# AUTOSHAPING: FURTHER STUDY OF "NEGATIVE AUTOMAINTENANCE"[1]

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The key pecking of pigeons was autoshaped to three key colors paired with food in discrete trials. Then, the effects of three different color-correlated contingencies were compared: reward (presentation of food contingent on pecking), omission (presentation of food prevented by pecking), and extinction (no food). Two measures of performance were used: initial response (the number of trials with each color on which at least one peck was made) and multiple response (the total number of pecks per trial). In general, the reward color produced more pecking than the omission color, the omission color more than the extinction color, and the extinction color more than on blank trials with an unlighted key, although (relative to reward) omission produced a higher level of initial than of multiple responding. These results point clearly to the importance of stimulus-reinforcer contiguity in the control of pecking.

The considerable attention now being paid to the phenomenon of autoshaping is due in large measure to the implication that skeletal behavior such as key pecking in pigeons may be controlled by "stimulus-reinforcer" rather than "response-reinforcer" relations (Williams and Williams, 1969; Jenkins, 1973). Of the various arguments advanced in support of this view, the most influential perhaps is based on the fact of "negative automaintenance": pigeons that have begun to peck a key whose illumination has been followed repeatedly by food will continue to do so even when an omission contingency is scheduled—that is, even when pecking prevents the presentation of food (Williams and Williams, 1969). The persistence of responding under these conditions, in which response-reinforcer contiguity is eliminated, has been attributed to the contiguity of keylight and food on whatever trials pecking fails to occur, but the evidence is far from conclusive.

In the first experiment reported by Williams and Williams (1969), negative automaintenance was demonstrated but unanalyzed. Their second experiment was designed to determine whether the phenomenon could be attributed either to "the generalization of feeder-oriented pecking" or (response to the key having been scheduled to turn off the keylight) to "reinforcement from stimulus change". Two key colors (or patterns) were used for each animal, with reinforcement contingent upon response to one, and the other on extinction. From the failure of the animals to maintain responding to the extinction color in their second experiment, Williams and Williams concluded that the maintenance of responding in their first experiment must have been due to stimulus-reinforcer contiguity, but it would seem unwise to rest so important a conclusion on so inexact a comparison. The two experiments differed in a number of respects, of which the most important perhaps is that extinction responding was measured in the context of concurrent response-contingent reinforcement while omission responding was not. Furthermore, a subsequent set of informal comparisons by Herrnstein and Loveland (1972) showed no significant differences between omission and extinction. The only systematic comparisons of omission and extinction have been made under free-operant rather than discrete-trials conditions (Nevin, 1968; Zeiler, 1971). Not only did omission fail to sustain key pecking in those experiments, despite the substantial stimulus-reinforcer contiguity, but suppression of responding was even more rapid with omission than with extinction. The purpose of the present experiment was to make a further

comparison of omission and extinction under discrete-trials conditions like those in which omission training has been found to produce sustained responding by Williams and colleagues (see also Schwartz and Williams, 1972). To provide a broader context for the evaluation of the effects of omission training, the effects of response-contingent reinforcement also were measured concurrently.

## METHOD

### Subjects

Six experimentally naive male homing pigeons, 1 to 2 yr old, were maintained at 80% of free-feeding weight on a 24-hr feeding schedule.

### Apparatus

The animals were trained in a ventilated picnic chest divided into two compartments. The partition was made of aluminum except for a 4-cm strip of milk-white Plexiglas at the top, running the entire width of the chest, through which the animal's compartment (27 cm long, 27 cm wide, and 30 cm high) was provided with general illumination. A Plexiglas key, 2.5 cm in diameter, was mounted in the partition at a height of 19 cm. The key was opaque except for a circular central area, 1 cm in diameter, which could be illuminated from behind by a white, a red, or a green lamp. The grain-feeder was a motor-driven Plexiglas box (7.5 cm wide, 10 cm long, and 5 cm high) normally retracted from the animal's compartment, its opaque front flush with the panel. When operated, it extended 5.5 cm into the compartment and was illuminated by a yellow lamp. All events of the experiment were scheduled automatically, and responses were recorded with a printing counter.

### Procedure

As soon as the animals were taking food readily from the food box, they were key-trained. On each trial, the onset of the keylight was followed after 8 sec by a 5-sec presentation of food, whether or not the animal responded to the key. Each daily session of 20 trials consisted of a randomly ordered series of five conditioning trials with each of the three key colors (white, red, and green) and five blank trials (without keylight or food) on which responding to the unlighted key was

measured. The mean intertrial interval was 60 sec if all four kinds of trial are counted, but proportionally longer if only those trials are counted on which a stimulus was presented. This first stage of the training was terminated for each animal when it responded to a lighted key (independently of color) on five of any 10 consecutive trials.

In the second stage of the experiment, there were forty 8-sec trials in each daily session, 10 with each of the three key colors, and 10 blank. Each of the key colors was associated with a different contingency—reward, omission, or extinction. At least one response to the reward color was required for presentation of food at the end of the 8-sec interval; if no response was made, the keylight was turned off and the trial terminated. A single peck at the omission color prevented presentation of food at the end of the 8-sec interval; if no peck occurred, food was presented. The extinction color never was followed by food, being turned off irrespective of the animal's behavior after the 8-sec interval. In no case was the duration of the stimulus affected by response. The relation of color to contingency was balanced over the group by assigning one of the six birds to each of the six possible color-contingency combinations.

## RESULTS

In Figure 1, responding in the second stage of the experiment to each of the colors and on blank trials is plotted in terms of the mean number of trials per session on which the key was pecked at least once ('initial response'). The curves show that initial response to each of the colors was high at the onset, remained high for the reward color, fell off to some extent for the omission color, and declined progressively to a low level for the extinction color; probability of response to the unlighted key on blank trials was low throughout. The six individual performances, one of which is plotted in Figure 2, were like the mean performance in all respects. Every one of the birds made more initial responses to the reward color than to the omission color, more to the omission color than to the extinction color, and more to the extinction color than to the unlighted key on blank trials. A formal statistical analysis showed significant variance due to conditions ($F = 108.50$, $df = 3/15$, $p < 0.01$) and sessions ($F = 7.07$, $df = 11/55$, $p < 0.01$),
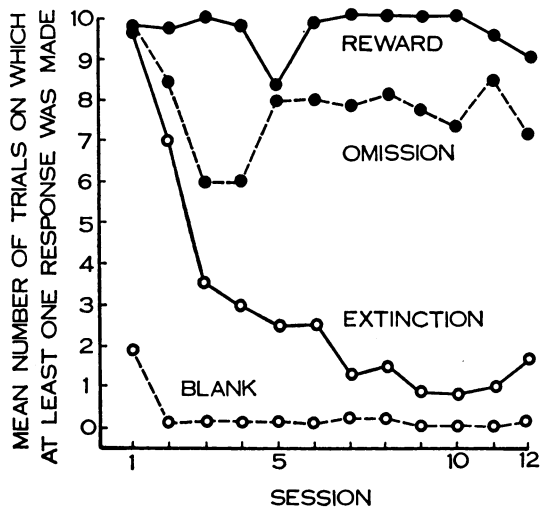
Fig. 1. Mean initial response to the reward, omission, and extinction colors, and to the unlighted key on blank trials. The curves are plotted in terms of the number of trials on which there was at least one peck. There were 10 trials with each color and 10 blank trials in each session.

and a significant conditions by sessions interaction ($F = 6.07$, $df = 33/165$, $p < 0.01$). The differences between reward and omission, between omission and extinction, and between extinction and response on blank trials also were significant ($p < 0.01$).

Figure 3 is plotted in terms of the mean number of pecks per trial under each condition ('multiple response'). Like initial response, multiple response to the three colors was high
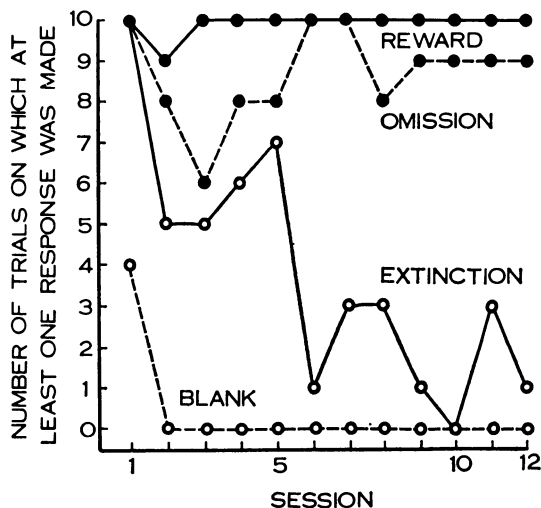


Fig. 2. Initial response in a representative animal. (Compare Figure 1.)
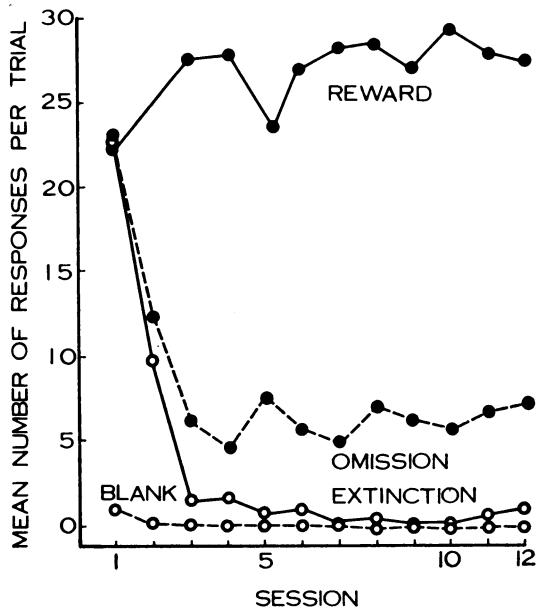


Fig. 3. Mean multiple response to the reward, omission, and extinction colors, and to the unlighted key on blank trials. The curves are plotted in terms of the number of pecks per trial.

at the outset, remained high for the reward color but declined for the other two, more sharply for the extinction color than for the omission color, while on blank trials it was low throughout. The multiple-response scores of the six birds closely resembled the mean performance with one exception. While every animal responded more to the reward color than to the omission color, and more to the extinction color than on blank trials, only five of the six animals responded more to the omission color than to the extinction color; for the deviant bird, multiple response to the two colors was essentially the same. Analysis of variance based, of course, on the data for all six animals, showed significant effects of conditions ($F = 43.53$, $df = 3/15$, $p < 0.01$) and sessions ($F = 5.54$, $df = 11/55$, $p < 0.01$), as well as a significant conditions by sessions interaction ($F = 6.97$, $df = 33/165$, $p < 0.01$). Omission did not, however, differ significantly from extinction, although reward differed from omission, and omission from blank trials ($p < 0.01$).

## DISCUSSION

While the difference between omission and extinction as measured in terms of multiple

response did not meet the conventional criterion of statistical significance, the difference in initial response was significant, and it seems safe to conclude that key pecking was facilitated by the omission contingency, at least under the conditions of the present experiment. The only reasonable explanation of this finding is that the tendency of a pigeon to peck at a lighted key is strengthened by the contiguity of keylight and food. It should be noted that we have in this simple within-subjects comparison of omission and extinction, a completely self-contained and unequivocal demonstration of the control of pecking by the stimulus-reinforcer relation. The omission contingency of course prevents response-reinforcer contiguity and, since color is balanced in the design, there is no reason to believe that non-associative effects, such as sensitization or generalization, would favor response to one or the other stimulus.

Relative to reward, omission produced much better initial than multiple responding in the present experiment. Two explanations of this fact, not mutually exclusive, suggest themselves. The first is in terms of a ceiling effect; the initial-response measure simply is not sensitive to differences in response strength beyond the level required to produce a single peck on each trial. The second explanation is in terms of the sensory feedback from pecking. While the omission color alone—that is, in the absence of the feedback from pecking—always is followed by food, the color plus feedback never is followed by food. There is, then, a strong initial tendency to peck at the color (the $S^D$), but a much weaker tendency to peck again, since the initial peck converts $S^D$ to $S^\Delta$. In the reward case, of course, the color plus feedback is the $S^D$, and multiple responding therefore should be high; initial responding must be sustained by generalization or by the response-reinforcement relation. It is interesting to note that very much the same results on the relation of initial to multiple responding have been obtained in experiments on the behavior of goldfish in the shuttlebox under conditions of avoidance (the aversive analogue of omission) and punishment (the analogue of reward)—although initial responding is lower in punishment than in avoidance, multiple responding is proportionately much higher (Woodard and Bitterman, 1973). If shuttling is a product of conditioned activation, the difference in multiple responding can be explained in terms of discriminated feedback, since the signal plus feedback from responding always is paired with shock in the punishment case, but never in the avoidance case. Shuttling in goldfish is another example of skeletal behavior in the control of which stimulus-reinforcer relations now are being found to play an important part.

The discrepancy between the present results and those of Nevin (1968) and Zeiler (1971), both of whom found more pecking in extinction than in omission under free-operant conditions, is not difficult to understand in the light of the finding of Brown and Jenkins (1968) that the onset of the keylight plays an important role in autoshaping. Food delivered periodically in the presence of a continuously illuminated key does not produce as strong a tendency to peck the key as does food delivery shortly after the illumination of a key that is dark between trials. In Pavlovian terms, the interval between the onset of the conditioned stimulus and the onset of the unconditioned stimulus is much shorter in discrete-trials than in free-operant omission training, and conditioning therefore is better. The level of response in omission training probably is influenced also by the extent to which incompatible behavior is strengthened by adventitious response-reinforcer contiguity. The finding of Schwartz and Williams (1972) that pigeons peck less at an omission color than at a yoked control color that is followed by food with the same frequency as is the omission color (but independently of response) certainly points to adventitious reinforcement, either of pecking at the control color, or of "other" behavior in the presence of the omission color, or of both. The discrepancy between the Nevin-Zeiler results and our own might be due in part, therefore, to greater opportunity for the development of incompatible behavior in free-operant training. In any case, the fact that there are at least certain conditions in which omission performance exceeds extinction performance provides unmistakable evidence of the effectiveness of the stimulus-reinforcer relation in the control of pecking.

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