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THE EFFECT OF THE TEMPORAL SIMILARITY BETWEEN THE CS AND US ON AUTOSHAPING IN THE PIGEON

by

Ⓒ Donald D. Severance

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH
IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE

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Date ..10 December 1980..

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ABSTRACT

Three experiments were conducted to test the hypothesis that the temporal similarity of the stimulus and reinforcer would facilitate autoshaping in the pigeon. In the first experiment, a two-key autoshaping procedure was used. Each of the four stimuli used in the experiment was followed by reinforcement on an equal proportion of presentations. The frequency of presentation of each stimulus was different such that only one stimulus had the same total presentation time as the reinforcer. Four groups were used, each differing from the other in the frequency of reinforcement and/or the duration of the individual stimulus. The hypothesis that a preference would be shown for the stimulus with the same total presentation time as the reinforcer was not supported in any of the four groups. In the second experiment, the pigeons were initially exposed to a discrimination training procedure to facilitate attending to the stimuli. Three new stimuli were used. One was always associated with reinforcement, one was never associated with reinforcement, and the third was not correlated with reinforcement. Following this training, the pigeons were exposed to the autoshaping procedure used in Experiment I. The results of Experiment 2 were similar to those in Experiment 1, suggesting that the increased attending to the stimuli did not effect the pattern of responding to each of the stimuli. The high rates of responding to the stimuli in the first two experiments may have masked any preference in responding to the stimulus which occurred with the same total presentation time as the reinforcer. In the third experiment, an extinction procedure was used to retest the initial hypothesis. While the rate of responding decreased, no preference was found for the stimulus which occurred for the same total presentation time as the reinforcer. The results of the three experiments were discussed in relation to the interpretation of autoshaping as a Pavlovian paradim.

INTRODUCTION

In 1968, Brown and Jenkins published the first study of autoshaping, a procedure for training pigeons to peck illuminated response keys. Prior to their study, methods of training pigeons to keypeck relied on providing reinforcement contingent upon the response of the pigeon. The most common procedure used was the method of successive approximations. In this procedure, the experimenter observed the pigeon's behavior in the experimental chamber and reinforced movements successively closer to the keylight until the pigeon was reinforced only for pecking the key. Brown and Jenkins' procedure eliminated the need for direct observation of the pigeon and demonstrated that the explicit contingency between the pigeon's response and reinforcement was not a necessary condition for the acquisition or maintenance of the keypeck response. In one of their experiments, twelve experimentally naive pigeons were first given ten magazine training trials in which the birds were trained to approach and eat from a lighted grain hopper. Each pigeon then received two sessions of 80 pairings of an eight-second keylight immediately followed by a four-second presentation of grain. The responses of the pigeons had no programmed consequences during these sessions. Brown and Jenkins' results showed that eleven of the twelve subjects pecked the keylight at least once and that ten of these maintained responding beyond the first keypeck. This procedure to condition the pigeon's keypeck is termed autoshaping.

Brown and Jenkins' work led to a proliferation of research due to the questions it raised about the traditional bounderies between operant and classical (Pavlovian) conditioning. Traditionally, the pigeon's keypeck had been considered an operant, responsive only to response-reinforcer (R-S) contingencies. Brown and Jenkins' research, however, indicated that stimulus-reinforcer (S-S) contingencies might play a major role in conditioning the keypeck response. Thus, an analysis of a naive pigeon's learning in the autoshaping procedure could contain both operant and Pavlovian components. In the autoshaping procedure, a food deprived pigeon is first trained to eat from the grain magazine. The bird is trained to approach and eat from the grain hopper whenever the hopper mechanism operates and the hopper is illuminated. This is an operant conditioning procedure in which the sound of the hopper operation and the illumination of the hopper light serve as discriminative stimuli (S^Ds) for the responses (Rs) of approaching and eating grain, the reinforcer (S^{R+}). Once the pigeon is magazine trained, the keylight is paired with hopper presentations. This procedure fits the Pavlovian model where the conditioned stimulus (CS), the keylight, is paired with the unconditioned stimulus (US), grain. The US elicits the unconditioned response (UR), pecking, and after several pairings with the US, the CS begins to elicit pecking, the conditioned response (CR). Though this analysis appears to explain autoshaping, it is overly simplified and does not include other mechanisms which have been shown in subsequent research to play a role in the acquisition and maintenance of the autoshaped keypeck response.

One alternative explanation of the maintenance of the autoshaped keypeck is that the responding is maintained by adventitious reinforcement. As the keypeck response is closely followed by reinforcement, a loose R-S contingency exists which strengthens the response. Williams and Williams (1969) produced evidence which disputed this interpretation. In their first experiment, thirteen naive pigeons were initially magazine trained. Subsequently one bird was trained to keypeck using the method of successive approximations. Two other subjects were autoshaped with a positive response contingency where a keypeck terminated the keylight and operated the grain hopper. These three subjects were then trained on a FR1 timeout procedure. In this procedure, the key was illuminated for six seconds unless a keypeck occurred. A keypeck terminated the keylight and operated the grain hopper as in some autoshaping procedures. The procedure differed from autoshaping procedures in that if no response occurred during the six-second keylight, no grain presentation occurred. After this training for these three birds and after the magazine training for the remaining ten, the subjects were placed in an autoshaping procedure with a negative response contingency. Six-second presentations of the keylight were followed by four-second grain presentations if no response occurred to the keylight. A keypeck resulted in the termination of the keylight and prevented reinforcement. All but one of the subjects developed responding under this procedure and consistently responded on more than 10% of the trials. As reinforcement could not follow keypecks in this procedure, Williams and Williams concluded that the stimulus-reinforcer associations between the keylight and grain maintained responding in their procedure. This procedure has been referred to as automaintenance or omission training.

Hursh, Navarik, and Fantino (1974) studied a response-reinforcer relationship which exists in the automaintenance paradigm. On trials where no response occurs, the termination of the keylight is paired with reinforcement, making keylight termination a secondary reinforcer. On trials where a keypeck occurs, the response results in keylight termination, which, as a reinforcer, increases the probability of the reoccurrance of the response. Hursh, et. al. reasoned that by inposing a delay between the response and keylight termination or by eliminating the keylight termination-reinforcement contingency, responding could be reduced or eliminated in the automaintenance procedure. In their first experiment, four pigeons with varied histories of keypecking were exposed to an automaintenance procedure in which six-second keylight presentations were followed by four-second presentations of grain unless a keypeck occurred. A keypeck terminated the keylight and prevented reinforcement. The two subjects that maintained responding under this procedure were then placed in a modified automaintenance procedure in which keylight termination was delayed for two seconds after a response. This procedure was labeled a trial-offset-delay (TOD) procedure. On the standard automaintenance procedure, these birds responded on between 80 and 100 percent of the trials. After the introduction of the TOD, the birds responded on less than 20 percent of the trials. The two birds that failed to respond on the original automaintenance procedure were exposed to a continuous reinforcement (CRF) schedule where every keypeck was followed by reinforcement and to a trial CRF procedure similar to Williams and Williams' FR1 timeout procedure in an effort to generate responding on the automaintenance procedure. Both birds failed to respond on the automaintenance procedure after exposure to these procedures. In Experiment II, an additional procedure was introduced. The stimulus-overlap (SO) procedure was similar to the automaintenance procedure except the keylight remained on during the grain presentations. This procedure eliminated the keylight offset-reinforcer contingency. Six naive and two experienced pigeons served as subjects. The six naive subjects were first magazine trained. Three of these pigeons were then placed in a standard autoshaping procedure and the remaining five subjects were exposed to the automaintenance procedure. After responding stabilized for the subjects in the autoshaping procedure, they were also placed in the automaintenance procedure. The subjects which acquired automaintenance were subsequently exposed to the TOD and/or SO procedures. Of the three subjects that acquired automaintenance, one stopped responding when placed in the SO procedure and failed to reacquire responding when re-exposed to the original automaintenance procedure. Another subject ceased responding when placed in a TOD five-second procedure and the third responded on approximately half the trials under all procedures. Hursh, et. al. concluded that the responding in an automaintenance procedure was difficult to generate and that the responding was probably maintained by the response-reinforcer contingency between keypecks and keylight termination.

Myerson, Myerson, and Parker (1979) studied autoshaping without the possibility of adventitious reinforcement or the keypeck-keylight offset contingency. In their experiment, six naive pigeons were first given one session of magazine training. The subjects were then paired into three groups of two birds. Within each pair, the "leader" was exposed to a modified autoshaping procedure in which a seven-second keylight was followed by a 3.5-second presentation of grain if no keypeck occurred. If a keypeck occurred during the seven-second stimulus, the trial timer was restarted. Thus, the keylight would terminate and grain would be presented only when no response to the keylight occurred for seven seconds. In this procedure, the keylight-grain association was present on every trial, but reinforcement never occurred within seven seconds of a response. Previously identified response-reinforcer contingencies were eliminated while the stimulus-reinforcer contingency remained. The "follower" bird in each pair was yoked to the leader bird. Each follower received the same keylight stimuli and reinforcements as its respective leader, but responses by the follower had no scheduled consequences. Two pair of the birds received 40 sessions of 30 trials on this procedure, followed by 40 sessions with the leader-follower roles reversed, and 20 additional sessions in their original roles. The third pair of birds received 56 sessions of training in the original procedure only. All six subjects acquired keypecking within two sessions and maintained responding throughout the experiment. Myerson, et. al. concluded that autoshaped responding could be maintained without an adventitious response-reinforcer contingency or a response-keylight termination contingency. While these results appear to conflict with those of Hursh, et. al., there is a similarity. In their first experiment, Hursh, et. al. reported that after the introduction of the TOD, their subjects responded on less than 20% of the trials. In the present study, three of the five birds in the leader roles responded on less than 25% of the trials. While both studies showed a low rate of responding, both showed response maintenance without any identifiable R-S contingencies. In taking the results of both studies together, it appears that neither an adventitious response-reinforcer contingency or a keypeck-keylight termination contingency is necessary for the maintenance of the autoshaped keypeck. However, it also appears that such R-S contingencies have a major effect on the strength of the autoshaped response.

Studies of autoshaping have also looked at the keypeck itself in an effort to clarify the learning process involved. Jenkins and Moore (1973) conducted a series of experiments on the form of the autoshaped keypeck. In a Pavlovian interpretation of autoshaping, the CS comes to elicit the same response as the US. Therefore, it would be expected that the keypeck should resemble the response to the reinforcer. Jenkins and Moore's first experiment evaluated the form of the keypeck with either food or water reinforcement. Twelve naive pigeons were used, six were water deprived and six were food deprived. Each bird was magazine trained and then given two sessions of autoshaping with eight-second stimuli followed by four-second presentations of the reinforcer appropriate to the bird's deprivational state. The autoshaping trials were filmed and evaluated by student judges for the form of the key contact. The judges correctly identified 87% of the key contacts as occurring during either food or water sessions. While these results appear to indicate that the form of the keypeck resembles the response made to the reinforcer, the keypecks may have been influenced by the type of deprivation instead of the reinforcer received. In Experiment 2, this was studied with two naive pigeons under food deprivation and two pigeons under water deprivation. Each bird was magazine trained and then autoshaped with the reinforcer appropriate to the bird's deprivational state to a criterion of 20 trials with a response within a session of 30 trials. Following this, the type of deprivation was switched for each bird and ten trials of extinction were given. Extinction trials consisted of eight-second presentations of the keylight without any reinforcer presentations. Following this, the hungry birds were allowed to eat from the food hopper on 30 presentations and the thirsty birds were allowed to drink from the water hopper on 30 presentations. This was followed by 10 additional extinction trials. Every fifth trial of the session in which the autoshaping criterion was met was filmed, as were all extinction trials. The results showed that responses to the key generally resembled those from the autoshaping session, even after the deprivational state had been switched and the birds had consummed a different reinforcer in the experimental chamber. But as the dominant deprivational state appropriate to the reinforcer may have been necessary for the initial appearance of the reinforcer-related response form, a third experiment was conducted. In this experiment, four pigeons were both food and water deprived. They were then magazine trained with both the food and water delivery devices. Two birds were autoshaped with grain reinforcers until a criterion of 20 trials with a response in a session of 30 trials was met. Ten trials of extinction were given in the subsequent session. In the following session, autoshaping was resumed with water as the reinforcer. A third bird received the same treatment except it was first autoshaped with water and subsequently with food. The fourth pigeon was discarded from the study after it failed to autoshape with water reinforcers. The results showed that in the initial autoshaping and subsequent extinction, the keypeck resembled the response to the subsequent extinction, the keypeck resembled the response to the reinforcer. In subsequent autoshaping, the form of the keypeck gradually acquired the characteristics of the response to the new reinforcer.

Jenkins and Moore identified two more possible explanations beyond the Pavlovian interpretation for the results found in the first three experiments. The first was that response generalization occurred from the lighted reinforcement device to the lighted key. The second was that the repeated activation of one, [illegible] of consummatory response influenced the response to the lighted key. In Experiments 4 and 5, these possibilities were tested. In Experiment 4, a single pigeon, deprived of both food and water was first trained to eat and drink from the reinforcement devices. The bird was then autoshaped in a two-key procedure, where the left key was illuminated before the presentation of water and the right key was illuminated before grain presentation. Nine sessions of 30 food and 30 water trials, randomly intermixed, were presented. Every fifth water and every fifth food trial during the final three sessions was taped and evaluated. The results showed that on food trials, the predominate rating was an eating response and that on water trials, the judges predominately rated the keypeck as a drinking response. In Experiment 5, a procedure similar to Experiment 4 was used, but the force of the response was also measured. The results supported those previously found. Responses on food-reinforced trials were found to consistently be of higher force than responses on water-reinforced trials. Most of the food-reinforcer pecks were from 50 to 200 g force while most of the water reinforced pecks occurred with less than 50 g force. Jenkins and Moore's results support a Pavlovian account in which the CS comes to elicit the response elicited by the US. However, their results do not explicitly deny the role of R-S contingencies in autoshaping.

Swartz (1977, Experiment I) studied the duration of keypecks in autoshaping and automaintenance. Twenty-four naive pigeons were magazine trained and hand shaped to peck the illuminated response key. Each pigeon was then exposed to a CRF procedure in which a keypeck terminated the keylight and operated the grain hopper for four seconds. The keylight remained illuminated except during reinforcement throughout these sessions. Twenty-four sessions of 50 reinforcements were given to each bird. The birds were then divided into two groups of twelve. One group was exposed to an autoshaping procedure in which six-second keylight stimuli were followed by four-second grain presentations. Responses had no scheduled consequences. The second group was exposed to an automaintenance procedure in which a keypeck during the trial prevented reinforcement at the end of the trial. After 14 sessions of 50 trials on these procedures, the groups were reversed for an additional 14 sessions. The results showed that early in CRF training, the median duration of the responses was less than 20 milliseconds for 22 of the 24 pigeons. For 14 of the pigeons, the median duration of the keypecks was greater than 30 milliseconds by the end of CRF training. The median duration increased by at least 10 milliseconds by the end of CRF training for 20 of the pigeons. On the autoshaping procedure, the median duration was greater than 30 milliseconds for 18 of the pigeons. On the automaintenance procedure, the median duration was less than 20 milliseconds for 19 of the pigeons. These results were independent of the order of training. When returned to the CRF procedure, the median duration was greater than 30 milliseconds for 16 pigeons and was at least 10 milliseconds longer than pecks on the automaintenance procedure for 20 pigeons. The results indicate that on the automaintenance procedure, keypecks are reliably shorter in duration than on procedures which have positive R-S contingencies.

In their original study, Brown and Jenkins (1968) observed pigeons' behaviors during autoshaping. They reported that across trials, an increase in activity occurred during the keylight. This activity gradually became concentrated around the response key, and finally, pecking movements at the key occurred. In the autoshaping and automaintenance procedures, behaviors occurring during the keylight would be adventitiously reinforced by the subsequent grain or water presentation. This reinforcement of prepecking behaviors could facilitate the emergence of the keypeck. Thus, while the emergence of the keypeck may appear to be controlled by S-S contingencies, R-S contingencies in the form of prepecking behavior-grain associations may be responsible. Wessells (1974) studied the effects of reinforcement on the prepecking behaviors of pigeons in autoshaping. In his first experiment, Wessells systematically observed the emergence of keypecking to determine if prepecking behaviors increased in frequency prior to the emergence of the keypeck. An increased frequency of prepecking behaviors would support the theory of adventitious reinforcement of prepecking behaviors. Three naive pigeons were first given one session of magazine training. Each bird was then exposed to one session of autoshaping in which six-second keylights were followed by four-second grain presentations regardless of the bird's behavior. The autoshaping session was videotaped and three categories of key-directed behaviors were scored: 1) orientation to the key, 2) approach toward the key, and 3) pecks at the key. The results showed that orientation and approach responses steadily increased in frequency before the initial keypeck for all three birds. From this result it would appear that adventitious reinforcement of prepecking behaviors does occur and that such reinforcement may have an effect on subsequent keypecking. In Experiment II, Wessells manipulated the reinforcement contingency for approach behavior to assess its effect on the autoshaped keypeck. Two pigeons were initially magazine trained and placed in an autoshaping procedure similar to the one employed in Experiment I. After each bird completed three consecutive sessions with a response on 90% of the trials, a negative contingency for approaching the key was introduced. In this procedure, approach to the keylight, defined as the slightest detectable movement toward the key, terminated the keylight and prevented reinforcement. Unlike the results of studies with a negative contingency for keypecks, Wessells found that the negative contingency for approach toward the keylight was effective in eliminating the approach behavior. Orientation toward the key remained high throughout the experiment, indicating that the subjects were attending to the keylight. These results appear to indicate that the reinforcement of prepecking behaviors is necessary for the development of autoshaped keypecking.

A replication of Wessell's results was attempted by Peden, Browne, and Hearst (1977). In their first experiment, eleven naive pigeons were first given 40 magazine training trials and then placed in either an autoshaping or an omission-for-approach procedure. In the autoshaping procedure, eight-second keylights were followed by five-second grain presentations regardless of the pigeon's behavior. In the omission-for-approach procedure, approaches toward the keylight, as measured by microswitches under the floor of the experimental chamber, terminated the keylight and prevented reinforcement. One group received 40 sessions of 50 trials of omission-for-approach training followed by 25 sessions of 50 autoshaping trials. The second group received 25 sessions of autoshaping followed by 40 sessions of omission-for-approach training. The results showed that, unlike Wessell's birds, both groups lost 49% of the possible reinforcers in the omission-for-approach procedure. Prior training on the autoshaping procedure did not affect omission-for-approach performance, but experience with omission-for-approach seemed to interfere with subsequent performance on the autoshaping procedure.

In Experiment II, the effect of a near or far stimulus was assessed factorially with a keylight or hopperlight stimulus within omission-for-approach training. Their results showed a significant effect of the distance of the stimulus from the reinforcement. The omission-for-approach procedure was more effective in reducing approach behavior with stimuli that were distant from the grain hopper than with stimuli near the grain hopper. No significant effect was found for the type of stimulus nor was there an interaction between the type of stimulus and distance of the stimulus from the grain hopper. In Experiment III, Wessells' procedure was replicated to determine if the differences in results were due to the use of an automated device to determine approach instead of the experimenter-judged approach used by Wessells. Ten pigeons and two experimenters were used. All the pigeons were initially magazine trained. Two pigeons were autoshaped to Wessells' criterion of three consecutive sessions in which a peck occurred on 90% of the trials. An additional two birds received only ten autoshaping sessions. These four birds plus two which only received magazine training were then given 15 sessions of experimenter-judged omission-for-approach training followed by ten sessions of exposure to the automatic omission-for-approach procedure. The remaining four subjects received eight autoshaping sessions followed by 15 sessions of experimenter-judged omission-for-approach training. The results showed that in Wessells' procedure, the mean percentage of trials with an approach was 78% with the lowest percentage for one bird being 39%. Peden, et. al. suggest that the differences between their results and those of Wessells' may have been due to Wessells having inadvertantly established a competing stimulus-reinforcer or response-reinforcer correlation rather than simple omission-for-approach. A fourth experiment was conducted to determine if the decreased responding in the omission-for-approach procedure was due to the decreased number of keylight-reinforcer pairings or to the negative response-reinforcer contingency. Twelve naive pigeons were given three sessions of magazine training. Four pigeons received automated omission-for-approach training. In this omission-for-approach procedure, an approach toward the keylight did not terminate the keylight prematurely, but it did prevent reinforcement. For each of the birds in this procedure there were two yoked partners. The yoked birds received the same stimuli and reinforcers as the master subject, but responses by the yoked birds had no scheduled consequences. Seven of the eight yoked birds showed higher approach rates than the master birds. This result indicates that the negative response-reinforcer contingency does affect the approach behavior of pigeons. Due to the overall strength of the approach responses in all their experiments, Peden et. al. concluded that the stimulus-reinforcer relation was more important than the response-reinforcer relation in maintaining the approach response in their test situations.

While the research reviewed thus far has indicated the necessity of the S-S relation in autoshaping, Hitzing and Safar (1970, Experiment I) demonstrated that keypecking could be engendered without any stimulus-reinforcer pairings. In their procedure, twelve naive pigeons were first given two sessions of 40 keylight-only presentations. Their results showed that none of the birds pecked the keylight during the first two sessions. When exposed to the keylights following magazine training, nine of the twelve birds pecked the keylight within the first 16 trials and one bird pecked the key on the 83rd trial. The other two subjects made no keypeck response during the final two sessions. While these results indicate that a stimulus-reinforcer relation is not necessary for the acquisition of keypecking, Hearst and Jenkins (1974) pointed out three differences between the present experiment and most autoshaping procedures. First, the experimental chamber was nonstandard, having flat black walls instead of the glossy grey walls of commercial chambers. Second, the present experiment did not use a houselight to illuminate the chamber, unlike most autoshaping experiments. The third difference was in the presentation of the initial keylight-only trials in the present experiment. The need for the keylight-only trials was not experimentally assessed in the present procedure, nor is it a procedure generally used in autoshaping experiments.

Steinhauer, Davol, and Lee (1976) studied the role of magazine training on subsequent autoshaping. In their first experiment, they replicated Hitzing and Safar's (1970, Experiment I) procedure with a standard apparatus, a continuously illuminated houselight, and without the initial keylight-only sessions. Their results showed that all four birds pecked the keylight within six trials. These results support those of Hitzing and Safar and suggest that keylight-grain pairings are not necessary to engender keypecking. In their second experiment, the amount of magazine training was manipulated to assess its effect on subsequent autoshaping. Sixteen naive pigeons were divided into four groups of four birds each. Each group then received either zero, three, ten, or twenty-five magazine trials. A magazine training trial was defined as holding the hopper up with the hopperlight illuminated until the pigeon had eaten from the hopper for four seconds. Following magazine training, each pigeon was exposed to an autoshaping procedure in which eight-second keylight presentations were immediately followed by four-second presentations of grain. Training for each pigeon continued until the bird pecked the key or for 100 trials, whichever came first.

Their results showed that none of the subjects given zero magazine training trials autoshaped. Eleven of the remaining subjects autoshaped. The only exception was terminated from the study when it failed to magazine train. The results showed that, in general, the greater the number of magazine training trials, the fewer autoshaping trials to the first peck. The mean trials of the first peck for the zero, three, ten, and twenty-five magazine training trials conditions were 100.00, 16.75, 24.00, and 2.33 respectively. In Experiment III, three naive pigeons were trained in a manner similar to the zero magazine training trials condition in Experiment II. The birds were observed until they began responding and the trials on which each bird ate from the grain hopper were recorded. The results showed that all three birds regularly ate from the hopper before pecking the keylight. The results of these experiments support a generalization account of autoshaping. In most autoshaping experiments with pigeons, the hopperlight serves as a discriminative stimulus for the availability of food. A generalization account of autoshaping would suggest that due to the similarity of the keylight and hopperlight, the responding which occurs to the hopperlight could generalize to the keylight. The results of Experiment I support this hypothesis. A generalization account would also suggest that the strength of the generalization would be a function of the strength of the stimulus control of the hopperlight. The results of Experiment II supported this contention in that autoshaping was facilitated as a function of the exposure to the hopperlight as a discriminative stimulus in magazine training. The results of Experiment III further support a generalization account in showing that pigeons must be eating from the illuminated hopper before keypecking occurs.

Davol, Steinhauer, and Lee (1977) provided additional evidence for the role of generalization in autoshaping. Experiment I was a replication of Brown and Jenkins' (1968, Experiment IV) autoshaping experiment, except the houselight remained on during reinforcer presentations. The results indicated that the use of a continuously illuminated chamber did not adversely effect autoshaping. In Experiment II, the role of the hopperlight in autoshaping was assessed. Fifteen naive pigeons were randomly assigned to three conditions. Subjects in Conditions 1 and 2 were placed in an autoshaping procedure where eight-second presentations of the keylight were followed by four-second presentations of grain, if no keypeck occurred. Keypecks terminated the keylight and operated the grain hopper. For the subjects in Condition 1, the hopperlight was never illuminated during the two sessions of autoshaping. Pigeons in Condition 2 received only one session of 100 autoshaping trials, but the hopperlight was illuminated during every reinforcer presentation. The subjects in Condition 3 received one session of 100 keylight-only trials presented on the same schedule as the keylights in Conditions 1 and 2. While no reinforcement occurred during this session, keypecks did terminate the keylight. All birds were observed to be eating from the grain hopper during magazine training and during the autoshaping procedure. The results showed that in Condition 1, one subject responded on two trials and the remaining four birds failed to keypeck in 200 trials. In Condition 2, all five birds autoshaped. The mean trial of the first peck was 37.2, with a range of 18 to 81. In Condition 3, one pigeon pecked on two trials and the remaining four birds failed to keypeck in 100 trials. These results support a generalization account of autoshaping for all subjects, while autoshaping in Condition 1, where no hopperlight was used, was virtually nonexistant. The results for Condition 3, in which the hopperlight was not used, also suggest that the results of Steinhauer, Davol, and Lee (1976, Experiment I) were due to generalization from the hopperlight to the keylight. In Experiment III, Davol, et. al. varied the correlation between the onset of the hopperlight and grain presentation. A generalization account of autoshaping would predict that autoshaping would be facilitated as a function of the stimulus control of the hopperlight. Thus, autoshaping should occur at a slower rate if the hopperlight is not a perfect predictor of grain presentation than if the hopperlight is always presented with grain. Fifteen naive birds were randomly assigned to three experimental conditions. Each pigeon then received 24 magazine training trials. For pigeons in the 100% condition, all magazine training trials were illuminated with the hopperlight. In the 92% condition, two magazine training trials were presented without hopper illumination. Subjects in the 75% condition received six trials without hopper illumination. Following magazine training, each bird was exposed to 200 autoshaping trials in which eight-second presentations of the keylight were followed by four-second presentations of grain in the illuminated hopper. The results showed that all five birds in the 100% condition keypecked within 11 trials. Acquisition of keypecking in the other conditions was considerably slower. In the 92% condition, the mean trial of the first peck was 128.4 with one bird failing to respond in the 200 trials. Three birds failed to autoshape in the 75% condition. The mean trial of the first peck for this condition was 127.8. These results indicate that the acquisition of the autoshaped keypeck is a function of the correlation between hopperlight illumination and grain presentation. In Experiment IV, the effect of the similarity of hue between the hopperlight and the keylight on autoshaping was examined. Ten naive pigeons were initially given 25 magazine training trials. For five of the subjects, the hopper illuminated with a red light during grain presentations throughout the experiment. For the remaining subjects, a white hopperlight was used. Following magazine training, a two-key autoshaping procedure was implemented. In this procedure, two response keys were illuminated simultaneously for eight seconds and their offset was immediately followed by four-second presentations of grain. One of the keylights was illuminated red and the other white. Their results showed that all ten birds initially responded to the keylight which matched the hue of the hopperlight. For the subjects trained with the white hopperlight, responses to each key were distributed relatively equally after the initial response. Pigeons trained with a red hopperlight maintained a preference for the red keylight. The results support a generalization account of autoshaping in that the hue of the hopperlight affected the initial response of the subjects. The results also suggest that once keypecking is initiated, pigeons tend to prefer a red stimulus.

The results of studies of generalization from the hopperlight to the keylight provide alternative explanations for the results of the other studies reviewed in this paper. None of the studies which removed the defined R-S contingency provided adequate controls for the effects of generalization. In the studies of automaintenance, in Myerson's et. al. procedure, and Peden's et. al. procedure, the results may have been due to generalization from the hopperlight to the keylight instead of the keylight-reinforcer contingency. Support for this contention can be found from the results of Myerson, et. al. They reported that for all six birds, most keypecks occurred shortly after the onset of the keylight. A generalization account would suggest this as the pigeon is initially trained to respond to the onset of the hopperlight, whereas a Pavlovian interpretation would suggest that the responses would occur toward the end of the keylight as the offset of the keylight is paired with reinforcement.

The results of Swartz's (1977, Experiment I) study showing shorter duration pecks during an automaintenance procedure than during autoshaping or CRF procedures can be explained using a generalization account of autoshaping. Short duration pecks could be generalized pecks from the hopperlight to the keylight while long duration pecks are responses under the control of the specific R-S contingency. Jenkins and Moore (1973) controlled for the effects of generalization in their final two experiments. However, they did not control for the effects of adventitious reinforcement on the form of the response.

While generalization appears to be a major factor in autoshaping, Oberdieck, Cheney, and Strong (1978) provided evidence that autoshaping could be obtained without the use of a hopperlight. In Experiment I, three naive pigeons were initially given ten magazine training trials. The hopperlight was never illuminated during magazine training or at any point in the experiment. Following magazine training, an autoshaping procedure was implemented. In this procedure eight-second presentations of the keylight were followed by three-second presentations of grain, regardless of the pigeon's behaviors. On Days 1 and 2, 100 pairings were given. No training was conducted on Day 3 due to the birds being sated. On Days 4 through 16, 40 keylight-grain pairings were given. The results showed that all three birds autoshaped. The mean trial of the first peck was 83.0 with a range of 45 to 152. These results indicate that illumination of the hopperlight during grain presentations is not a necessary condition for autoshaping to occur. Experiment 2 was conducted to control for the satiation effects present in Experiment 1. Three naive and three experienced pigeons were given 20 magazine training trials.

As in Experiment 1, the hopperlight was never illuminated during the experiment. On Day 2, and on each subsequent day, 40 keylight-grain pairings were given. All six birds autoshaped in this procedure; the mean trial of the first peck was 5.67 for the experienced birds and 65.67 for the naive birds. While the results of both experiments indicate that autoshaping can be obtained without a hopperlight, they are in sharp contrast to the results of Davol, et. al. (1977, Experiment II) where birds given similar training failed to autoshape in 200 trials. Oberdieck, et. al. suggest the differences may have been due to species differences in the subjects used. The present experiment used wild homing pigeons while Davol, et. al. used Columba pigeons. The authors provided no support for this position. Another possible explanation for the differences in results can be found in the apparatus used. Davol, et. al. used a standard chamber in which the houselight was mounted on the same wall as the hopper opening. Light from the houselight could not have shown in the hopper opening to illuminate the grain due to the placement of the houselight relative to the hopper. In the present experiment, the houselight was mounted in the center of the ceiling. Light from the houselight may have been reflected off the hopper when it was raised, facilitating some generalization from the hopper to the keylight. Thus, the results of the present experiment do not conclusively show that autoshaping can be obtained without generalization from the hopper to the keylight.

Woodruff and Williams (1976) demonstrated autoshaping without prior magazine training or the use of a reinforcement hopper. Each pigeon used in the study had a small cannula implanted in its beak through which water could be injected directly into the bird's mandible.

The four pigeons in the autoshaping procedure were then given four sessions of 50 pairings of a six-second keylight followed by a six-second injection of 0.4 to 0.5 cc of water into the pigeon's mandible. Following autoshaping, each bird was given sessions of 50 extinction (keylight-only) trials until a criterion of two consecutive sessions without a response was met. Two of the subjects then received four additional autoshaping sessions. Four pigeons received training in an autoshaping procedure with stimulus overlap. This procedure was identical to the procedure above except the keylight terminated with the offset instead of the onset of reinforcement. Two birds received ten sessions of this procedure while the other two subjects received five sessions of this procedure followed by five sessions of the first autoshaping procedure. Three pigeons were exposed to an omission training procedure. This procedure was identical to the first autoshaping procedure except that pecks during the keylight prevented reinforcement at the offset of the keylight. The final four subjects were exposed to an associative control procedure. In this procedure 50 key illuminations were presented on the same schedule as the first group (once every 66 seconds on the average). Reinforcement occurred randomly throughout the session as determined by a probability gate. Thus, approximately the same number of keylight stimuli and reinforcements were presented in each session as in the autoshaping groups, but no correlation existed between the occurrance of the keylight and reinforcement. The results for the autoshaping groups showed that all four birds autoshaped. The mean of the trial of the first peck was 39 with a range of 15 to 75. By the fourth session keypecks occurred on more than 80% of the trials for all four birds. Criterion for extinction was reached within eight sessions for three of the subjects with the fourth bird requiring 25 sessions to cease responding. Responding was rapidly reacquired for both birds re-exposed to the autoshaping procedure, but only one of the birds regained its original level of responding. The results for the stimulus-overlap condition were similar to the autoshaping condition. The mean of the trial of the first peck was 43 with a range of 8 to 75. The level of responding during the keylight was similar to the first group. All three birds in the omission-training group autoshaped. The mean trial of the first peck was 71 with a range of 69 to 73. Responding gradually increased and then decreased to very low levels for all three birds. In the associative-control group, none of the birds pecked the illuminated key. These results show that autoshaping is not dependent on generalization from the hopper to the keylight. Woodruff and Williams suggest the results are due to associative factors in conjunction with a "learned-release" mechanism. This view of autoshaping states that biologically pre-organized behaviors are released by stimuli that signal the delivery of a reinforcer. Thus, they contend that the autoshaped keypeck is a reflexive type response controlled by the S-S contingency between the keylight and reinforcer. While this hypothesis does not appear to explain the poor response rate in the omission training group, Woodruff and Williams noted that during this procedure appetitive behaviors did occur, but the behaviors were directed away from the response key.

Woodruff and Williams' theory does not explain Davol's et. al. (1977) failure to obtain autoshaping when no hopperlight was used. An explanation for the difference in results is that in studies using a reinforcement hopper, response competition retards acquisition of keypecking, while no response competition exists in studies not using a hopper. In traditional autoshaping studies, the subject is trained to approach and eat from the reinforcement hopper before the autoshaping procedure is implemented. The responses of approaching and pecking at the hopper compete with the keypeck response, thus retarding the rate of acquisition of the keypeck response. In studies using a hopperlight, generalization from the hopperlight to the keylight offsets this response competition and rapid conditioning occurs. In Woodruff and Williams' study, no pretraining of competing responses which could interfere with subsequent autoshaping occurred. Thus, the acquisition of the keypeck response occurred at a similar rate in Woodruff and Williams' study and in traditional autoshaping studies while it was grossly retarded in Davol's et. al. study.

Support for the role of response competition can be found in traditional studies of autoshaping after extended magazine training. Enberg, Hansen, Welker, and Thomas (1972) obtained evidence that extensive magazine training retards the subsequent acquisition of the autoshaped keypeck. In their study, one group of pigeons was magazine trained and subsequently trained to press a treadle to obtain three-second grain presentations. Subjects in this group earned 1020 reinforcers over 34 days of training on this procedure. The hopper group was given the same number of food presentations over the same period of time as the treadle group, but food presentation was independent of the subjects' behavior. Each subject in the control group was handled daily, but received training in the experimental chamber only on the final day of the pretraining phase. During that session, each subject received 30 hopper presentations. Following pretraining, all subjects were exposed to an autoshaping procedure in which eight-second presentations of the keylight were followed by three-second presentations of grain. Autoshaping was continued until a criterion of a response on at least eight of ten consecutive trials was reached. The treadle was absent from the chamber during autoshaping sessions. The results showed that the median trial to criterion for the treadle, control, and hopper groups was 60, 79, and 121, respectively. While the hopper group autoshaped slower than the control group, Enberg, et. al. discounted a response competition explanation for their results as the treadle group had been trained with an incompatible response for keypecking, yet this group showed superior autoshaping relative to the control group.

Swartz, Reisberg, and Vollmecke (1974) pointed out that in Enberg's, et. al. (1972) study, two procedural details made it difficult to discount a response competition explanation for their results. First, the criterion of a response on at least eight of ten consecutive trials made it difficult to determine if the effects observed were on the acquisition or maintenance of autoshaping. Second, as the treadle was absent in the autoshaping procedure, pigeons in the treadle group were unable to make the incompatible response of treadle pressing during autoshaping. The first part of Swartz's, et. al. experiment was designed to clarify these ambiguities. Four groups of three pigeons each were used. All groups were magazine trained until the latency of approach to the feeder was minimal in ten consecutive hopper operations. Subjects in the treadle and treadle out groups were then trained to treadle press for reinforcement. Pigeons in these groups earned in excess of 600 reinforcers over 23 days of training. The free food group was given 630 response-independent presentations of grain over 21 sessions while subjects in the naive group only received the initial magazine training in the pretraining phase. Following pretraining, all birds were exposed to an autoshaping procedure in which six-second keylight presentations were followed by four-second presentations of grain. This procedure was continued for 14 sessions of 30 trials each. The treadle was present during this procedure for all except the treadle out group. Using Enberg's et. al. criterion, the results showed the mean trials to criterion for the treadle, treadle out, naive, and free food groups were 43, 42, 65, and 72, respectively. This pattern of results is similar to that found by Enberg, et. al. in that the treadle groups reached criterion sooner that the controls (naive group) while the birds given extended magazine training (free food group) were somewhat slower in reaching criterion. However, the results were not similar when the first trial with a peck was used as the dependent measure. The mean trial of the first peck for the treadle, treadle out, naive, and free food groups was 29, 26, 13, and 22, respectively. The results support a response competition explanation in that all groups given extended pretraining autoshaped slower than the controls. While the competing response is explicit for the treadle groups, the specific competing response for the free food birds is difficult to assertain without direct observation of the subjects. However, from previous research (see Skinner, 1948) it would be expected that during free food delivery some behavior is adventitiously reinforced and this behavior would compete with the acquisition of keypecking. Swartz, et. al. also presented data from the final five sessions of autoshaping which support a response competition explanation. The treadle out group responded on every trial during the final five sessions of autoshaping. The naive birds responded on 91% of the trials while the treadle and free food groups responded on 85% of the trials. When the average number of responses on those trials in which at least one response occurred was computed, the results were similar in pattern to the proportion of trials data. The mean number of responses on trials in which at least one response occurred for the treadle out, treadle, naive, and free food groups were 12.0, 5.3, 8.5, and 4.5, respectively. On both measures, the groups which could have exhibited competing responses learned in pretraining (free food and treadle) responded at a lower rate than those given only one session of magazine training prior to autoshaping. These results support the view that learning which occurs during magazine training can interfere with subsequent acquisition of the autoshaped keypeck.

While the apparent discrepancy in the results of Woodruff and Williams (1976) and Davol, Steinhauer, and Lee's (1977) studies can be resolved by a response competition hypothesis, the results of both studies suggest a greater role of the R-S contingency in autoshaping than previous research indicated. One of the major arguments supporting the role of the S-S contingency in autoshaping has been the demonstrated maintenance of responding in the presence of a negative response-reinforcer contingency. The failure of Woodruff and Williams' automaintenance group to maintain responding supports the hypothesis that in studies of automaintenance where responding was maintained, the results were primarily due to generalization from the hopperlight to the keylight instead of the keylight-reinforcer contingency. Woodruff and Williams' results further suggest that the keypeck response is primarily responsive to R-S contingencies. While responding was not maintained in the automaintenance group, high levels of responding were found if the reinforcement of keypecking could occur. The results of the research reviewed suggest an operant interpretation of autoshaping is feasible.

In an analysis of autoshaping, it can be argued that a differential rate of reinforcement exists between behaviors involving orientation to the keylight and other behaviors which occur during the procedure. On trials on which reinforcement occurs in temporal conjunction with the keylight, behaviors during the keylight will be followed by reinforcements after a short delay. Behaviors which do not involve orientation to the keylight can occur during the trial or the intertrial interval (ITI). While these behaviors can occur in close temporal conjunction with reinforcement, the probability is that such behaviors will have occurred a relatively long time prior to reinforcement due to the greater length of the ITI relative to the trial stimulus. As the behaviors of orienting to the keylight would occur in closer temporal conjunction with reinforcement, these behaviors should increase in probability relative to other behaviors, and therefore should become the dominant response in the autoshaping procedure. This analysis suggests that autoshaping would be facilitated as a function of the ratio of ITI duration to trial stimulus duration. As the ratio of ITI to trial duration increases, the delay to reinforcement after behaviors not involving the keylight would become proportionately longer relative to behaviors involving the keylight. Due to the proportionately smaller delay to reinforcement, we could then predict that the behaviors involving the keylight would be strengthened to a greater degree relative to other behaviors. This contention is supported by Baldoch (1974, in Swartz and Gamzu, 1977) who found that the acquisition of the autoshaped keypeck was facilitated when the ratio of trial to ITI duration was smaller.

While this analysis explains how behaviors involving orientation to the keylight become conditioned, it does not yet explain why the keypeck emerges as the predominate behavior. From this analysis and from Wessells' (1974) work, orientation to the keylight is the first behavior conditioned. Wessells reported that the behavior of approaching the key then emerges, followed by the development of keypecking. An operant analysis would suggest that as the behavior of orienting to the keylight is reinforced, it would be strengthened. However, it does not predict the systematic emergence of new behaviors. Brown and Jenkins (1968) suggested that the keypeck emerged from a species-specific tendency for pigeons to peck things at which they look. This explanation is plausible when one examines the types of behaviors the pigeon is most likely to exhibit in the autoshaping experiment. Due to the motivation of a deprived subject and the reinforcement history of the subject in the experimental situation, a high level of appetitive behaviors would be expected from the organism. In autoshaping experiments using a magazine hopper, the orientation-approach-peck chain of behaviors is conditioned to the reinforcement hopper and response generalization could contribute to the emergence of the keypeck. In studies which do not utilize a reinforcement hopper, the emergence of the keypeck could come from the tendency for pigeons to peck things at which they look. In its natural environment, the pigeon's behavior of orientation alone or the orientation-approach chain is never reinforced by primary reinforcement in an appetitive situation. Only the orientation-approach-peck sequence is reinforced, strengthing the probability of occurrance of the whole chain instead of only one or two components. It can then be argued that if the orienting response is reinforced, it increases the probability of the occurrance of the orientation-approach-peck chain. This would explain the emergence of the keypeck in autoshaping. Similarly, in Woodruff and Williams' (1976) auto-maintenance group, pecks which were off the response key were reinforced while keypecks were not. Thus, the behavioral chain was altered in its last component by the response-reinforcer contingency.

While the preceding analysis of autoshaping is incomplete in empirical support, the research to date does not rule out such an analysis. While research such as Peden, Browne, and Hearst's (1977) appears to discount the necessity of adventitious reinforcement of prepecking behaviors, their findings may have been the result of generalization from the hopperlight to the keylight. The results of most of the studies which sought to isolate the effects of the S-S contingency in autoshaping have been confounded by the role of generalization. Thus, studies need to be conducted to control the effects of generalization and to further the understanding of the role of generalization in autoshaping.

The present research is concerned with the dimensions of the stimulus and reinforcer that facilitate generalization in autoshaping experiments. The similarity of hue between the hopperlight and keylight was shown to facilitate autoshaping in Davol, Steinhauer, and Lee's final experiment. Other studies have also found the similarity of hue between the stimulus and reinforcer facilitates autoshaping (Fisher and Catania, 1977; Sperling, Perkins, and Duncan, 1977).

Rescorla and Furrow (1977, Experiment III) found similar results for the dimension of form in a second-order autoshaping procedure. In their procedure, 16 experienced pigeons were initially exposed to a discriminative autoshaping procedure. In the first session, 16 five-second presentations each of blue, horizontal-line, green, and vertical-line keylight stimuli were presented in random order. The blue and horizontal-line stimuli were followed by five-second grain presentations. The other two stimuli were never followed by reinforcement. On subsequent discrimination sessions there were 16 presentations each of the blue and horizontal-line stimuli and 12 presentations each of the green and vertical-line stimuli. During these sessions only four of the blue and four of the horizontal-line stimuli were followed by reinforcement. After a criterion of 85% of the responses occurring to the blue and horizontal-line stimuli was met, the birds were divided into two groups. The two groups were balanced for stimulus preference and response rate. Each group then received two sessions of second-order conditioning. For Group Similar, each session consisted of 12 trials of the vertical-line followed by the horizontal-line and 12 trials on which the green stimulus immediately followed the blue stimulus. Four trials each of the blue and the horizontal-line followed by grain were also presented. For Group Dissimilar, the procedure was identical except the blue stimulus followed the vertical-line stimulus and the horizontal-line stimulus followed the green stimulus. The results showed that both groups acquired responding to the second-order stimulus. The results for the final half of the second session showed a response rate of 96 responses per minute to the second-order stimuli in Group Similar as compared to a response rate of 29 responses per minute for Group Dissimilar. During these trials Group Similar responded on 98% of the presentations of the second-order stimuli and Group Dissimilar responded on 60% of the trials. The results indicate that the similarity of form facilitates keypecking within an autoshaping paradigm.

Studies of the effect of the temporal similarity of the keylight and hopperlight have not shown temporal similarity to be a factor in autoshaping. Balsam, Brownstein, and Shull (1978) varied the duration of grain presentations to assess the effect of reinforcer duration on autoshaping. Two experienced and four naive birds were used in the first experiment. They were initially given two sessions of hopper training. In the first of these sessions, each subject was allowed to eat from the raised, illuminated hopper for 30 seconds. Subsequently, five hopper presentations each of two, four, and eight seconds were presented in the same randomly generated order for each subject. The second session consisted of an additional fifteen hopper presentations as in session one. On the third day, an automaintenance procedure was implemented. Each of these sessions consisted of 40 trials of an eight-second keylight presentation followed by reinforcement if no keypeck occurred. Keypecks prevented reinforcement at the end of the stimulus. Each condition consisted of 10 consecutive sessions in which only one of the three grain durations was presented. Each subject was exposed to each condition once followed by re-exposure to the initial condition. The four naive pigeons were equally divided between the two- and eight-second conditions in the initial sessions. The results showed no significant difference across conditions for the dependent measures of trial to the first peck, response rate, probability of a response as a function of the number of consecutive keylight-grain pairings, or probability of no response as a function of the number of consecutive trials without a keylight-grain pairing (trials with a peck). On trials in which a peck occurred, the eight-second condition showed a slightly shorter latency to the first peck than the two- or four-second conditions. Except for the latency data, the results suggest that the temporal similarity of the stimulus and reinforcer does not facilitate autoshaping. One of the previously naive pigeons used in Experiment I and the two remaining experienced pigeons were used in Experiment II. The procedure for Experiment II was identical to the first experiment, except an autoshaping procedure was used instead of an automaintenance procedure. In Experiment II, keypecks had no scheduled consequences and reinforcement occurred on every trial. On measures of proportion of trials responded on, response rate on trials with a response, and latency of the first peck on trials with a response, no systematic differences were found as a function of conditions. The results from Experiment II replicated those of Experiment I in showing no significant effect of the temporal similarity of the stimulus and reinforcer on autoshaping.

In studying several variables affecting autoshaping, Perkins, Beavers, Hancock, Hemmendinger, Hemmendinger, and Ricci (1974) ran two experiments in which the effects of the temporal similarity of the stimulus and reinforcer were assessed. In Experiment II, the effect of stimulus duration on autoshaping was assessed. Four experimentally naive birds served as subjects. Each subject was given two initial sessions of hopper training. On the third day, an autoshaping procedure was implemented. Each bird was exposed to four different stimuli, yellow, green, blue, and red, which were of 4-, 8-, 16-, and 32-second duration, respectively, for the first 54 sessions. During Sessions 55 to 67, the yellow, green, blue, and red stimuli were of 32-, 16-, 8-, and 4-second duration, respectively. Except for Sessions 8 and 9, all sessions consisted of 24 cycles in which each stimulus was presented once. Thirty cycles were presented in Sessions 8 and 9. For the first six sessions, the proportion of presentations of each stimulus that was followed by four-second access to grain was 1/12. For the remaining 61 sessions the proportion was 1/6. The results showed a lower rate of responding to the 32-second stimulus with no significant difference in the response rate to the remaining three stimuli. Experiment IV only used two durations of stimuli, 4 and 32 seconds. The results were consistent with those in Experiment II in showing a lower rate of responding to the 32-second stimulus when a four-second reinforcer was used. The results of both experiments suggest an effect of stimulus duration, but the results taken together do not suggest an effect due to the temporal similarity of the stimulus and reinforcer.

While the results of the previous experiments do not support the hypothesis that the temporal similarity of the stimulus and reinforcer facilitate autoshaping, Testa (1975) demonstrated that the temporal similarity of the US and CS facilitated conditioning in a standard classical conditioning procedure. In Experiment I, 31 rats were initially trained to bar press for food on a variable interval one-minute (VI 1) schedule of reinforcement. All sessions lasted for two hours. After six sessions of bar pressing only, CS-US presentations were superimposed during bar pressing. The CS was a light which was located under the grid floor for groups BP and BC. The CS was located at the ceiling for groups TC and TP. For group BC and TC, the CS was a constant intensity while it was pulsed (0.5 second on, 0.5 second off) for groups BP and TP. Each CS presentation lasted one minute. The US consisted of a 0.3 milliampere shock delivered through the grid. The US occurred during the final five seconds of the CS and was pulsed (0.5 second on, 0.5

second off). Two pairings of the CS and US were given each session for three sessions. On Day 10, an extinction procedure was implemented. Four CS-only presentations were superimposed during bar pressing. On Days 11 and 12, six reconditioning trials in which the CS and US were paired occurred during each session. A stimulus generalization test was given on Day 13; a novel CS was presented alone four times during the session. The novel stimulus for each group was the stimulus which had a different location and temporal intensity pattern than the CS used in conditioning. A suppression ratio, $x/(x+y)$, where x is the number of bar presses during the CS and y is the number of bar presses during the minute preceding the CS, was computed for each CS presentation. The results showed a significant effect of the temporal intensity pattern in the initial conditioning phase and the generalization test. While the results supported the hypothesis that the temporal similarity of CS and US facilitated conditioning, Testa pointed out that the results could be due to the pulsed CS being more salient than the constant CS. In Experiment II, two types of CS's, wave-floor and pulsed-ceiling, were paired with two types of US's, wave-floor and pulsed-ceiling, to control for the effect of the salience of each CS. The wave-floor CS was a light with a rectified wave intensity pattern located at the floor. The wave-floor US was an air blast with a rectified waveform which originated at the floor. The pulsed-ceiling CS was a pulsed light located at the ceiling. Similarly, the pulsed-ceiling US was a pulsed air blast originating from the ceiling. Thirty-two rats were randomly assigned to four groups of eight subjects each. Each group received training with a different CS-US pair. As in Experiment I, the rats were initially trained to bar press. This training lasted for three two-hour sessions. During the third session, two CS-only trials were also presented. On Day 4, a third CS-only trial was presented and followed by four trials with the CS and US paired. Each CS occurred for 58 seconds and the US occurred during the final eight seconds of the CS. No training or exposure to the chamber occurred for the following 15 days. On the following two days, eight reconditioning trials were presented. On the final day, four extinction (CS-only) trials were presented. The results for the conditioning, reconditioning, and extinction phases showed that for each US, greater suppression of bar pressing occurred to the similar CS than to the dissimilar CS. These results show a facilitative effect of the similarity of the CS and US and, together with the results of Experiment I, support the hypothesis that temporal similarity of the CS and US facilitates conditioning.

The results of Testa's (1975) research suggest that temporal similarity of the stimulus and reinforcer facilitates conditioning, yet the autoshaping research to date has not supported this hypothesis. A possible resolution of this discrepancy may result from a redefinition of temporal similarity. Temporal similarity has been defined in terms of the duration of the individual stimulus and reinforcer presentations. However, research in concurrent schedules (see de Villiers, 1977) has shown pigeons are sensitive to the total reinforcement time within a session. Thus, the definition of temporal similarity may need to be modified to include the frequency as well as the duration of the stimulus and reinforcer. It would then be expected that autoshaping would be facilitated as a function of the similarity of the product of the frequency times the duration of the stimulus relative to the reinforcer. The research to date does not provide definitive evidence about the validity of this hypothesis. In Perkins', et. al. (1978) research, none of the stimuli occurred for the same total presentation time within a session as the reinforcer. In Balsam's, et. al. (1978) experiments, groups with an eight-second reinforcer duration had the total presentation time of the stimulus and reinforcer equated. However, in Experiment I, the dependent measure, keypecks, prevented reinforcement. Thus, once a subject began responding, the equality between the stimulus and reinforcer presentation time was eliminated. In Experiment II, every stimulus presentation was followed by reinforcement. Perkins, et. al. (1975) suggested that when every stimulus is followed by reinforcement, responding approaches maximum rate. Thus, any effects of generalization in Balsam's, et. al. study may have been masked. No experiments have studied the effect of the temporal similarity of the stimulus and reinforcer defined as the total presentation time within a session. The following experiments were designed to assess the effect of the temporal similarity of the stimulus and reinforcer presentation time on autoshaping.

EXPERIMENT 1

As Balsam's, et. al. (1978) results may have been a product of a ceiling on response rate, a choice procedure utilizing a partial reinforcement schedule was devised to assess the role of the temporal similarity of the stimulus and reinforcer in autoshaping. A two-key autoshaping procedure similar to that of Davol, Steinhauer, and Lee's (1977, Experiment IV) procedure was used with four stimuli. The stimuli were presented two at a time on separate keys with each stimulus occurring at a different frequency. This allowed the presentation of four stimuli with different total presentation times for each subject. By manipulating the frequency of reinforcement and/or the duration of the individual stimulus presentations, the total presentation time of the reinforcer could be matched to one of the four stimuli to which the subject was exposed. This procedure was used to test the hypothesis that a preference, indexed by an enhanced rate of responding, would be shown for the stimulus that matched the reinforcer in total presentation time.

METHOD

Subjects

Sixteen experimentally naive homing pigeons were maintained at 80-85% of their free-feeding weight throughout the experiment. Twelve of the subjects were adult males and the remaining four were adult females.

Apparatus

The inside dimensions of the experimental chamber measured 30.5 cm long, 34.5 cm wide, and 33.0 cm high. The inner and outer walls of the chamber were metal and 0.3 cm thick with 1.3 cm of insulating material between the walls. Inside the chamber was a response panel which housed the food hopper, response keys, and houselight. Two 2.5 cm diameter response keys were centered 15 cm apart on the response panel 22.5 cm above the grid floor. A 5.7 cm by 5.1 cm hopper opening was centered on the panel 8.0 cm from the floor. The 28 vdc houselight was centered 29.0 cm from the floor. The response keys required a force of 10 g to operate and were illuminated from behind by standard IEE display cells. The chamber was situated next to the solid-state programming equipment in the experimental room. Extraneous noise was masked by a ventilating fan in the chamber and cooling fans on the programming equipment.

Procedure

Hopper Training. Each bird was given one 30 minute adaptation session in the training chamber with the houselight illuminated. Each pigeon was then given one session of hopper training, during which each bird was first trained to approach and eat from the hopper within one second of the hopper presentation. This was immediately followed by 30 three-second presentations of the hopper on a VT 30-second schedule. Throughout the experiment, reinforcement consisted of a three-second presentation of mixed grain, during which the hopper light was illuminated. The houselight was illuminated throughout the session.

Autoshaping. Following hopper training, the birds were randomly assigned to one of four groups of four birds each, with the restriction that one female was assigned to each of the four experimental groups. On each trial the keys were illuminated six seconds for groups 40/6 and 80/6 and the keys were illuminated three seconds for groups 20/3 and 40/3. At the termination of the keylight, reinforcement occurred with a probability of 0.20 for group 20/3, 0.40 for groups 40/3 and 40/6, and 0.80 for group 80/6. Each trial was followed by an ITI on a VT 30-second schedule.

For all birds, six combinations of four stimuli served as stimulus pairs. For each session of fifty trials, the pairs of stimuli were presented with the following frequencies: A+B, 22; A+C, 12; A+D, 6; B+C, 6; B+D, 2; and C+D, 2. Thus, stimulus A was presented on forty or 80% of the trials, stimulus B was presented on thirty or 60% of the trials, stimulus C was presented on twenty or 40% of the trials, and stimulus D was presented on ten or 20% of the trials. Four orientations of white lines (0°, 45°, 90°, and 135°) on black backgrounds served as the stimuli. Each line orientation was assigned a different frequency for each bird in each group, and the four sets of line orientation/ frequency of presentation pairings were the same in each of the four groups.

Within each pair of stimuli, the number of presentations was balanced on each of the keys for each component within a session. The order of occurrence of the pairs of stimuli was random within each session. A total of ten random session sequences were used in the experiment.

The probability of reinforcement was the same for each stimulus within each session as it was for each pair of stimuli within each block of five sessions.

Table 1 shows the total presentation time for each stimulus and the reinforcer for each group within a session. It can be seen that for groups 20/3 and 40/6, stimulus D had the same duration as the reinforcer, while stimulus C occurred for the same time as the reinforcer in groups 80/6 and 40/3. It was therefore predicted that for groups

20/3 and 40/6, stimulus D would be preferred as its rate by duration was equal to the reinforcement, and for groups 40/3 and 80/6, stimulus C would be preferred by the same reasoning.

Responses were recorded for each trial on each key and 16 sessions were run in Experiment 1.

RESULTS

Two birds failed to autoshape in the experiment and were deleted from the analysis. One bird was in group 80/6 and the other bird was in group 40/6. Two types of data were analyzed, the response rate and the proportion of trials on which at least one response occurred.

Within each group, one session's trial data for one subject were lost due to either equipment failure or experimenter error. The response rate data for three of these subjects were also lost. This amounted to 1.79% of the trials data and 1.34% of the response rate data. To maintain equal cell frequencies for the purpose of statistical analysis, the mean of the corresponding cell was substituted for each data point.

Table 2 shows the mean response rate and the mean proportion of trials with at least one response for each stimulus, within each group, for blocks of four trials and across all sixteen sessions. As can be seen from both the trial and response rate data, no consistent or strong preferences were shown in any group, except in group 40/3 where the predicted stimulus was responded to on a slightly greater proportion of trials than any other stimulus in blocks 2-4.

A 4x4x16 unweighted-means analysis of variance was conducted on both sets of data, the results of which are presented in Table 3. The only significant result in the analysis was the effect of trials (trial data, F=14.87, df=15/150, $p<.0001$; response rate data, F=19.25, df=15/150, p<.0001). The effects of groups, stimuli, and all the interactions were not significant in either analysis.

DISCUSSION

The significant trials effect was expected as both the response rate and trials responded on measures should increase across sessions as the birds acquired the autoshaped keypeck response.

The hypothesis that a preference would be shown for the stimulus which occurred for the same total presentation time as the reinforcer was not supported. Unlike the studies which studied the generalization of hue from the reinforcer to the stimulus, the discrimination of total presentation time of the four stimuli requires several presentations of each stimulus over time. Considering how uniform the data are across stimuli, the birds may have autoshaped to a keylight without attending to the stimulus dimension which had a unique value for each stimulus, total presentation time. Without this attending, and subsequent discrimination of the stimuli in terms of presentation time, no preference would be found as the stimuli were uniform in form, intensity, hue, and the probability of reinforcement. Thus Experiment 2 was conducted to explore this possibility.

EXPERIMENT 2

Thomas, Freeman, Svinicki, Burr, and Byons (1970) demonstrated that discrimination training between two values of one stimulus dimension affected responding to several values of a second stimulus dimension. In their procedures, pigeons in the true discrimination (TD) groups received discrimination training between two stimuli which differed in either hue or line angularity. Subjects in the pseudo-discrimination (PD) groups were presented the same stimuli, but reinforcement occurred nondifferentially between the two stimuli. Either during discrimination training or immediately following it, each subject was also exposed to one value of a second stimulus dimension. Following this initial training, each subject was exposed to five values of the second stimulus dimension in a generalization test. The results showed that TD subjects showed a sharper generalization gradient than PD subjects. This means that TD subjects had a greater proportion of responses to stimuli which were most similar to the stimulus they were originally exposed to than did the PD subjects. The final experiment of Thomas, et. al. showed this effect was due to a sharpened generalization gradient for TD subjects rather than flattened generalization gradient for PD subjects. These results indicate that discrimination training along one stimulus dimension facilitates attending to other stimulus dimensions.

The results of Experiment 1 were hypothesized to have been due to a lack of attending to the stimulus dimension of presentation time. Experiment 2 was designed to provide discrimination training between hues to subsequently facilitate attending to stimulus presentation time in the Experiment 1 procedure. It was hypothesized that this increased attention would facilitate the effects of generalization between the stimulus and reinforcer presentation time in the autoshaping paradigm.

METHOD

Subjects

The fourteen pigeons that autoshaped in Experiment 1 were used as subjects. They were maintained at 80-85% of their free-feeding weight throughout the experiment.

Apparatus

The apparatus was the same as that described in Experiment 1.

Procedure

Discrimination Training. Following the final day of training in Experiment 1, each pigeon was given five sessions of discrimination training. Each session consisted of 24 presentations of the stimulus pair, S^+S^{0+}, followed by a three second presentation of the hopper, interspersed with 24 presentations of the stimulus pair, S^-S^{0-}, which was never followed by reinforcement. Between presentations of the stimulus pairs was an ITI on a VT 30 second schedule. Red, yellow, and green keylights served as stimuli. Each bird within a group received a different combination of the red, green, and yellow stimuli as S^+, S^-, and S^0 and these combinations were repeated across groups.

Each block of 16 trials within each session was balanced in the number of presentations of each stimulus pair. The order of presentation of the stimulus pairs within each block was random. The individual presentation time of a stimulus pair was 3 seconds for pigeons from groups 20/3 and 40/3 and 6 seconds for pigeons from groups 40/6 and 80/6. As in Experiment 1, responses were recorded for each trial on each key.

Autoshaping. Following discrimination training, the birds were given the identical treatment as they received in Experiment 1. All birds were assigned to their original groups and received the same stimuli at the same frequency, followed by the same probability of reinforcement as in Experiment 1.

RESULTS

For the discrimination training phase, Table 4 shows the mean response rate and mean number of trials with at least one response for each stimulus within each session for each group and for each stimulus, and each session within each group. S^o when paired with S^+ is presented separately from S^o when paired with S^- to show the pattern of responding for each type of trial. The data show that all groups showed a preference for S^+ in the first session and the preference increased across sessions. The data also show a similar pattern of responding across groups on S^+ trials, but different patterns across S^- trials. Group 20/3 showed a higher rate of responding on S^- trials than the other groups, but responded more to S^o, while group 40/6 maintained a high level of responding to S^- relative to S^o.

Four by four by five unweighted-means analysis of variance were conducted on the data (see Table 5). The results of both analysis showed a significant effect of stimuli (trials data, $F=56.96$, $df=3/30$, $p<.0001$; response rate data, $F=27.27$, $df=3/30$, $p<.0001$) and a significant stimuli by trials interaction (trials data, $F=12.83$, $df=12/120$, $p<.0001$). The analysis of the trials data also showed a significant three way interaction ($F=1.85$, $df=36/120$, $p<.01$) and the analysis of the response rate data showed a significant effect of trials ($F=3.45$, $df=4/40$, $p<.05$). All other effects were not significant.

Table 6 shows the mean response rate and the mean proportion of trials with at least one response for each block of four sessions for each stimulus within each group and the mean for each stimulus within each group on the autoshaping procedure. The data indicate no preference was shown for the stimulus which matched the reinforcer in presentation time, except in the response rate data for groups 80/6 and 40/3 where the response rate to stimulus C is slightly greater on both blocks in each group.

However, the 4x4x8 unweighted-means analysis (see Table 7) on this data showed no significant effects.

DISCUSSION

The results of the first phase of this experiment clearly show that when given the explicit discrimination task, the birds quickly learned the contingencies between the stimuli and the presentation of reinforcement. However, this training did not affect the birds performance on the autoshaping procedure. No preference was shown for the stimulus which had the same presentation time as the reinforcement.

These findings indicate that the discrimination training between hues did not facilitate the effects of stimulus generalization in autoshaping. Assuming the discrimination procedure was effective in increasing attending to the stimulus presentation time in the autoshaping procedure, the results indicate that the failure to obtain a preference for the stimulus which matched the reinforcer in presentation time in Experiment 1 was not due to a lack of attending to the relevant stimulus dimension.

EXPERIMENT 3

In the first two experiments, no effect of generalization from the hopper presentation time to the stimulus presentation time was found. A partial reinforcement schedule was used in both experiments to avoid ceiling effects on response rates. However, the data indicate that response rates were very high, and this could have possibly masked any preferences due to stimulus generalization. Therefore, an extinction procedure, presenting the stimuli from the autoshaping procedure without reinforcement, was used to see if extinction would be more gradual to the stimulus which previously had the same total presentation time as the reinforcement.

METHOD

Subjects

The 14 pigeons used in Experiment 2 served as subjects. They were maintained at 80-85% of their free-feeding weight throughout the experiment.

Apparatus

The apparatus used was the same as that described in Experiment 1.

Procedure

The pigeons were assigned to the same four groups as in the previous two experiments. Each bird received three sessions of 48 individual presentations of stimuli. No grain was presented in any of the sessions. The 48 trials in each session were broken down into six blocks of eight trials, in which each of the four stimuli used in the autoshaping procedure of Experiments 1 and 2 were presented once on each key. The order of presentation within each block of eight trials was random. The length of each stimulus presentation was the same within each group of birds as it was in the previous experiments (i.e. three seconds for groups 20/3 and 40/3, and six seconds for groups 40/6 and 80/6).

Data were collected on the number of responses to each stimulus and the number of trials with at least one response for each stimulus.

RESULTS

Data for stimulus A in the first session for one bird (#1968, group 40/3) were lost for both trials and responses due to experimenter error. This amounted to a loss of 0.60% of the trial and response rate data. The procedure for replacing the missing data was the same as in Experiment 1.

Table 8 presents the mean response rate and mean number of trials with at least one response for each stimulus within each session for each group and the mean for each stimulus and each trial in each group. The data show no strong preferences for any stimulus in any group. Extinction appears to be less rapid for the groups with three-second stimuli. This can be seen in groups 40/6 and 40/3 where reinforcer duration was equal in the previous studies. Group 40/3 averaged 20 responses per minute on the final session compared to 8 responses per minute for group 40/6. Rate of extinction also appears to be positively correlated with the probability of reinforcement in the previous studies. Group 80/6 averaged 10 responses per minute on the final session whereas group 20/3 was still averaging 58 responses per minute.

Table 9 presents the 4x4x3 unweighted-means analysis of variance on the data. The results of both analysis showed a significant effect of trials (trial data, $F=33.75$, $df=2/20$, $p<.0001$; response rate data, $F=14.73$, $df=2/20$, $p<.0005$). In the trials data the groups by stimuli interaction was significant ($F=3.41$, $df=9/30$, $p<.05$). No other effects were significant in either analysis.

DISCUSSION

The results indicate that even in extinction no preference exists for the stimulus which previously had the same presentation time as the reinforcer. The significant groups by stimulus interaction does not appear to be caused by a preference for the predicted stimulus in any group except 40/6. Here the mean number of trials with at least one response was five for the predicted stimulus compared to four for each of the remaining three stimuli. However, the number of trials with a response for the predicted stimulus was less than at least one other stimulus in each of the three remaining groups, indicating that the interaction was not due to preferences for predicted stimuli.

The trials effect is a result of decreased responding across sessions. While the data appear to indicate a difference in the rate of extinction across the groups, neither analysis had a significant groups by trials interaction.

Thus, the results of the extinction procedure also fail to support the hypothesis that a preference is shown for a stimulus which occurs for the same presentation time as the reinforcer.

GENERAL DISCUSSION

The results of the three experiments presented here concur with the results of Perkins, et. al. (1975) and Balsam, et. al. (1978). No support was obtained for the hypothesis that generalization from the reinforcer duration to the stimulus duration facilitates the autoshaped keypeck. The experiments indicated that, with or without previous experience with discrimination training, equal presentation time of the stimulus and reinforcer did not affect the response to the stimulus during the acquisition, maintenance, or extinction of the autoshaped keypeck response.

That the hypothesis was not supported in the present research is disturbing, especially in light of the research on the effect of generalization along other stimulus dimensions on autoshaping, and in light of Testa's (1975) finding that the temporal similarity of the stimulus and reinforcer facilitates conditioning within a classical conditioning paradigm.

The present experiments were designed to control for possible ceiling effects while using a choice procedure to demonstrate the effect of generalization due to temporal similarity. While different values of stimulus duration and stimulus and reinforcement frequencies were used, none of the combinations of these values yielded significant results.

The failure to support the hypothesis in the present research may have been due to the utilization of the two-key choice procedure. While experiments such as Davol, et. al. (1977, Experiment IV) used a two-key procedure in demonstrating the facilitation of autoshaping as a function of the similarity of hue between the stimulus and

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reinforcer, the use of a two-key procedure in the present research may have prevented demonstrating the effect of temporal similarity of the stimulus and reinforcer on autoshaping. In the Davol, et. al. procedure, it was not necessary for the subject to attend to the total duration of both stimuli for generalization to occur. By attending briefly to each key, the subject could discriminate which stimulus was similar to the hopperlight in hue. In the present autoshaping procedure, on the other hand, it was necessary for each subject to attend to both keys on every trial in order to discriminate which stimulus was similar to the reinforcer in total presentation time. Assuming that, in responding to one of the stimuli, the subject was not attending to the other stimulus, the bird would not be able to discriminate the total presentation time of any of the stimuli accurately, unless it always responded to one of the stimuli. As none of the subjects responded to one specific stimulus on every trial the stimulus was presented, it would not be expected that any of the subjects were able to discriminate the stimulus that was equal to the reinforcer in total presentation time. Thus, no preference could be shown for a stimulus due to its temporal similarity to the reinforcer.

Another possibility in the present study was that the subjects responded to stimulus pairs instead of the individual stimulus. However, none of the pairs of stimuli were presented for the same total duration as the reinforcer in any of the conditions. Had a preference been shown for any stimulus pair, a significant effect of stimuli should have been found as more responses would have occurred to the two stimuli in that stimulus pair.

A modification of the autoshaping procedure could eliminate the procedural problems discussed above. A single key procedure utilizing the same number of presentations of each of the stimuli and reinforcer would have the same predicted results as were expected in the first experiment. The individual presentations of each stimulus might be randomly alternated between two keys as the present autoshaping procedure could be implemented after several sessions of the single key procedure. The use of the two-key procedure here might be more sensitive to preferences than the one key procedure as a response toward one stimulus in a two-key procedure is simultaneously a response away from another stimulus. Thus, the discrimination of several stimulus durations along with the reinforcer duration could be established in the single key procedure and, if necessary, the hypothesis that a preference would be shown for the stimulus that matches the reinforcer in total presentation time could be tested further using the two-key choice procedure.

Another possible weakness of the present study may have been the number of stimuli used. In a single key procedure, the use of two stimuli could yield the same results as could be found with four stimuli. With only two stimuli to discriminate between, the facilatory effect of generalization due to the temporal similarity of the stimulus and reinforcer should occur at a more rapid pace due to the simplification of the procedure.

Assuming the hypothesis that the temporal similarity of the stimulus and reinforcer facilitates autoshaping is false, at least two questions are raised. The first of these revolves around why stimulus dimensions such as hue and form generalize from the reinforcer to stimuli in autoshaping while the temporal dimension does not. A possible explanation would be that as the visual system of the pigeon is more developed than its other sensory systems, the visual dimensions of stimuli used in the generalization paradigms in autoshaping would be highly salient relative to other dimensions of the stimuli.

The other question that the denial of the hypothesis raises comes from Testa's (1975) finding that the temporal similarity of the stimulus and reinforcer facilitated learning in a classical conditioning paradigm. If a similar result cannot be found in autoshaping, it would suggest that autoshaping does not fit the classical conditioning paradigm as well as some authors (e.g. Hearst and Jenkins, 1974; Swartz and Gamzu, 1977) suggest. The results would add to the questions about the underlying mechanisms raised in the introduction of this paper. These questions will only be answered by further research in the area of autoshaping.

In summary, the present research did not support the hypothesis that generalization due to the temporal similarity of the stimulus and reinforcer would facilitate autoshaping. However, the failure to support the hypothesis may have been due to the methodology used, and a procedure which would avoid the errors of the present procedure was briefly presented.

Table 1: Total duration in seconds per session for each stimulus and the reinforcer for each group in Experiment 1.

Group	Stimulus A	B	C	D	Reinforcer
80/6	240	180	120	60	120
40/6	240	180	120	60	60
40/3	120	90	60	30	60
20/3	120	90	60	30	30

Table 2: Mean response rate and proportion of trials each stimulus was responded to within each group for each block of four sessions in Experiment 1. (Predicted stimulus follows group name)

		Responses per minute				Proportion of trials			
		Stimulus				Stimulus			
Group	Trial Block	A	B	C	D	A	B	C	D
80/6C	1	28	23	29	25	.32	.27	.28	.35
	2	52	47	54	44	.45	.44	.46	.44
	3	58	68	67	69	.44	.50	.50	.48
	4	54	56	64	59	.46	.46	.55	.50
	$\bar{X}$	48	48	54	50	.42	.42	.45	.44
40/6D	1	16	20	16	18	.23	.27	.20	.24
	2	36	36	38	37	.41	.40	.42	.41
	3	33	47	36	40	.40	.50	.40	.45
	4	45	45	55	48	.46	.43	.52	.47
	$\bar{X}$	33	37	36	36	.37	.40	.38	.39
40/3C	1	16	16	15	18	.29	.26	.28	.34
	2	39	41	43	41	.45	.48	.50	.48
	3	39	43	47	40	.45	.45	.48	.44
	4	42	44	50	52	.44	.44	.48	.47
	$\bar{X}$	34	36	39	38	.41	.43	.43	.43
20/3D	1	7	9	9	8	.12	.14	.13	.10
	2	26	30	27	30	.30	.31	.31	.33
	3	43	47	50	45	.44	.44	.49	.42
	4	50	51	50	54	.46	.50	.47	.51
	$\bar{X}$	32	34	34	34	.33	.35	.35	.34

TABLE 3

Unweighted-means analysis of variance on the response rate and trials in Experiment 1.

	Trials Data				Response Rate Data			
Source	SS	df	MS	F	SS	df	MS	F
Groups (G)	1.06	3	.35	.93	36295.80	3	12098.60	.45
Subjects within groups	3.79	10	.38		269055.83	10	26905.58	
Stimuli (S)	.07	3	.02	1.71	1911.50	3	637.17	2.13
Trials (T)	9.77	15	.65	14.87*	175437.75	15	11695.85	19.25*
GxS	.05	9	.01	.42	842.57	9	93.62	.31
GxT	1.85	45	.04	.94	30540.44	45	678.68	1.12
SxT	.55	45	.01	1.41	6977.50	45	155.06	1.29
GxSxT	1.31	135	.01	1.13	17309.80	135	128.22	1.07
Error 1	.38	30	.01		8958.19	30	298.61	
Error 2	6.57	150	.04		91120.43	150	607.47	
Error 3	3.86	450	.01		53848.09	450	119.66	

*p<.0001

Table 4: Mean response rate and number of trials each stimulus was responded to within each group for each session of the discrimination training in Experiment 2.

		Responses per minute					Number of trials				
				Stimulus					Stimulus		
Group	Trial Block	S^+	S^{O+}	S^-	S^{O-}	$\bar{X}$	S^+	S^{O+}	S^-	S^{O-}	$\bar{X}$
80/6	1	11	4	4	7	6	4	2	2	3	3
	2	28	5	8	16	14	9	1	3	6	5
	3	29	0	2	8	10	9	0	3	3	4
	4	64	0	6	5	19	16	0	4	3	6
	5	48	0	0	1	12	15	0	1	2	4
	$\bar{X}$	36	2	4	8	12	11	1	2	3	4
40/6	1	45	1	18	7	18	12	1	8	4	6
	2	57	0	16	2	19	13	0	7	1	6
	3	74	1	7	3	21	18	1	5	3	7
	4	76	0	4	1	20	20	0	1	2	6
	5	72	0	17	1	23	17	0	6	1	6
	$\bar{X}$	65	0	13	3	20	16	1	6	2	6
40/3	1	19	2	10	13	11	8	2	5	6	5
	2	59	0	15	31	26	19	1	7	13	10
	3	61	1	19	4	21	19	0	8	2	7
	4	74	0	6	1	20	21	0	3	1	6
	5	76	0	1	1	19	20	0	0	0	5
	$\bar{X}$	58	1	10	10	20	17	0	4	4	7
20/3	1	42	8	33	20	26	13	3	9	6	8
	2	71	13	32	44	40	17	3	10	11	10
	3	66	11	23	37	34	16	3	7	10	9
	4	81	13	11	38	36	20	3	5	11	10
	5	86	11	19	25	35	21	3	8	6	9
	$\bar{X}$	69	11	23	33	34	17	3	8	9	9

TABLE 5

Unweighted-means analysis of variance on the discrimination training of Experiment 2.

	Trials Data				Response Rate Data			
Source	SS	df	MS	F	SS	df	MS	F
Groups (G)	824.58	3	274.86	3.19	17181.88	3	5727.29	2.37
Subjects within groups	860.91	10	86.09		24512.94	10	2415.29	
Stimuli (S)	7670.84	3	2556.95	56.96***	117951.35	3	39317.12	27.27***
Trials (T)	136.08	4	34.02	1.88	3103.15	4	775.79	3.45*
GxS	432.86	9	48.10	1:07	7923.15	9	880.35	.61
GxT	203.48	12	16.96	.94	1480.82	12	123.40	.55
SxT	1056.32	12	88.03	12.83***	17415.90	12	1451.32	11.96***
GxSxT	456.15	36	12.67	1.85**	4536.78	36	126.02	1.04
Error 1	1346.73	30	44.89		43246.00	30	1441.53	
Error 2	724.68	40	18.12		9000.27	40	225.01	
Error 3	823.19	120	6.86		14560.86	120	121.34	

*p<.05 **p<.01 ***p<.0001

Table 6: Mean response rate and proportion of trials each stimulus was responded to within each group for each block of four sessions in the autoshaping procedure of Experiment 2. (Predicted stimulus follows group name)

		Responses per minute				Proportion of trials			
		Stimulus				Stimulus			
Group	Trial Block	A	B	C	D	A	B	C	D
80/6C	1	49	56	66	40	.34	.45	.46	.33
	2	48	52	65	60	.40	.46	.45	.43
	X̄	48	54	66	50	.37	.46	.45	.38
40/6D	1	41	49	42	50	.44	.50	.43	.48
	2	39	41	41	39	.40	.42	.41	.38
	X̄	40	45	41	44	.42	.46	.42	.43
40/3C	1	44	48	52	44	.47	.48	.48	.45
	2	48	47	52	48	.48	.45	.48	.48
	X̄	46	47	52	46	.47	.46	.48	.46
20/3D	1	53	50	49	50	.49	.45	.45	.46
	2	50	53	48	53	.45	.48	.44	.49
	X̄	52	51	49	52	.47	.47	.44	.48

TABLE 7

Unweighted-means analysis of variance on the autoshaping procedure of Experiment 2.

	Trials Data				Response Rate Data			
Source	SS	df	MS	F.	SS	df	MS	F
Groups (G)	.22	3	.07	.22	8170.73	3	2723.58	.11
Subjects within groups	3.31	10	.33		247681.12	10	24768.11	
Stimuli (S)	.05	3	.02	.55	1766.85	3	588.95	1.25
Trials (T)	.12	7	.02	1.69	509.07	7	72.72	.32
GxS	.18	9	.02	.62	4738.62	9	526.51	1.12
GxT	.35	21	.02	1.67	5081.95	21	242.00	1.08
SxT	.24	21	.01	1.37	5552.90	21	264.42	1.65
GxSxT	.66	63	.01	1.26	11848.00	63	118.06	1.17
Error 1	.98	30	.03		14106.81	30	470.23	
Error 2	.69	70	.01		15694.16	70	224.20	
Error 3	1.74	210	.01		33618.39	210	160.09	

Table 8: Mean response rate and number of trials each stimulus was responded to within each group for each session of Experiment 3. (Predicted stimulus follows group name)

		Responses per minute					Number of trials				
		Stimulus					Stimulus				
Group	Trial Block	A	B	C	D	$\bar{X}$	A	B	C	D	$\bar{X}$
80/6C	1	57	72	77	51	64	7	9	7	6	7
	2	11	17	15	11	14	3	3	3	2	3
	3	16	7	8	8	10	2	2	2	1	2
	$\bar{X}$	28	32	33	23	29	4	4	4	3	4
40/6D	I	54	53	54	63	56	8	7	7	9	8
	2	25	43	29	32	33	3	5	4	5	4
	3	4	5	12	10	8	0	1	2	2	1
	$\bar{X}$	28	34	32	35	32	4	4	4	5	4
40/3C	1	68	91	95	80	83	9	10	10	10	10
	2	60	56	64	60	60	7	6	6	7	7
	3	17	24	20	18	20	2	3	3	4	3
	$\bar{X}$	48	57	60	53	54	6	7	6	7	6
20/3D	1	78	89	82	80	82	10	11	11	10	10
	2	75	73	73	80	75	9	9	10	9	9
	3	55	57	66	55	58	7	8	9	8	8
	$\bar{X}$	70	73	74	71	72	8	9	10	9	9

TABLE 9

Unweighted-means analysis of variance for the extinction procedure of Experiment 3.

	Trials Data				Response Rate Data			
Source	SS	df	MS	F	SS	df	MS	F
Groups (G)	701.95	3	233.98	3.88	50117.73	3	16705.91	1.38
Subjects within groups	603.01	10	60.30		120671.10	10	12067.11	
Stimulus (S)	8.19	3	2.73	2.35	1064.04	3	354.68	2.28
Trials (T)	783.88	2	391.94	33.75***	62064.39	2	31032.19	14.73**
GxS	30.71	9	3.41	2.94*	793.80	9	88.20	0.57
GxT	92.71	6	15.45	1.33	11558.61	6	1926.43	0.91
SxT	11.07	6	1.84	1.16	771.77	6	128.63	1.15
GxSxT	27.96	18	1.55	0.98	2611.46	18	145.08	1.30
Error 1	34.88	30	1.16		4673.34	30	155.78	
Error 2	232.24	20	11.61		42127.51	20	2106.38	
Error 3	95.54	60	1.59		6699.81	60	111.66	

*p<.05 **p<.0005 ***p<.0001

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