

## THE ROLE OF THE RESPONSE-REINFORCER CONTINGENCY IN NEGATIVE AUTOMAINTEANCE<sup>1</sup>

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When a response key is briefly illuminated before a grain reinforcer is presented, key pecking is reliably developed and maintained in pigeons, even if pecking prevents reinforcement (negative automaintenance). This experiment demonstrated that pigeons are sensitive to a negative response-reinforcer contingency, even though it does not eliminate responding. Within individual pigeons, two kinds of trials were compared: red key trials, in which reinforcement was negatively contingent on responding, and white key trials, in which reinforcement was unrelated to responding. Reinforcement frequency in non-contingent trials was yoked to the obtained reinforcement frequency in negatively contingent trials. All eight pigeons pecked substantially more on the non-contingent key than on the negative key, and preferred the non-contingent key to the negative key on occasional "choice" trials where both were presented together. When the stimuli correlated with the two conditions were reversed, the pigeons' behavior also shifted. These response differences are taken as evidence that pigeons are sensitive to the negative response-reinforcer contingency.

Brown and Jenkins (1968) reported a method for the automatic shaping (autoshaping) of key pecking in pigeons. If a response key is illuminated for several seconds before the operation of a feeder, experimentally naive pigeons will begin to peck the key. Williams and Williams (1969) followed up this observation by exploring whether a positive response-reinforcer contingency was necessary to support sustained responding in this situation. In their procedure, trials in which no peck occurred terminated with reinforcement, as in the Brown and Jenkins procedure. However, pecks to the illuminated key immediately turned it off and terminated the trial without reinforcement. Despite the negative response-reinforcer contingency, pecking was maintained at substantial levels for an extended series of trials ("negative" automaintenance).

The failure of the negative response-reinforcer contingency to eliminate key-pecking on the negative automaintenance procedure is

in sharp contrast to the many experiments (*e.g.*, Honig, 1966) that demonstrate that the rate of key pecking is extremely sensitive to, and easily modified by, its consequences. In attempting to explain this apparent failure of contingent non-reinforcement, consideration has been given to the conditions that underlie the development of pecking in the experimental situation. Williams and Williams (1969) and Gamzu and Williams (1971) pointed to the importance of the stimulus-reinforcer contingency in maintaining key pecking. Staddon and Simmelhag (1971) noted that pecking is a part of the pigeon's normal feeding pattern and that it tends to dominate the pigeon's activity in time periods just preceding the regular delivery of a response-independent reinforcer when the pigeon is in the state of food deprivation. They attribute the fact that the peck is directed at the illuminated key to the key's predictive value with respect to food.

Neither the non-arbitrary origin of the pecking response, nor the postulated involvement of stimulus-reinforcer relationships in the emergence or directedness of key pecking, directly answers the question of whether there is any involvement of response-reinforcer contingencies in the determination of automaintained pecking. This question was confronted in the present experiment through the use of

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a procedure that permitted the comparison of response rates and preferences between keys that were alike in their association with the reinforcer (that is, matched on stimulus-reinforcer or respondent characteristics), but different in the scheduled relationship between peck and reinforcer (response-reinforcer or operant characteristics). Under these conditions, any differences observed in rate or preference would demonstrate sensitivity to response-reinforcer relationships within the automaintenance situation. The method is developed from Williams and Williams' comparison of automaintained pecking to simultaneously presented keys of different colors. On one key (negatively contingent key) pecking immediately darkened the key and prevented reinforcement. On the other key ("irrelevant key") pecking had no scheduled consequence. Typically, within 100 trials of exposure to the two keys presented simultaneously, pecking was directed almost exclusively at the irrelevant key and reinforcement therefore occurred on nearly every trial. In that procedure, both the probability of reinforcement on particular trials, and the reinforcement frequency within the session, depended on which key was chosen; it is not clear, therefore, whether the marked preference for the irrelevant key reflected an operant influence on pecking itself, or an operant effect on some other aspect of the sequence of behaviors preceding those involving pecking—approaching one or the other key, for example. Furthermore, in auto-shaping, the key serves both as stimulus and as operandum; it is not obvious that stimulus-reinforcer relationships are themselves independent of whether or not the stimulus/operandum is responded to, or whether or not the stimulus is response-terminated. To overcome these difficulties, the "irrelevant key" procedure was modified in the present experiment as follows. First, the duration of illumination of both keys was made independent of responding, and frequency of reinforcement was equated for negative and irrelevant key presentations through the use of a yoking procedure. In addition, negative and irrelevant keys were presented separately on the majority of trials; thus, not only was effective exposure controlled, but independent rates of response could be directly compared. On occasion, however, nonreinforcement paired presentations were provided to permit a com-

parison of the relative effectiveness of control of the negatively contingent and irrelevant keys.

## METHOD

### *Subjects*

Eight pigeons were maintained at 80% of their free-feeding weights. Four (1062, 1149, 1303, 1322) had been previously exposed to negative automaintenance procedures; three (1429, 1189, 1614) were naive, and one's (1001) responding had been positively auto-shaped. The naive pigeons were trained to eat from the feeder, after which all eight pigeons were exposed to the procedure described below.

### *Apparatus*

One wall of a standard pigeon chamber contained a three-key pigeon panel with keys that could be illuminated by various colored lights. The keys were about 8 in. (20 cm) above the floor of the chamber and about 4 in. (10 cm) apart center-to-center. A food magazine was centered 5 in. (12.5 cm) below the center key. A deflector was placed on the houselight, located 2.75 in. (7 cm) above the center key, so that the light was directed toward the ceiling of the chamber. Only the side keys were ever illuminated.

### *Procedure*

Each daily session consisted of fifty, 6-sec trials in which one of the two side keys was illuminated with red or white light, and ten, 6-sec choice trials in which both side keys were illuminated, one red and one white. The red stimulus was correlated with negative automaintenance conditions: after 6-sec, the stimulus went off and the feeder operated; pecks during the stimulus prevented reinforcement. However, unlike the Williams and Williams (1969) procedure, key pecks did not turn off the stimulus. The white stimulus was correlated with a yoked "irrelevant" condition. Pecks had no scheduled consequence, and the yoked trial terminated with reinforcement only if an earlier, paired, negative automaintenance trial had terminated with reinforcement. Thus, reinforcement frequency in the two conditions was equal. The order of negative automaintenance and yoked irrelevant-key trials was randomized within blocks of ten trials, with the constraints that (1) the first trial

in each block of 10 was negative automaintenance, and (2) there were five negative automaintenance and five yoked irrelevant-key trials in each block of 10. Thus, it was extremely unlikely that the pigeons could detect the relationship between outcomes of negative automaintenance trials and their yoked irrelevant-key trials.

After each five trials of this sort, a choice trial was arranged. Here, both red and white stimuli were illuminated simultaneously on different keys, and the pigeon could peck at either or both until the 6-sec trial elapsed. Reinforcement never occurred on these choice trials. Nevertheless, the pigeons responded on these trials throughout the experiment. In both kinds of trials, key color and position were uncorrelated; that is, the red and white stimuli were equally likely to come on on either of the two side keys. Trials were separ-

ated by an intertrial interval of 10 to 90 sec, with a mean of 30 sec.

This procedure was conducted for 36 sessions, after which the stimuli correlated with the two conditions were reversed, for 24 sessions.

## RESULTS

Figure 1 shows (a) the proportion of trials during which at least one response occurred and (b) responses per minute in the negative automaintenance and yoked irrelevant stimuli when they were presented separately. The data are averaged across the eight subjects for blocks of four sessions (200 trials). It is clear that pecking during the negatively contingent stimulus was less substantial by both measures presented, and that when the relationship between key color and contingency was reversed

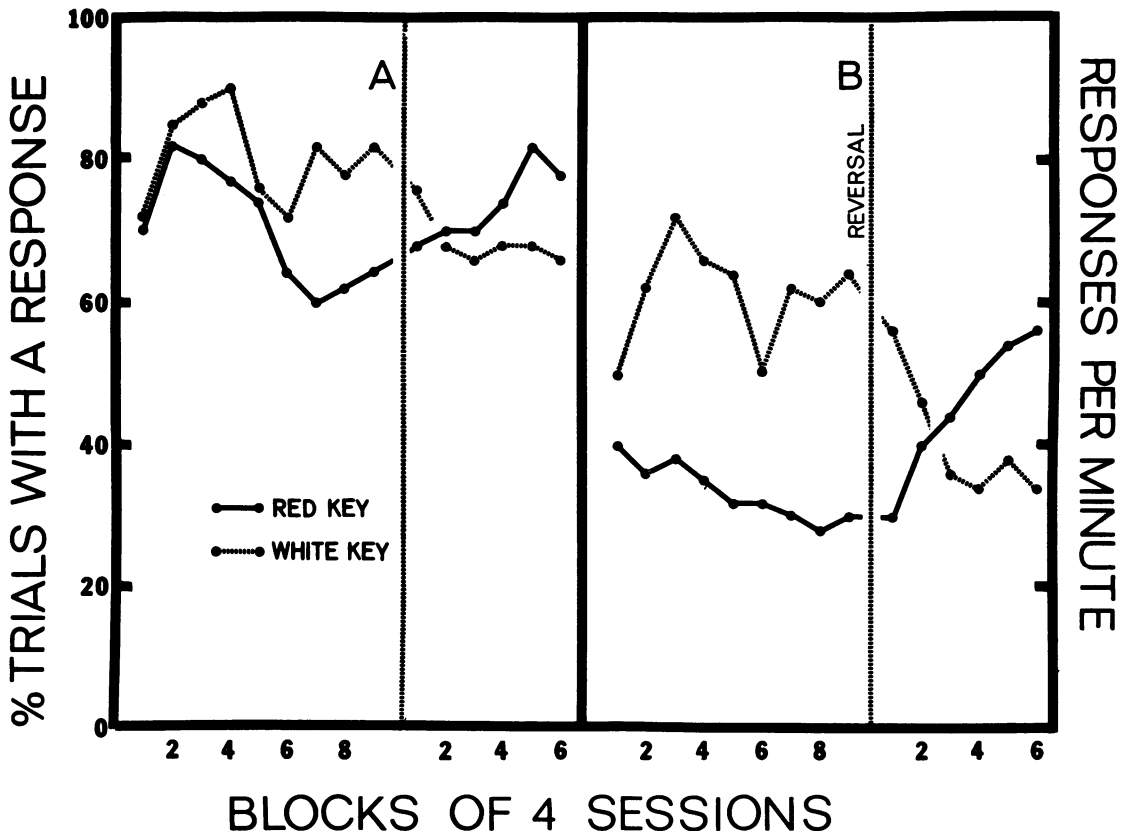


Fig. 1. Percentage of trials with at least one response (Panel A) and responses per minute (Panel B) throughout the experiment, averaged across all eight subjects in four-session blocks and separated according to key color. To the left of the striped vertical line, the red key was associated with the negative automaintenance condition, the white key with the yoked control. To the right of the striped vertical line, the significance of the key colors was reversed.

an appropriate shift in performance levels took place. These differences are particularly marked with respect to the rate measure: there is about a two to one difference in favor of the yoked irrelevant-key during the last 12 sessions before the reversal.

Figure 2 shows comparable functions for the choice trials. Although the overall percentages and response rates are somewhat lower than those of Figure 1, the differences in responding during negative automaintenance and yoked irrelevant stimuli are present and similar in direction and magnitude to those presented in Figure 1. Pigeons almost never pecked both keys on the same choice trials. The only pigeon that did so with some regularity (1189) still pecked only one key more than 75% of the time.

Data for individual birds under the various experimental conditions are presented in Table 1. The data are averaged across the last 10 sessions for each procedure indicated, and are shown separately for pre- and post-

reversal. It is apparent from the table that the averaged curves are descriptive of individual performances and that individual reversals of the average effect are few and not systematic. In all, there are eight different comparisons of responding in the two conditions for each pigeon: proportion of trials with a response, and response rate, in individual trials, and choice trials, pre- and post-reversal. Five of the eight comparisons are in the right direction for one Pigeon 1322, six of eight for Pigeons 1303 and 1614, seven of eight for Pigeon 1149, and eight of eight for the others.

DISCUSSION

The yoked irrelevant key, on which no response-reinforcer contingency was in force, sustained higher rates of responding and was chosen more frequently than the negatively contingent key. Since the yoking procedure guaranteed that each key was equally often paired with reinforcement, and since key dura-

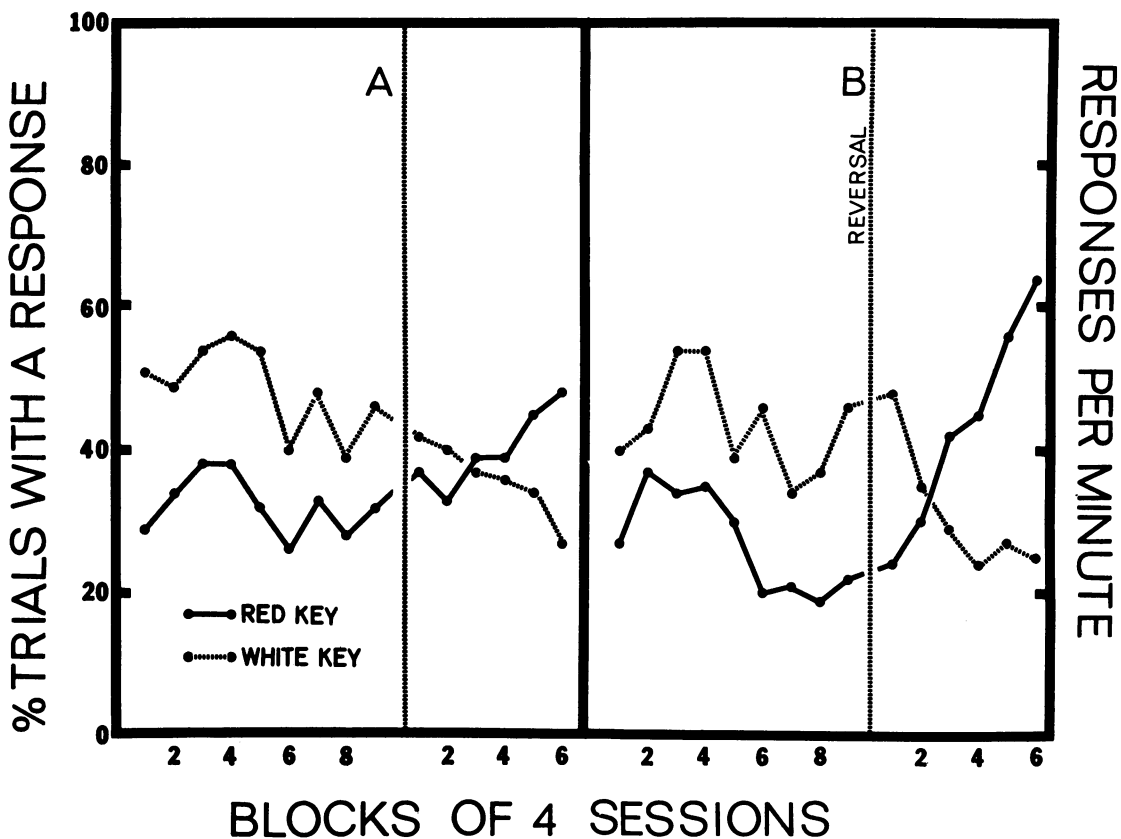


Fig. 2. Performance on choice trials. See Figure 1 for details.

Table 1

Proportion of trials in which at least one response occurred, and responses per minute, for individual subjects, in negative automaintenance and yoked irrelevant stimuli, averaged across the last 10 sessions of the original procedure and of the stimulus reversal.

	<i>Pigeon</i>							
	<i>1062</i>	<i>1149</i>	<i>1303</i>	<i>1322</i>	<i>1429</i>	<i>1189</i>	<i>1614</i>	<i>1001</i>
Negative automaintenance %	74	36	62	61	49	84	75	38
Yoked irrelevant %	88	83	89	60	83	88	85	67
Negative automaintenance rate	48	18	18	22	21	60	36	15
Yoked irrelevant rate	83	50	44	25	43	98	65	88
	<i>Choice Trials</i>							
Negative automaintenance %	23	22	49	26	16	53	39	13
Yoked irrelevant %	65	39	23	33	49	59	45	28
Negative automaintenance rate	28	13	16	17	16	23	35	13
Yoked irrelevant rate	68	39	36	29	21	72	44	22
	<i>Stimulus Reversal</i>							
Negative automaintenance %	80	70	67	43	45	87	85	63
Yoked irrelevant %	90	72	77	53	78	98	80	90
Negative automaintenance rate	50	37	20	21	25	76	39	21
Yoked irrelevant rate	124	44	30	21	32	101	28	66
	<i>Choice Trials</i>							
Negative automaintenance %	37	63	45	24	27	34	33	22
Yoked irrelevant %	59	07	23	38	46	64	51	42
Negative automaintenance rate	58	20	18	22	14	37	25	16
Yoked irrelevant rate	105	79	21	13	45	109	26	81

tion was constant and equal under both conditions, the observed differences in performance must reflect the effective influence of the different response-reinforcer contingencies that were correlated with the two keys. The present experiment, therefore, provides evidence that the response-reinforcer contingency contributes to the rate of automaintained pecking and to schedule preference. Put another way, the fact that pecking occurs under conditions of negative automaintenance does not mean that the pecking engendered by a stimulus-reinforcer relationship is entirely insensitive to its consequences, but only that the negative consequences of pecking are less powerful than the circumstances that directly generate pecking behavior.

To consider how operant relationships might influence pecking in the present situation, let us conceptually divide behavior in the presence of a single key into two parts: a part that involves approaching and pecking the key (key-directed set) and the remaining behavior in the presence of the key (residual

set). Under conditions of negative automaintenance, responses in the key-directed set are introduced and sustained primarily by stimulus-reinforcer characteristics. This is because key pecking prevents reinforcement and thus, operant considerations weigh against the occurrence of responses in this set. On any such trial, however, behaviors in the residual set are more likely to be followed by the reinforcer than behaviors in the key-directed set, again because key pecking prevents presentation of the reinforcer. Since sustained pecking does occur under conditions of negative automaintenance, it is apparent that the combined effects on residual-set behaviors of relatively favorable response-reinforcer relationships, and possible generative relationships (Staddon and Simmelhag, 1971) are not sufficiently strong to block the occurrence of behaviors in the key-directed set. Thus, the stimulus-reinforcer relationships present in the negative automaintenance situation increase the likelihood of occurrence of members of the key-directed set, while response-reinforcer relationships

have a similar effect on members of the residual set. Under conditions of stable negative automaintenance these two opposing factors are in equilibrium.

Let us now contrast this situation to one where a yoked irrelevant key is employed. Because of the yoking procedure, the generative factors influencing the two sets of behaviors are the same, but there is a shift in the response-reinforcer correlation. Specifically, the likelihood that behaviors in the key-directed set will be followed by the reinforcer is increased (from the level near zero), while the likelihood that behavior in the second set will be reinforced is reduced because the reinforcer does not necessarily occur on trials where all behavior is from this set. If either or both of these response-reinforcer relationships influences behavior, there will be a departure from the equilibrium condition of negative automaintenance in favor of the greater occurrence of responses from the key-directed set. Thus, the present results clearly show that the response-reinforcer contingency influences performance under conditions of negative automaintenance, even though the changes observed do not indicate whether the tendency to peck is *weakened* by non-reinforcement under negative automaintenance, or *strengthened* by occasional adventitious reinforcement on the yoked key, or both. However, the fact that response-reinforcer factors do operate under conditions of automaintenance demonstrates that automaintained behavior is under the combined influence of stimulus-reinforcer and response-reinforcer relationships. The joint operation of these factors in the present experiment strongly suggests the possibility of carry-over to conventional operant situations involving pigeons' pecking (see also Schwartz and Williams, 1971).

The observed preference for the yoked irrelevant key likewise cannot be accounted for simply by appeal to stimulus-reinforcer relationships: these variables were equated for both keys. The observed preference must reflect the operation of a response-reinforcer contingency as discussed above. The possibility that the negative response-reinforcer contingency is in and of itself the condition that is directly avoided seems unlikely, since it is doubtful that it can serve as a stimulus (Silberberg, 1971). Rather, it seems probable

that the effectiveness of the response-reinforcer contingency arises from its influence on behavior in the presence of the keys. One possibility is that behavior that interferes with pecking (residual set behavior) is learned under negative automaintenance conditions, but is relatively aversive; this might be the case if such responses involve greater effort than responses in the key-directed set (Chung, 1965). A second and particularly interesting possibility is that the performance of key-directed behavior—the behavior that is directly engendered by stimulus-reinforcer relationships—strengthens preference for the yoked irrelevant key. The latter possibility is in line with demonstrations that organisms will perform arbitrary operants that produce circumstances that release species-specific behavior patterns (*e.g.*, Hogan, 1967).

The present results provide clear indication that operant factors (response-reinforcer relationships) are present and influential in the negative automaintenance situation, even though they are not of overriding importance. A simple application of respondent principles cannot account for the phenomenon as originally described (Williams and Williams, 1969) and it cannot account for the rate and preference results of the present study. An indication of the way operant factors can modulate the performance of automaintained behavior has been given above. The analysis suggests that while automaintained behavior departs in important ways from the familiar patterns seen with arbitrary responses, the concepts and procedures developed from the operant framework are, nevertheless, influential in the automaintenance situation.

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