

THE EFFECTS OF A CHANGE IN REWARD PROBABILITY ON
PREFERENCE FOLLOWING AUTOSHAPING WITH TWO-SIGNAL
SEQUENCES: AN EXTENSION OF THE EGGER AND MILLER
INFORMATION HYPOTHESIS

by

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INTRODUCTION

Egger and Miller (1962) hypothesized that if a reinforcing stimulus is made contingent on a sequence of two signals the more informative signal in the sequence will become the more effective conditioned reinforcer. They first trained two groups of rats to press a bar for a food pellet. After several training sessions the bar was removed from the chamber and Pavlovian conditioning was given. For one group a "free" pellet was contingent on a sequence of two signals, S1 and S2, presented 2 sec and 1.5 sec prior to each pellet delivery. S1 presentation overlapped S2 presentation and both terminated shortly after pellet delivery. For this group S1 was an informative signal and S2 was a redundant signal. The other group received the same S1-S2-food sequences and also received S1 alone randomly interspersed with the regular sequences. When S1 was presented alone food never followed which made S1 an unreliable predictor of food delivery. Tests of the conditioned reinforcing effect of S1 and S2 followed the Pavlovian conditioning. At the start of the test session the bar was reinserted into the chamber and the rats were allowed to press for food; then the barpress was partially extinguished by withholding food for 10 min while the rats continued to press; and finally conditions were changed so that either S1 or S2 was contingent on a barpress. In the first test session half the subjects in each group were presented S1 following every third barpress while the others received S2. In the second test session the contingencies were reversed. The group for which S1 had been a reliable predictor during conditioning showed more recovery of barpressing if S1 were contingent

on the barpress than if S2 were. For this group S1 apparently was a more effective conditioned reinforcer. The group for which S1 was an unreliable predictor during conditioning showed greater recovery of barpressing when S2 was contingent on the barpress than when S1 was.

Egger and Miller argued that when S1 and S2 were both reliable predictors of food S1 became a more effective conditioned reinforcer because S2 provided only redundant information about the probability of food delivery. When S1 was an unreliable predictor S2 signalled an increase in probability of food delivery and became a more effective conditioned reinforcer than S1.

The information hypothesis of conditioned reinforcement proposed by Egger and Miller is interpreted in this paper as implying that the reinforcing effect of a signal depends on whether or not the signal indicates an increase in reward probability. Signals in a sequence which indicate an increase in reward probability should be effective conditioned reinforcers and strengthen the response on which they are contingent. Signals which indicate no change in reward probability, i.e., are redundant, should not be effective conditioned reinforcers. Egger and Miller pointed out however that under some conditions their information hypothesis would not hold up. A signal immediately preceding reward which is made redundant by another signal occurring hours before should be a more effective conditioned reinforcer because of its greater temporal proximity to reward.

But what happens to a signal in a sequence which indicates a decrease in reward probability? Interpretations of conditioned reinforcement which stress that information is intrinsically reinforcing (Berlyne, 1957; Hendry, 1969; Schaub, 1969) imply that a signal which

reduces uncertainty about the outcome (reward or no-reward) will acquire a reinforcing effect regardless of whether the signal indicates an increase or decrease in reward probability. However, Dinsmoor, Browne, and Lawrence (1972) and Jenkins and Boakes (1973) reported that an informative signal which indicated a decrease in reward probability did not have a reinforcing effect.

Jenkins and Boakes (1973) tested the reinforcing value of a signal which indicated a decrease in reward probability by giving pigeons conditioning trials in a chamber which had two protruding discs. At the beginning of each trial the discs were illuminated together. On some trials there was brief change in illumination on either one or both of the discs just before illumination ceased. Half the trials were followed by grain presentation so that illumination of the discs indicated a reward probability of 0.5. A change on one of the discs served to reduce uncertainty about the trial outcome because when this change occurred grain never followed. The change on the other disc did not reduce uncertainty because grain presentation was equally likely when this change occurred and when it did not occur, i.e., reward probability remained 0.5. Jenkins and Boakes found that pigeons oriented more often toward the disc on which the change failed to reduce uncertainty, and that the pigeons made more auto-shaped keypecks to this same disc. The results were interpreted to be incompatible with an uncertainty reduction hypothesis of conditioned reinforcement since the birds did not prefer to orient toward the disc which reduced uncertainty.

In the experiment to be reported here a strategy similar to that of Jenkins and Boakes was adopted to examine the reinforcing effect

of a signal which indicates a decrease in reward probability. Jenkins and Boakes measured conditioned reinforcement value by noting which of the two discs the pigeons more often observed during conditioning. In the present study conditioned reinforcement value was measured after pigeons had received extensive conditioning. Therefore the present experiment can be thought of as having two separate phases: a conditioning phase examining auto-shaped keypecking to signals which indicate different probabilities of grain and a test phase in which conditioned reinforcement is measured by making signals contingent on a keypeck.

Conditioning Phase

During conditioning food-deprived pigeons were presented each of the four different two-signal sequences shown in Fig. 1 in a discrete trial procedure. Below each sequence is the probability that grain will follow that sequence and above each sequence is a schematic representation of the reward probability indicated by each component signal. An Information Positive (IP) sequence was initiated by S_1 followed by S^+ , and the Information Negative (IN) sequence was also initiated by S_1 but followed by S^- . The probability of grain following S^+ and S^- was .875 and .125, respectively. An equal number of IP and IN sequences were presented so that the probability of grain presentation given S_1 was 0.5. This made S^- a less reliable predictor of grain than S_1 , i.e., the probability of grain on a trial was greater during S_1 than during S^- . The Redundant Positive (RP) sequence was initiated by S_{rp} followed by S'_{rp} and the Redundant Negative (RN) sequence was initiated by S_{rn} followed by S'_{rn} . The second signals in the RP and RN sequences were redundant because the probability of grain remained the same as it had been during the preceding signal.

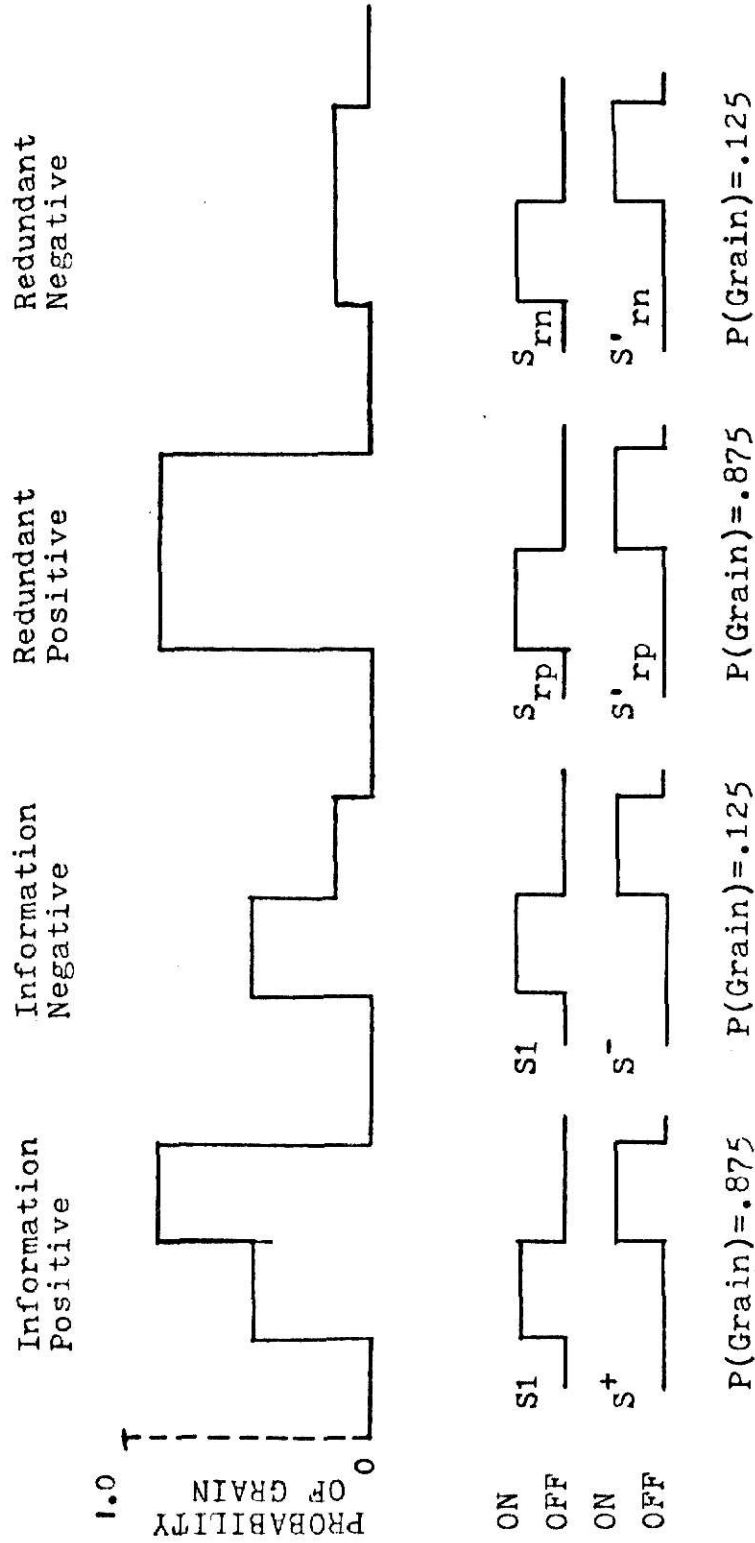


Figure 1. Schematic representation of the four sequences presented during the conditioning phase and the reward probability associated with component signals.

Investigations of auto-shaped keypecking suggest several factors which may influence pecking rates in autoshaping procedures. Gonzales (1973) and Perkins *et al.* (1974, Exp. 3 and 4) found that auto-shaped keypecking rates are higher to signals which indicate greater probability of grain presentation. Rates to S^+ and S'_{rp} could therefore be expected to be higher than rates to S^- and S'_{rn} . Ricci (1973; see also Hemmendinger, 1974) found that temporal proximity to grain presentation was an important variable affecting auto-shaped pecking rates. Rates were higher with increasing temporal proximity to grain presentation in a four-signal sequence which always terminated with food. Ricci's results suggest that S'_{rp} and S'_{rn} should maintain higher rates than S_{rp} and S_{rn} , respectively, because S'_{rp} and S'_{rn} are temporally closer to grain presentation.

Another factor which may influence pecking rates in autoshaping procedures is information of a change in probability of grain. As shown in Fig. 1 probability of grain is the same in the presence of S^+ and S'_{rp} , and in the presence of S^- and S'_{rn} . But S^+ and S^- are informative signals because they both indicate a change in probability while S'_{rp} and S'_{rn} indicate no change. A contrast-like phenomenon would produce a higher rate to S^+ than to S'_{rp} because S^+ signals an increase in probability of grain. Conversely, a lower rate to S^- than to S'_{rn} might be observed because S^- signals a decrease in probability of grain.

Test Phase

The test phase was employed to measure the reinforcing effect of a change from S_1 to S^- in the experimental condition, and the effect of a change from S_{rn} to S'_{rn} in the control condition by using a two-key

pigeon chamber. On each test trial signals were presented and terminated on both keys simultaneously. Test trials were initiated with presentation of S1 on both keys for experimental birds and with presentation of S_{rn} on both keys for control birds. On a test trial experimental birds could peck one key which resulted in a change to S^- or peck the other key which maintained S1. Similarly, control birds could peck one key which resulted in a change to S'_{rn} or peck the other key and maintain S_{rn} . At no time during test trials was grain contingent on keypeck. It was expected that as a result of the conditioning phase a certain level of keypecking would be maintained by S1 and S_{rn} because it had been reported elsewhere that signals followed by grain 10% and 50% of the time would maintain moderate to high rates of auto-shaped keypecking (Perkins et al., 1974). It was further expected that the effects of a change from S1 to S^- , and a change from S_{rn} to S'_{rn} could be determined by which key birds pecked most often during the test phase.

On the basis of the present formulation of Egger and Miller's information hypothesis a change from S1 to S^- should have a punishing effect and weaken the tendency to peck the key which produces S^- because its onset indicates a decrease in the probability of grain. S'_{rn} should act neither as a punisher nor a positive reinforcer because S'_{rn} provides only redundant information about the probability of grain. Even though S^- and S'_{rn} signal the same absolute probability of grain they should affect the responses on which they are contingent in different ways since they provide different information. Birds in the experimental group should peck the key which changes S1 to S^- less often than birds in the control group peck the key which changes S_{rn} to S'_{rn} . In other words, the effect of making S^- and S'_{rn} contingent on a

response cannot be predicted from absolute probability, but instead, from probability relative to the antecedant conditions.

It is interesting to note that some authors (e.g., Alaway, 1971) have assumed that the reinforcement value of a signal can be inferred from the rate of auto-shaped keypecking to it. Such an assumption is contrary to the predicted results for two reasons. First, although the rate to S'_{rn} should be higher than the rate to S_{rn} during conditioning (Ricci, 1973), S'_{rn} should not have a reinforcing effect. Second, although a moderate amount of pecking to S^- is expected during conditioning (Perkins et al., 1974), S^- should be a punisher.

METHOD

Subjects: Data reported are from twenty-four experimentally naive pigeons obtained locally. Throughout the experiment the pigeons were housed in individual cages with continuous illumination and maintained at 75% of free-feeding weight. Fifteen birds appeared to be homers and nine white kings.

Apparatus: Two experimental chambers were used. The interior of each chamber was grey and measured 38.1 by 34.9 by 30.5 cm. Two translucent response keys mounted on the rear of the response panel were spaced 6.75 cm apart center to center, and 23.5 cm above the floor. Mounted behind each key was an Industrial Electronics Engineers stimulus projector from which different colors (red, green, blue, yellow, and white) or figures (circle and star) could be projected onto the key. The circle and star were white against a dark key surround. The diameter of the circle was .5 cm and the star measured .75 cm across from point to point. A 5.5 by 4.75 cm opening for the feeder was located 3.75 cm above the floor and 15.25 cm from either side of the chamber. Illumination was provided by a shielded houselight mounted flush with the ceiling. Scheduling of events was controlled by electromechanical equipment and an eight channel tape reader. Sodeco counters were used to record keypecks. The chambers were located in a room separate from the control equipment. White noise and a ventilation fan served to mask any extraneous noise in the experimental room.

Procedure: All birds first received two magazine training sessions. The bird was held in front of a raised feeder. When he began to eat

he was released and the chamber door was closed. After the bird had eaten for 10 sec the feeder was lowered and quickly raised. The duration of feeder operation was gradually decreased to 3 sec and the interval between grain presentations increased to 2 min.

Conditioning sessions began the third day and continued for 18 daily sessions. During each conditioning session the four sequences shown in Fig. 1 were each presented 16 times. Fourteen of the 16 IP and RP sequences were immediately followed by grain presentation ($p=.875$). Two of the 16 IN and RN sequences were followed by grain presentation ($p=.125$). All grain presentations were for 3 sec.

Pilot work showed that when a sequence is presented on two keys simultaneously some pigeons develop marked key preferences. Therefore some single-key presentations were included in an attempt to insure that the birds did not peck one key exclusively. When a sequence was presented on both keys the signals on the keys were always the same. For each of the four sequences there were 8 two-key presentations, 4 right-key presentations, and 4 left-key presentations per session.

Durations of the component signals varied in increments of three from 3 to 21 sec. The duration of the first signal was negatively correlated with the duration of the second so that the duration of any sequence was always 24 sec. This resulted in seven pairs of component signal durations (3-21, 6-18, ..., 21-3). For a particular type of sequence, i.e., pair of component stimuli, each pair of durations was presented twice per session except the 12-12 pair which was presented four times. Over the 18 conditioning sessions the same proportion of grain presentations followed each pair of durations within each type of sequence.

The sequences were presented in an unsystematic order with the constraints that the same sequence was not presented more than three times in succession and that there were no more than four successive rewarded or non-rewarded sequences. The inter-stimulus interval was always 42 sec. Inter-trial interval (ITI) durations were 39 sec following a rewarded sequence and 42 sec following non-rewarded sequences. The houselight remained on except during grain presentation when the only illumination was provided by the feeder light. The chamber was darkened at the end of the session and subjects were returned to their home cages within 30 min.

Subjects were assigned to one of three conditions which differed according to the colors used as the initial signals. The colors blue, yellow, and white were counterbalanced across the initial signals S_1 , S_{rp} , and S_{rn} . Four subjects in each condition had the star as S^+ and the circle as S'_{rp} ; the reverse was true for the other half. Of these four subjects two received red as S^- and green as S'_{rn} , and vice versa for the other two.

During conditioning the number of pecks in the presence of each signal was recorded. Right key pecks were recorded separately from left key pecks. The subjects were run in two squads of 12. For the first squad the star was S^+ and for the second the circle was S^+ .

Test sessions were initiated on the twenty-first day and subsequently were alternated daily with further conditioning sessions. There were eight test sessions and seven reconditioning sessions during this phase.

Subjects were assigned to one of two groups, either the Experimental (E) or the Control (C) group. For E subjects each test trial began with presentation of S_1 on both keys. There was a short

interval at the beginning of each test trial during which time all pecks were ineffective. The interval was 3 sec half the time and 6 sec the other half. The first peck to occur after this interval is referred to as a criterion response. When the criterion response was to one key, the change key, the color on both keys changed from S_1 to S^- . When the criterion response was to the other key, the no-change key, S_1 remained on both keys. There was only one criterion response per trial and keypecks which followed were ineffective. For C subjects each test trial began with presentation of S_{rn} . A criterion response to the change key resulted in S'_{rn} and to the no-change key maintained S_{rn} . For half the subjects in either group the change key was on the right. If no criterion response occurred on a test trial the keys turned dark after 24 sec of S_1 or S_{rn} presentation. In each test session there were 64 trials a random half of which were followed by grain regardless of the birds' behavior. ITI durations were 39 sec following a rewarded sequence and 42 sec following a non-rewarded sequence.

Group assignment was made on the basis of the relative frequency of pecks to each key over the last three conditioning sessions in such a way that the mean proportion of pecks to the right key was about the same for both groups. There was the constraint that half the subjects comprising a group be subjects which had red as S^- during conditioning. Once the groups were formed a flip of a coin decided which was Group E and Group C. The change key was on the right for the first squad and on the left for the second squad.

During test sessions pecks to the right and left keys were recorded separately in the interval preceding the criterion response.

A print-out counter indicated if a criterion response was made on each test trial and if so on which key it was.

RESULTS

Conditioning Phase

Preliminary tests were made on pecking rates to determine if there were differences between the squads and if colors and figures produced systematic effects. The data from the last three conditioning sessions were analyzed as an indication of steady-state performance. A test of the mean pecking rates of the two squads revealed no significant difference ($t=1.50$, $df=22$, $p>.05$). The test for differences in rates to the three colors counterbalanced among S_1 , S_{rp} , and S_{rn} was made with relative rates which are more sensitive to differences than are absolute rates. For each subject a relative rate to S_1 was derived by taking the ratio of the S_1 rate to the combined S_1 , S_{rp} , and S_{rn} rates. A one-way analysis of variance with colors as three levels indicated no significant differences ($F=1.47$, $df=2, 21$, $p>.05$). A relative rate to S^- was determined by taking the ratio of the S^- rate to the combined S^- and S'_{rn} rates. Mean relative rates to the two colors counterbalanced in S^- were tested and no significant difference was found ($t=.797$, $df=22$, $p>.05$). Similarly, the relative rate to S^+ was determined by taking the ratio of the S^+ and S'_{rp} rates and testing mean relative rates to the two figures counterbalanced in S^+ . No significant difference was found ($t=.508$, $df=22$, $p>.05$). Subsequent analyses of conditioning data were made collapsing across the squads and counterbalancing variables.

Mean pecks per sec to each signal are plotted in the left half of Fig. 2 as a function of sessions. It is apparent from inspection of Fig. 2 that conditioning produced substantial pecking

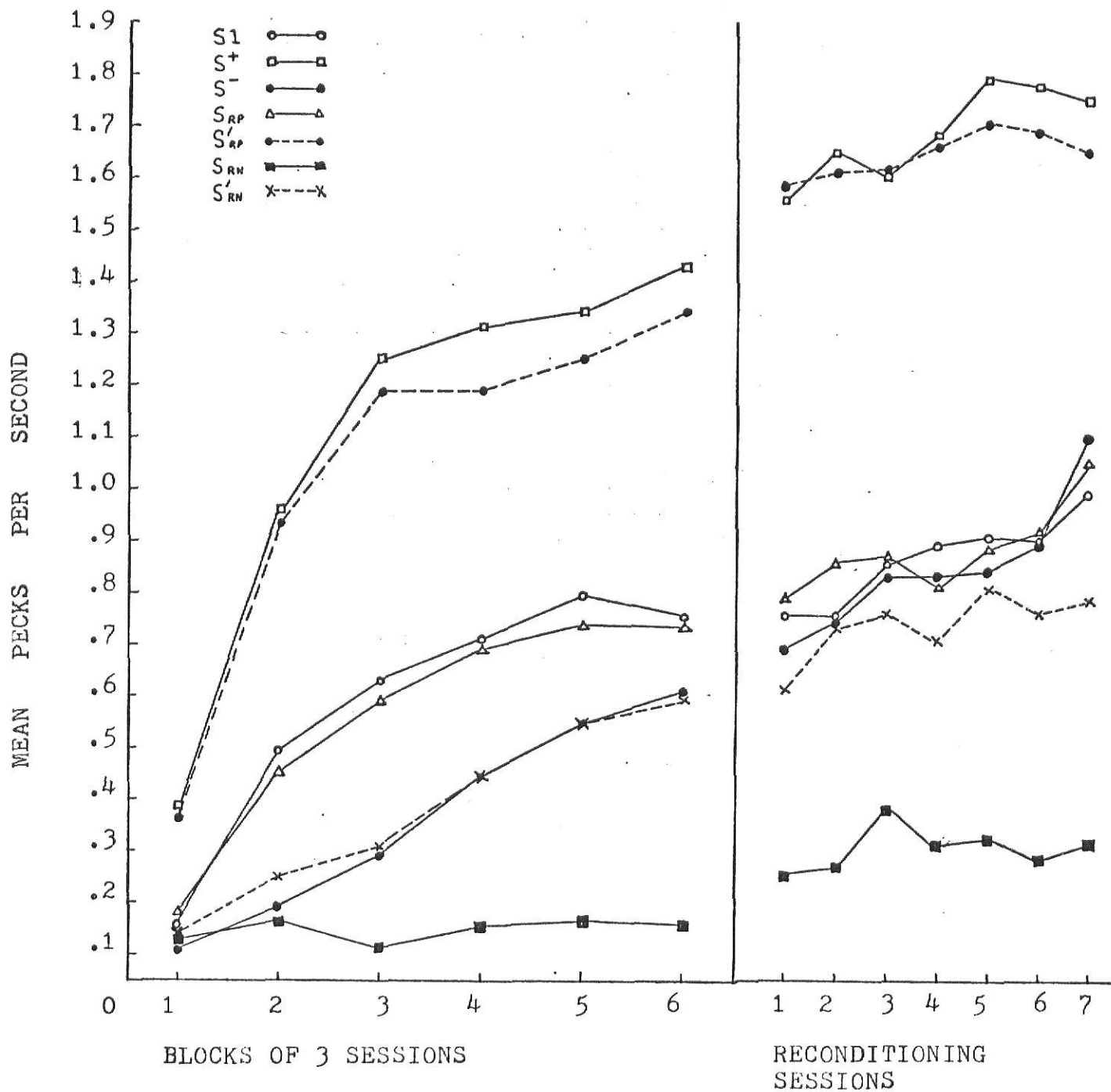


Figure 2. Left Half: Mean pecks per sec to each signal during the conditioning phase plotted as a function of blocks of three sessions. Right Half: Mean pecks per sec to each signal during conditioning sessions which alternated with test sessions.

and that by the end of conditioning there were differences among the rates.

Two types of statistical analyses were carried out on the mean rates from the last three conditioning sessions for each subject. Direct-difference t tests were made on the difference scores obtained from individual subjects for each comparison. The other statistical test was made with ratio scores. In testing the difference between S^+ and S^- the ratio of the S^+ rate to the combined S^+ and S^- rates was determined for each subject. If there is no real difference the expected mean ratio is 0.5. Both tests minimize the effect of individual differences; however, difference scores tend to give a greater weight to birds which have high rates while ratio scores give all birds an equal weight.

Specific comparisons made among the rates and the results are presented in Table 1. Both tests revealed significant differences between S^+ and S^- rates and between S'_{rp} and S'_{rn} rates. These differences which are consistent with other evidence (Gonzales, 1973; Perkins et al., 1974) indicate that rates are higher with greater probability of grain presentation. Two other comparisons were made to examine the effects of probability. A difference was found between S_1 and S_{rn} with both tests which supports the conclusion that auto-pecking rates vary directly with probability of grain presentation. However, S_1 and S_{rp} rates did not differ significantly although S_{rp} signalled a greater probability of grain. Lack of a difference between S_1 and S_{rp} rates suggests an interaction between probability of grain and proximity to grain. Since the present study was not designed to examine interactive effects between probability and

Table I: Results of Comparisons Made on Conditioning Data

Comparison		$(S^+) - (S^-)$	$(S'_{rp}) - (S'_{rn})$	$(S_{rp}) - (S'_{rp})$	$(S_{rn}) - (S'_{rn})$
Difference Scores	Mean	.937	.797	-.644	-.520
	S.D.	1.075	1.268	1.164	.942
Ratio Scores	\underline{t}	3.993***	2.882**	2.538*	2.531*
	Mean	.817	.776	.332	.187
Ratio Scores	S.D.	.199	.227	.190	.223
	\underline{t}	7.304***	5.571***	4.066***	6.428***
Comparison		$(S1) - (S^+)$	$(S1) - (S^-)$	$(S^+) - (S'_{rp})$	$(S^-) - (S'_{rn})$
Difference Scores	Mean	-.756	.178	.100	.002
	S.D.	1.028	.201	.575	.240
Ratio Scores	\underline{t}	3.371**	4.051***	.800	.042
	Mean	.273	.722	.572	.534
Ratio Scores	S.D.	.170	.234	.113	.269
	\underline{t}	6.131***	4.438***	2.931**	.580
Comparison		$(S1) - (S_{rn})$	$(S_{rp}) - (S1)$	$(S^+) - (S_{rp})$	$(S^-) - (S_{rn})$
Difference Scores	Mean	.700	-.019	.783	.523
	S.D.	1.001	.226	.943	.963
Ratio Scores	\underline{t}	3.190**	.424	3.807**	2.486**
	Mean	.925	.489	.782	.839
Ratio Scores	S.D.	.107	.129	.295	.235
	\underline{t}	18.150***	.392	4.391***	6.604***

for each test df=20

* $p < .05$ ** $p < .01$ *** $p < .001$

proximity no definite conclusions can be reached.

Several comparisons were made to examine the effects of proximity to grain presentation on autopecking rates. Significant differences were found between S_{rp} and S'_{rp} , and between S_{rn} and S'_{rn} . These differences are consistent with the results of Ricci (1973) which indicate that rates increase with increasing proximity to grain presentation. Further support for this conclusion was obtained by making comparisons between S^+ and S_{rp} and between S^- and S_{rn} . Significant differences were found with both of these comparisons.

In addition, significant differences were found between $S1$ and S^+ rates and between $S1$ and S^- rates. The S^+ rate was higher than the $S1$ rate presumably because of the greater probability and proximity associated with S^+ . The $S1$ rate was higher than the S^- rate although the proximity of S^- to grain presentation was greater. Since $S1$ signalled a greater probability of grain than S^- , the difference between $S1$ and S^- indicates that for the conditioning parameters employed in the present study probability may have a greater effect.

A significant difference in the S^+ and S'_{rp} rate was not obtained with the difference scores, but was with the ratio scores. Failure to find a significant difference with one test and not the other may be due to the nature of the tests themselves. There were only four out of 24 birds which had a higher rate to S'_{rp} than to S^+ and this difference was significant with a binomial test ($p < .01$). Also it can be seen in Fig. 2 that over the last half of conditioning, the S^+ rate is slightly higher than the S'_{rp} rate. Therefore there is evidence that the S^+ rate was higher. S^+ and S'_{rp} signalled the

same probability of grain, were equivalent in terms of proximity to grain presentation, but differed in that S^+ signalled an increase in probability. This apparent difference between rates to S^+ and S'_{rp} is consistent with the results of Alaway (1971).

No significant difference was found between S^- and S'_{rn} with either test. This result seems incompatible with the difference between S^+ and S'_{rp} . It is likely that if an increase in probability of grain results in a higher rate to S^+ than to S'_{rp} then a decrease in probability would produce a lower rate to S^- than to S'_{rn} . There is the possibility that the S^- rate was increased by a measurement artifact. The change from $S1$ to S^- was accompanied by a decrease in pecking rates. But some pecks to S^- just after the key color changed to S^- may have been generated by $S1$. Such "run-over" pecks would inflate the S^- rate measure.

Test phase

If the change from $S1$ to S^- has a punishing effect and the change from S_{rn} to S'_{rn} has a neutral effect the percent of criterion responses to the change key should differ for the two groups. Birds in Group E should make fewer responses to the change key. However this difference should not appear until Group E subjects discriminate the consequences of a criterion response to each key. With extensive testing E subjects might discriminate test sessions from conditioning sessions and peck either key equally often on test trials so that a difference between the two groups would disappear. It is also possible that the greater proximity of S'_{rn} to food than that of S_{rn} would result in more pecks by C birds to the change key. However, proximity should not differentially affect preference in the two groups because

the proximity of S^- to food is the same as that of S'^{rn} .

The data from several birds were unreliable because the birds pecked on only a few test trials. A standard was arbitrarily adopted that a subject had to make a criterion response on over half the test trials in at least six test sessions before its data were included in the analysis. This resulted in eight subjects in Group E and seven in Group C. The data of the Group E subjects dropped were examined to see if their low rates during the test phase could have been due to having the change key on the side which they preferred to peck during conditioning. No such relationship was found.

The mean proportions of criterion responses to the change key are plotted in Fig. 3 as a function of test sessions. The difference on the first test session shows that the C subjects made fewer criterion responses to the change key. This difference is not significant. Nevertheless it is opposite to the expected direction. Differences on test sessions two through six are in the expected direction.

There are several ways to test for the significance of possible effects of the stimulus change on the proportion of criterion responses to the change key. One would be to assume equal key preference and test how far the proportions deviate from 0.5. This approach is unsatisfactory for these data because most birds displayed a preference to peck one key over the other during conditioning. Another alternative would be to determine key preference in terms of a proportion based on the conditioning data and then examine deviations from this baseline. Since pecks on two-key presentations were not recorded separately from pecks on single-key presentations a satisfactory measure of baseline preference was not available.

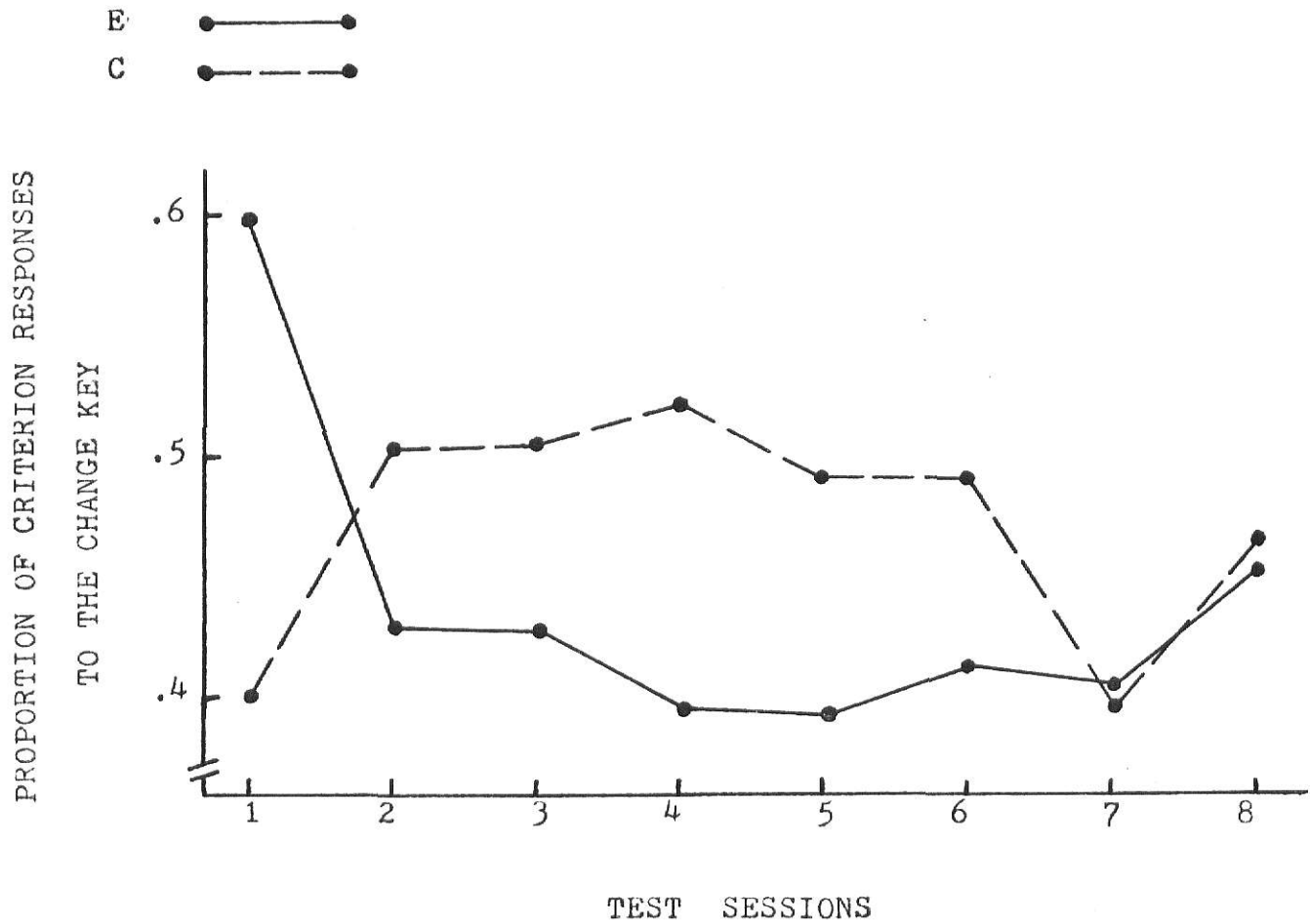


Figure 3. Mean proportions of criterion responses to the change key for Groups E and C plotted as a function of test sessions.

Instead, a least squares analysis of variance (Winer, 1971, pp. 599-603) was carried out on the proportion of criterion responses which produced a change. Results indicated no significant groups by sessions interaction ($F=1.19$, $df=7, 91$, $p>.05$). Separate t tests for each of the differences on sessions two through six did not reveal any significant differences between the two groups ($p>.05$ in each case).

The data from the first and second test sessions were tested to see if the change in the proportion of criterion responses to the change key differed for the two groups. Seven of eight birds in Group E and three of seven birds in Group C showed an increase in the proportion of criterion responses to the change key. The difference however was not significant as determined by Fisher's exact probability test ($p=.23$).

Pecking during the interval preceding the criterion response was not examined because the subjects in Group C seldom pecked during this period. Very often the first peck made on a test trial was the criterion response.

The mean pecks per sec for all subjects to each signal on reconditioning sessions are plotted in the right portion of Fig. 2. Noticeable rate increases occurred in the presence of each signal. The increases in rates to S_{rp} , S'_{rp} , and S^+ suggest that Phase I conditioning was terminated before steady state performance was reached. The increases for rates to S_{rn} , S'_{rn} , and S^- are presumably due in part to generalization from test sessions to reconditioning sessions. During test sessions S_{rn} , S'_{rn} , and S^- were more frequently followed by grain than in conditioning.

DISCUSSION

The results from the conditioning phase indicate that several factors may influence auto-shaped keypecking rates. Increases in both probability of grain and temporal proximity to grain presentation produce rate increases. While other studies have demonstrated either an effect of probability (Gonzales, 1973; Perkins et al., 1974) or proximity (Ricci, 1973), the present study shows these effects operate jointly with sequences of signals in which the probability of grain presentation changes. There is also evidence that the rate of pecking a signal may be influenced by the preceding signal. A signal preceded by a less reliable predictor may maintain a higher rate than another signal which indicates the same probability of grain but is made redundant by a preceding signal (see Alaway, 1971). This evidence however is sketchy and further work is needed to firmly establish this effect.

The results from the test phase fail to support the extension of the Egger and Miller information hypothesis outlined in the Introduction. No evidence was obtained that would suggest S^- had a punishing effect since the number of responses to the change key did not differ between the E and C groups. This result can be interpreted as supporting what might be termed an "absolutist" theory of reinforcement (see Perkins, 1972 for a full discussion). The absolutist position is that the reinforcement value of a conditioned stimulus can be predicted from the absolute probability of reward signalled by the conditioned stimulus. The absolute probability of grain signalled by S^- and S'_{rn} was identical. Therefore, from

the absolutist position a change from S_1 to S^- and a change from S_{rn} to S'_{rn} should not have differential reinforcing effects.

Although the absolutist interpretation of reinforcement fits quite nicely with the present results, this position seems untenable. Theorists such as Perkins (1972) and Premack (1965) have argued that the absolutist position is inadequate on both conceptual and empirical grounds. Perkins and Premack propose an interpretation of reinforcement which can be called a "relativity" view. Basically the relativity interpretation is that whether or not a conditioned stimulus will have a reinforcing effect depends on the conditions under which the conditioned stimulus is presented. In the present experiment S^- and S'_{rn} signalled the same absolute probability of grain but were presented, following a response, under different conditions. The conditions were designed so that a change from S_1 to S^- would provide relatively "bad news" while a change from S_{rn} to S'_{rn} would be uninformative.

Several reasons can be offered as to why no differences were found between the two groups. For one thing, S_1 and S_{rn} maintained little pecking on test trials. This could be due to the short ITI used during conditioning. Perkins et al. (1974) found that autopecking rates increased with increases in the duration of the ITI. Presumably a longer ITI would facilitate pecking to S_1 and S_{rn} and thereby provide more conclusive results during the test phase. Another possible reason is that the dependent measure, proportion of criterion responses to the change key, is not as sensitive as other measures. A more sensitive measure would be change in key preference. A baseline measure of key preference could be determined during conditioning

trials which involve two-key presentations. Then change in key preference during the test phase could be evaluated against this baseline. A third possibility is that the difference in probabilities of grain associated with S^+ and S^- was not large enough to make S^- relatively bad news. Future work with the procedure used in this study should therefore be carried out with a greater difference in probabilities of grain signalled by S^+ and S^- .

Because no difference was found in the effects of S^- and S'^{rn} during both phases it could be argued that the reinforcement value of a signal can be inferred from the rate of auto-shaped keypecking in the presence of the signal. Alaway (1971) has explicitly assumed this. Ayers (1966) and Rescorla (1972) seem to have made a similar assumption regarding the punishment value of a signal for an aversive event. These investigators assume the aversiveness of a conditioned punisher can be inferred from its suppressive effects when presented in a Pavlovian conditioning procedure. However, some serious problems arise when one attempts to infer either the reinforcing or punishing value of a conditioned stimulus from the effects of Pavlovian conditioning procedures. Kimble (1961, pp. 110-113) and Schneiderman (1972) have pointed out that in Pavlovian conditioning procedures different conditioned responses to the same conditioned stimulus do not correlate well with each other. This poor correspondence among different classically conditioned responses argues against inferring the reinforcement or punishment value of conditioned stimulus from the effects of Pavlovian conditioning procedures. If the strength of one conditioned response cannot be predicted on the basis of another conditioned response, how can one predict the reinforcement

or punishment value of a conditioned stimulus from the effects of Pavlovian conditioning procedures? A more appropriate approach is to measure the reinforcement or punishment value of a conditioned stimulus directly by making the stimulus contingent on a response as was done in the present experiment.

The type of procedure used in the present experiment is one way to test the extension of the Egger and Miller information hypothesis outlined in the Introduction. According to the present interpretation response-contingent signals which indicate an increase in reward probability should have a reinforcing effect. Response-contingent signals which indicate a decrease in reward probability should have a punishing effect. This interpretation of the information hypothesis can also be extended to conditioned punishment procedures as Seligman (1966) has shown. In conditioned punishment procedures response-contingent signals which indicate an increase in probability of the aversive event should have a punishing effect, and response-contingent signals which indicate a decrease in probability should have a reinforcing effect. The use of choice procedures allows one to measure the effect of a signal which indicates a change in the probability of the outcome relative to a signal which indicates no change in probability. Tests of conditioned reinforcement or punishment are conducted following a conditioning phase in which there has been no differential reinforcement for pecking either key. In addition, a measure of key preference can be determined before the test sessions are initiated.

An advantage in using the present procedure to measure conditioned reinforcement is that it avoids the problem of generalization

decrement (Kimble, 1961, pp. 293-302) which has made past studies (Egger and Miller, 1962; Seligman, 1966) difficult to interpret. That Egger and Miller (1962) found the redundant S2 to be a less effective conditioned reinforcer than the informative S1 may have been due to generalization decrement. During their conditioning phase Egger and Miller presented S2 while S1 was present, but during the test phase S2 was presented, following a response, without S1 present. This dissimilarity between conditioning and test conditions could account for the reduced effectiveness of S2 just as parsimoniously as could the information hypothesis they proposed. In the present study S^- and S'_{rn} were presented in the context of S1 and S_{rn} during both phases of the experiment which minimized the differences between conditioning and test conditions. If steps had not been taken to rule out the possibility of generalization decrement it is conceivable that quite different results would have been obtained. S^- in the context of S1 signalled a decrease in reward probability, but if S^- had been contingent on a keypeck in the context of the ITI it would have signalled an increase in reward probability and might have had a reinforcing effect. This problem of generalization decrement ties in with the relativity view of reinforcement because the effect of S^- should depend on the conditions under which it is presented. S^- should punish behavior under some conditions but reinforce behavior under others.

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THE EFFECTS OF A CHANGE IN REWARD PROBABILITY ON
PREFERENCE FOLLOWING AUTOSHAPING WITH TWO-SIGNAL
SEQUENCES: AN EXTENSION OF THE EGGER AND MILLER
INFORMATION HYPOTHESIS

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The theory of conditioned reinforcement proposed by Egger and Miller (1962, 1963) specifies that a signal must provide information about the primary reinforcing event if it is to become a conditioned reinforcer. In the present paper the Egger and Miller information hypothesis is broadened to cover those situations in which a signal may provide information about the primary reinforcing event by indicating a decrease in the probability that the event will occur. The present interpretation of the information hypothesis specifies that in a sequence of signals occasionally followed by reward a signal will: 1) become a conditioned reinforcer if it indicates an increase in reward probability; 2) become a conditioned punisher if it indicates a decrease in reward probability; or 3) have a neutral effect if it indicates no change in reward probability.

An experiment was conducted to test the present interpretation of the information hypothesis. Food-deprived pigeons were first given a conditioning phase in which four different two-signal sequences were presented on two response keys. Occasionally a sequence terminated with presentation of grain. In two of the sequences the change from the first to the second signal indicated a change in the probability that grain would follow. In one sequence the change was from a medium to a high probability, while in the other sequence the change was from a medium to a low probability. In the other two sequences the change from the first to the second signals did not indicate a change in reward probability. In one of these latter two sequences the probability that grain would follow was always high, while in the other the probability was always low. During the conditioning phase pigeons could peck the response keys

without affecting the sequence of events.

In the test phase pigeons were assigned to two groups. On each test trial birds in one group could peck one key to produce a change from a medium to low probability signal, or peck the other key and maintain the medium probability signal. Birds in the other group could peck one key to produce a change from one low probability signal to another low probability signal, or peck the other key to maintain the initial signal.

Results of the conditioning phase showed that rates of keypecking (auto-shaped keypecking) increased with increases in probability of grain presentation. The results of the test phase failed to support the present interpretation of the information hypothesis. Test phase results are discussed in terms of two contrasting viewpoints of reinforcement -- the "absolutist" and the "relativity" view. Although the results were consistent with the absolutist view it is argued that this view is inadequate.