reaching the 80% criterion under each probability value (for P=1.00 five sessions instead of seven were required).

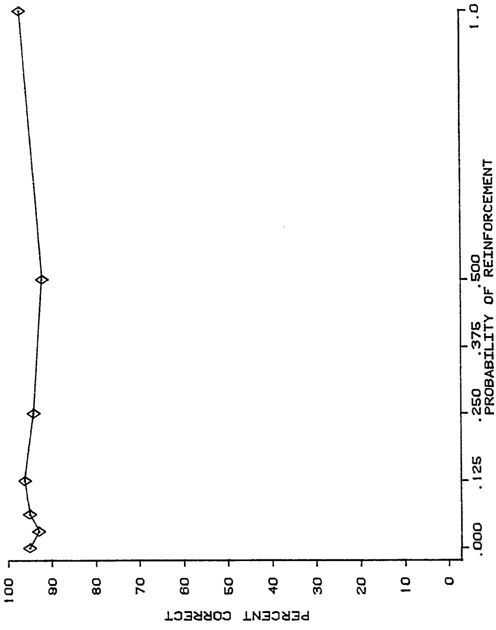
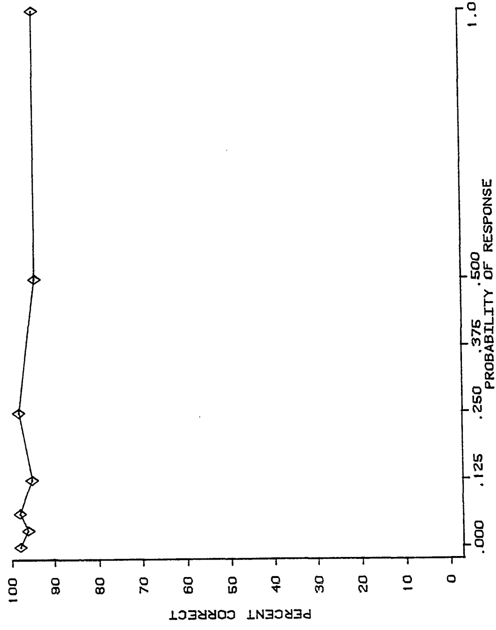
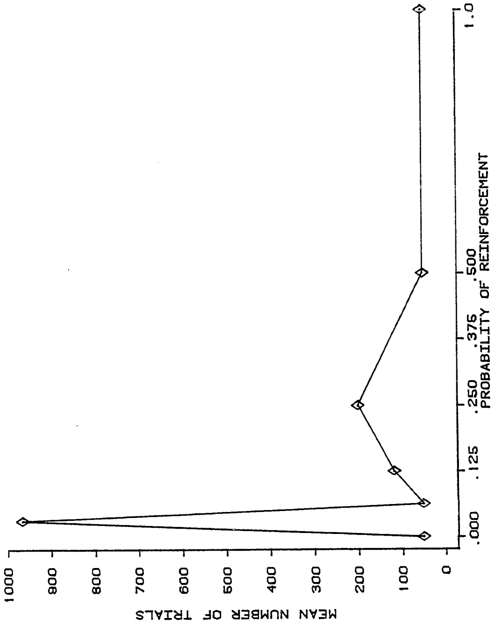

PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
.000
.125
.250
.375
.500
1.0
PROBABILITY OF REINFORCEMENT

Figure 18.- Grand means of individual means for the percent correct obtained by the baseline group exposed to the different response requirement probabilities. Each point is the mean for the first five of seven consecutive sessions after reaching the 80% criterion under each probability value (for P=1.00 five sessions instead of seven were required).


PERCENT CORRECT
100
90
80
70
60
50
40
30
20
10
0
.000
.125
.250
.375
.500
1.0
PROBABILITY OF RESPONSE

group, all three animals exposed to the probability of reinforcement variable reached the 80% criterion at all values of P. Figure 19 shows the mean number of trials to reach the first of seven consecutive sessions at 80% correct (the first of five consecutive sessions for P=1.000). There was an increase in the number of trials for all three animals at P=.03125. For bird number 12 it was necessary to increase the P value back to .250 to recover the 80% criterion performance and gradually decrease the P value again. The second time the P value was decreased for this animal, the performance fell below 80% correct at P=.0625. This sequence of .250, .125, and .0625, was repeated twice more before the animal reached the 80% criterion at both P=.0625 and P=.03125. The .03125 value was included in the baseline group function because there is evidence in the literature showing that a stable function changes direction at approximately this value. For example, Brandauer (1958) found that under Random Ratio reinforcement schedules there is a change in the response rate function at approximately P=.02. Using the same reinforcement schedules, Farmer and Schoenfeld (1967) found that there is an increase in the pause after reinforcement near P=.02. The increase in the number of trials at P=.03125 in the present study similarly indicates that reliable changes occur near this value of the probability of reinforcement variable.

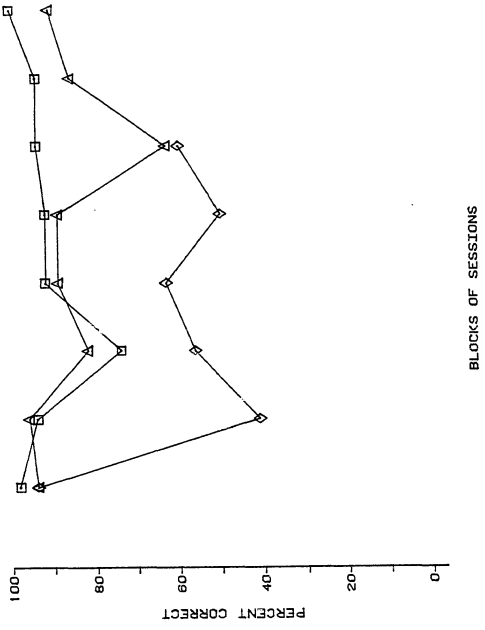
Figure 19.- Figure 19.- Mean number of trials to reach the first of seven consecutive sessions at 80% correct (the first of five consecutive sessions for P=1.00) for the baseline group exposed to the different reinforcement probabilities.


MEAN NUMBER OF TRIALS
1000
900
800
700
600
500
400
300
200
100
0
.000
.125
.250
.375
.500
1.0
PROBABILITY OF REINFORCEMENT

In the first probe for the groups under the probability of response requirement variable, 100% of the animals reached the 80% criterion at SR1=10 sec only at P=1.000. At P values less than 1.000, no systematic trend in the number of animals reaching the criterion was found. For the baseline group, all three animals exposed to P<1.000 reached the 80% criterion in the first session of 50 trials of exposure to each P value.

Figure 20 shows the percent correct for the baseline group exposed to the probability of reinforcement variable at P=0.000. There are individual differences both in the obtained percent correct and in the speed at which animals fall below 80% correct. Bird number 12 (diamonds) fell below 80% during the second block and did not recover to 80% during the remaining four blocks. The training for birds 14 (triangles) and 142 (squares) was extended for two blocks more than for bird 12 to determine if prolonged extinction would maintain the reduced percentage correct for bird 14 and eventually bring down the percent correct for bird 142. The percent correct for bird 14 went down on the sixth block, but it did recover on the seventh block. Bird 142 fell below 80% correct in the third block but it recovered in the following block and stayed above 80% for the remaining blocks. It would seem, from this Figure, that behavior was maintained during extinction for these two

Figure 20.- Mean percent correct for the baseline group at probability of reinforcement of 0. Each point represents the mean percent correct for a five session block. The three functions represent the individual animals.


PERCENT CORRECT
100
80
60
40
20
0
BLOCKS OF SESSIONS

birds. However, there was an increase in trial duration for bird 142 that is not visible in these data. The increase resembles the effect on trial duration produced by P=0.000 in the first probe (see Figure 11). The average trial duration for this bird increased from an average of 6 sec in the last five sessions at P=.03125 to over 4 minutes in the last five sessions at P=0.000. On some ocassions the trials at P=0.000 were so long (over two hours) that only one or two trials were completed in a session. The data presented in Figure 20 only include sessions with 20 or more trials. Thus it seems that the maintenance of a high percent correct was, at least for bird 142, an effect of extinction. The average trial duration also increased for bird 12 although to a lesser degree, from 8 sec to a maximum of 3 minutes.

Discussion

Several researchers have defined and given examples of self-control. Thus, Kanfer (1977) defines self-control in the following way: "When a subject can administer a reward to himself but does it only on reaching some self-selected or externally imposed criterion, he can be said to be exercising self-control." Risley (1977) says: "...when someone is seen resisting temptation, that is, not complying with immediate pressures nor seeking immediate available reinforcers, that person is attributed with will power, altruism, ethics, or more recently, self-control." And Skinner (1953, pp. 227-241)) puts it this way: "we may put a box of candy out of sight to avoid overeating. This sort of self-control is described as "avoiding temptation"..... It is the principle of "get thee behind me, satan."

A characteristic common to these examples and definitions, including Rachlin's "brute-force" self-control mentioned in the Introduction of this paper, is that all of them recognize the two features that define self-control in the paradigm of Cole et al. These two features are the facts that the reinforcer is available and the subject refrains from taking it.

Even though there seems to be agreement as to what self-control is, the experimental analogues used by earlier workers to study self-control do not have the features that characterize the self-control paradigm of Cole et al. Thus, for example, the choice procedure involves a wait in the absence of the reinforcer. The effect of presenting the reinforcer during the waiting period has its own consequences some of which have been experimentally demonstrated. In the studies of Mischel and Ebbesen (1970) using children, and of Grosch and Neuringer (1981) using pigeons, subjects were trained to make a specific response to get to a less preferred reward, or to wait and get a more preferred reward. The percent of trials on which waiting occurred was measured under two conditions: when the two rewards were present while the subject responded or waited, and when the two rewards were absent. In the Mischel and Ebbesen experiment, when both rewards were present, none of the children waited successfully, but when both rewards were absent, 75% waited successfully. Similarly, in the Grosch and Neuringer study the birds waited an average of 6.6% of the trials during the last 3 sessions when both rewards were present, and waited an average of 83.5% of the trials during the last 3 sessions when the reinforcers were absent. The waiting behavior, it may be surmised, would be maintained for as long as the reinforcers are absent. The fact that in the presence of the reinforcers the performance of the subjects deteriorated shows that having established waiting in the absence of the reinforcers does not guarantee that the subject will not approach food if it is presented to him during that time. The discrepancy in the results obtained in these two studies, specifically with respect to the fact that the subjects did not learn to wait in the presence of the reinforcers and the results obtained in the experiment reported here may be due to several differences in the procedures. For example, the gradual increase in reinforcer duration during the time the subjects were expected to wait in the present study allowed for the shaping of the waiting behavior. In the studies by Mischel and Ebbesen and by Grosch and Neuringer, the reinforcer was first introduced at its longest duration, thus precluding the effects that appeared in the present study when the introduction is gradually increased from low to high durations.

Although it is said that in the choice procedure the subject has a choice between a immediate but smaller reward, and a delayed but larger reward, the actual experimental procedure used in a choice paradigm only allows for the choice of different responses each one leading to a different reinforcer. However, there is no choice of reinforcers because they are not present at the moment the choice is made. Once the subject has made a particular response, there is no alternative to the contingency associated with that response. When the term "choice" is used to describe the fact that there is more than one response available to the subject the term "choice" has little analytical value because every situation is, in this sense, one of choice. Even in a basic training procedure, for example when CRF is in effect for a key-peck response, the subject can be said to have a choice between pecking and getting a reinforcer and not pecking and not getting a reinforcer.

Putting aside the lack of correspondence between the verbal description of self-control and the choice procedures used ostensibly to investigate it, there is still another problem when the choice procedure is used. The subject is said to have self-control if it makes the response that leads to the delayed but larger reinforcer. However, if the purpose of self-controlled eating is to decrease the overall consumption of food, it is undetermined whether this would be accomplished by a procedure that permits a subject to increase food consumption. Therefore, whether the choice procedure will produce a successful human dieter, for example, might well then depend on how much larger the amount of food must be to compensate for the increased delay.

Independently of which procedure is used for the study of self-control, there is little in the literature to suggest what is crucial about the procedure which produces self-control. This gap has been acknowledged by some researchers (Rachlin, 1978), but so far, few experimental efforts have been made to close it. As a consequence, a frequent finding is that a particular procedure will be only partially successful. Thus, Ainslie (1974) using a precommitment procedure for a choice paradigm, found that only 3 out of 10 pigeons selected the response leading to the larger reinforcer in most of the trials. In the Mazur and Logue study (1978), in which the delay for the smallest reinforcer was gradually faded out, only two out of four pigeons made the response leading to the larger reinforcer in the majority of the trials. Colotla et al. (1976), utilized a procedure that includes the defining features of the paradigm of Cole et al. but it did not require a key-peck. In the study by Colotla et al., doves were allowed to eat from the food presented for three seconds following the offset of a white key light. Following the offset of a red key light, food was also presented for three seconds, but the animals were not allowed to eat from it. If the subject approached the food after the red key light the food was immediately removed and an ITI of 20 seconds started. If the animal did not approach the food for three seconds the food was removed and the ITI started. The highest percent correct reported by the authors for any block of five consecutive sessions was 66.4% for one dove and 41.6% for the other. This level of performance contrasts with that obtained with the procedure employed here: at some probability values all animals acquired the self-controlled pattern and reached a higher percent correct than the 80% correct imposed as a criterion of acquisition by the experimenter.

Under the title of self-reinforcement, Mahoney and Bandura (1972), and Bandura and Mahoney (1974), obtained more successful results using a procedure similar to the one in experiment 7 from the study of Cole et al. In those two studies, pigeons were presented with food but they were allowed to eat only after they had completed the requirement of a Fixed Ratio (FR) schedule of reinforcement. If the pigeons approached the hopper before fullfilling the FR requirement, the hopper was removed and the next trial started. Although there were individual differences in the rate of progress among the three pigeons used in this study, they all learned to peck before they ate from the hopper. Some obvious differences from the procedure of Cole et al. are that, while in the study of Cole et al. the criterion waiting was a temporal one (i.e., the subject had to wait for a required period of time and the key-peck was required after the waiting), in the study by Mahoney et al. the criterion waiting was a ratio requirement (i.e., the subject had to peck on the key for a required number of times while the subject waited). Despite the differences between these two studies, the features they have in common are the ones which define self-control according to Cole et al. Since both procedures were effective in causing the subjects to refrain from eating for some time in the presence of food, the question of concern that emerges is what the characteristics were of these procedures which permitted the successful self-control performance to develop. The present study was an attempt to answer that question with respect to two aspects of the procedure.

The first aspect addressed was the key-peck requirement. Even though the key-peck was required in the procedure of Mahoney et al., its role was actually uncovered by Cole et al. when its elimination showed that without it the procedure for producing self-control lost effectiveness. When the key-peck is not required, only some of the subjects acquired the self-control pattern in the study of Cole et al. With the inclusion of the key-peck, the procedure became reliable, i.e., all of the subjects exposed to it reached and surpassed the criterion of acquisition. Against this background of requiring the key-peck on every trial or not requiring it at all, the present study attempted to find out the effect of intermittently requiring the key-peck. Intermittency was measured as the probability, P, of the response requirement. The present experiment replicated the results of Cole et al. at the extremes, i.e., at P=1.00 all subjects reached the acquisition criterion, while at P=0.00 only some of them did. The procedure proved to be not reliable at any of the intervening values of P here investigated. It seems that for the procedure to be successful with every subject, the key-peck response has to be required on every trial, or at least at a higher value than P=0.75. However, the efficiency of the procedure depends on the key-peck only during acquisition. Once the behavior has been acquired, the key-peck can be eliminated completely and the behavior will be maintained (at least over the course of five sessions). That is the case when the requirement is lowered gradually. Whether or not the behavior would be maintained if the key-peck requirement were dropped suddenly remains to be determined. The exposure to the procedure with no key-peck requirement, or with an intermittent key-peck requirement is not only unreliable but also changes the subject's history in such a way that it prevents the subject from easily acquiring the behavior later on even when the key-peck is required on every trial. In other words, a procedure effective with naive animals becomes unreliable when used with subjects previously exposed to $P<1.00$ of key-peck requirement.

This does not mean, of course, that the subjects who failed to acquire self-control under the present procedure would not be able to acquire it by perhaps initiating training at an earlier stage than the one used here, for example, by starting at S1 duration of .5 sec instead of 1 sec. It does mean, however, that there is a deterrent to the success of an otherwise reliable procedure. If extrapolation to the human case from a clinical point of view is indicated at all, it seems possible to assume that it would be better to start self-control training early in the individual's life, before a complicated history of unsuccessful training may make subsequent training more difficult. Moreover, it might be easier to establish self-control during childhood, when the restrictions necessary for acquisition are possible. It is during childhood, more than at any other point in life that the delivery of reinforcers is more under the control of individuals surrounding the subject than under the control of the subject himself, and it seems reasonable to assume that this situation could facilitate the training of a self-controlled pattern of behavior.

The second aspect investigated in the present study was the probability of reinforcement, a variable which exercises a powerful influence on behavior as the literature has repeatedly shown.

In the present experiment, a decrease in probability of reinforcement brought about a decrease in the number of subjects acquiring self-control, but this decrease occurred at lower values of P (0.250 and below) than it did for the P of response requirement (0.75 and below). This means that for the procedure to lead to reliable acquisition a greater proportion of trials must contain the key peck requirement than must contain the reinforcer (SR2, or the food that is actually consumed). Some reinforcement appears to be a necessary condition for the procedure to work at all. On the other hand, the response requirement is not strictly necessary because at P=0 of response requirement some animals reached the criterion for acquisition, while at P=0 of reinforcement none of the animals reached criterion.

Not only is reinforcement necessary for acquisition, but also for maintenance. Even though the self-controlled behavior pattern was maintained at lower P values of reinforcement than the P values at which the behavior was acquired, when reinforcement is totally absent the behavior gradually deteriorates (after more than five sessions of exposure).

While changes in the probability of key-peck requirement did not change the speed of acquisition in any systematic way, as measured by the number of trials to reach the criterion for acquisition, changes in the probability of reinforcement did produce such changes: as reinforcement probability decreased, the number of trials to the acquisiton criterion increased for those animals who finally did reach the criterion. These findings are in agreement with the results of the literature obtained with traditional schedules of reinforcement. Despite the complexity of self-controlled behavior, reinforcement affects self-controlled behavior in ways that are similar to reinforcement effects on other behavior patterns.

In summary, the present study confirms the findings of Cole et al. that self-controlled behavior can be acquired through a reliable procedure without the use of positive punishing stimuli.

The manipulation of two parameters of this procedure allowed for the following conclusions:

(1) Reinforcement is necessary for both the acquisition and the maintenance of self-controlled behavior. But, although reinforcement is both necessary and sufficient (when P is at least .03125 or higher) to maintain self-controlled behavior, it may be insufficient to establish it even when reinforcement probability is 1.0. An intervening response, together with the reinforcer, is required with a P value greater than .75 during acquisition to transform a partially successful procedure into one that is 100% reliable.

(2) This intervening response is unnecessary to sustain

the reliability of the procedure during maintenance.

(3) Although the role of this intervening response in the acquisition of self-control is not wholly clear, reinforcement in such acquisition can not compensate for the absence of such a response.

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