CENTRIFUGAL SELECTION OF
SIGNAL-DIRECTED PECKING[1]

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Pigeons were exposed to a schedule of stimulus-correlated food presentations. When key pecks terminated trial signals and cancelled the delivery of food, pecking was either gradually or rapidly redirected away from the keys, depending on whether the food-omission contingency was introduced from the outset or after exposure to a response-independent baseline. In all cases, the food-omission contingency substantially reduced or eliminated pecking at the keys.

By recombining the conditional relations among stimuli, responses, and reinforcers, Brown and Jenkins (1968) uncovered the phenomenon of autoshaping, i.e., the emergence of key pecking in a response-independent schedule of stimulus-correlated food presentations. Although a growing list of studies has since considerably extended Brown and Jenkins' findings, understanding of autoshaping has not advanced in the same proportion. Some plausible accounts have, nevertheless, been offered. Williams and Williams (1969), for example, suggested that autoshaping entailed a more *deterministic mechanism* than the simple adventitious reinforcement of operant responses (such as approaching the feeder area, looking at the keylight, or the accidental pairing of key pecks with the delivery of food). Adopting a view of behavior that stressed broad ethological notions and the concept of species-specific behavior, Williams and Williams described autoshaping as due to stimulus-reinforcer relations apparently powerful enough to override the effect of a response-reinforcer relation. As evidence of the superi-

ority of such a stimulus-reinforcer relation, Williams and Williams reported the phenomenon of "automaintenance", i.e., the persistent responding to a stimulus correlated with food, despite the fact that such responses cancelled the delivery of food.

The perplexing persistence of key pecking in the face of food-omission contingency has been the subject of several more recent studies. Silberberg (1971), for example, reported difficulty in establishing discriminations with the food-omission procedure and suggested that the failure to suppress key pecking in this procedure could constitute a special case of the general difficulty of bringing autoshaped responding under operant stimulus control. Schwartz (1971) showed that in the food-omission procedure, the typical key peck is of much shorter duration, and of a possibly different nature, than operant key pecks. In addition, Schwartz found that these shorter-duration "autopecks" were remarkably insensitive to their consequences, in that their relative frequencies could not be increased by standard differential reinforcement procedures. More recently, Schwartz (1972) suggested that these two types of key pecks may belong to two different classes of behavior, each subject to different sources of control, and differing in the extent to which these sources control each class. Finally, Schwartz and Williams (1972a) reported an attempt to determine the role of the food-omission contingency upon autoshaped key pecking. Although their results indicated that the food-omission contingency appeared to exert some influence, this influence did not appear to be one of over-

riding importance or effectiveness. Moreover, the exact role of the food-omission contingency was not clarified because, as Schwartz and Williams noted, their data did not indicate whether the tendency to key peck was in fact affected by the contingency. The purpose of the present experiments was to study in greater detail the influence of the food-omission contingency on the persistently "maladaptive" behavior generated by this procedure.

EXPERIMENT I

METHOD

Subjects

Six White Carneaux male pigeons served. Three were naive (Birds 687, 688, and 696) and three had histories of color discrimination training (Birds 605, 629, and 630). The experienced subjects had not been used for approximately one month before participating in this study. Birds were kept at 75% ±15 g of their free-feeding weights. Fresh water and grit were continuously available in the home cages.

Apparatus

A standard two-key operant conditioning chamber was used with the chamber door replaced by a one-way mirror to facilitate undetected direct observation and photography. Most sessions were observed, approximately half of them throughout the whole session, the remainder for roughly one-fourth of the session. For each subject, no more than two sessions elapsed without any observation; in some cases, full-session observations were conducted daily for many consecutive sessions. Observations were systematically logged and photographs were taken without any additional source of illumination. Within the chamber, keys were placed 10.5 cm apart, center-to-center, could be transilluminated by colored jewel lights, and required a force of approximately 10 g (0.10 N) to be activated. The upper edge of the feeder aperture was centered 10.5 cm below the keys. A 10-W houselight, illuminated throughout each session, was located in the top right-hand corner of the wall containing the keys and feeder. The chamber was housed in a dark room equipped with a source of white noise. A blower behind the wall containing the keys provided ventila-

tion and additional masking noise. Electromechanical recording and scheduling equipment was located in an adjacent room.

Procedure

Experienced birds were retrained, over a period of two days, to peck either key when transilluminated with a green keylight. Initially, brief exposures of the green keylight were gradually extended until birds were pecking it throughout presentations approximately 8 sec long. Naive birds were magazine trained in two days with no keylights present. Next, all birds were exposed to the experimental procedure described below.

Trials were separated by intertrial intervals averaging 30 sec and ranging from 15 to 60 sec, in 15-sec intervals, during which white lights illuminated both keys. At the end of each intertrial period, a pretrial stimulus (blue lights) illuminated both keys for 3.2 sec. Key pecks during the white and blue periods had no consequences. Upon termination of the pretrial stimuli, both keys were illuminated with green lights. If no key pecks occurred during the green stimuli these remained on for 8 sec, at the end of which food was presented for 3.5 sec. Both keys were darkened during feeder presentation. If a key peck occurred on either key during presentation of the green stimuli, both keylights immediately changed to white for the remainder of the trial (including feeder duration) and no food was presented. Onset time of the next trial was thus not altered by responding. Pecks on the dark keys, when the feeder was raised, also cancelled access to food. All key pecks produced a momentary orange illumination of the key, except when a key peck terminated the trial and cancelled the delivery of food, i.e., when a response changed the green lights to white. Sessions were conducted daily, weight permitting, and each consisted of 50 trials.

RESULTS

The number of trials in which a key peck terminated the trial and cancelled food is presented in Figure 1. The number of peck-terminated trials gradually declined in all subjects, although the extent of this decrease varied among birds. In general, initially high proportions of peck-terminated trials (over 80% for most birds in the early sessions) were often followed by sharp reductions and these,
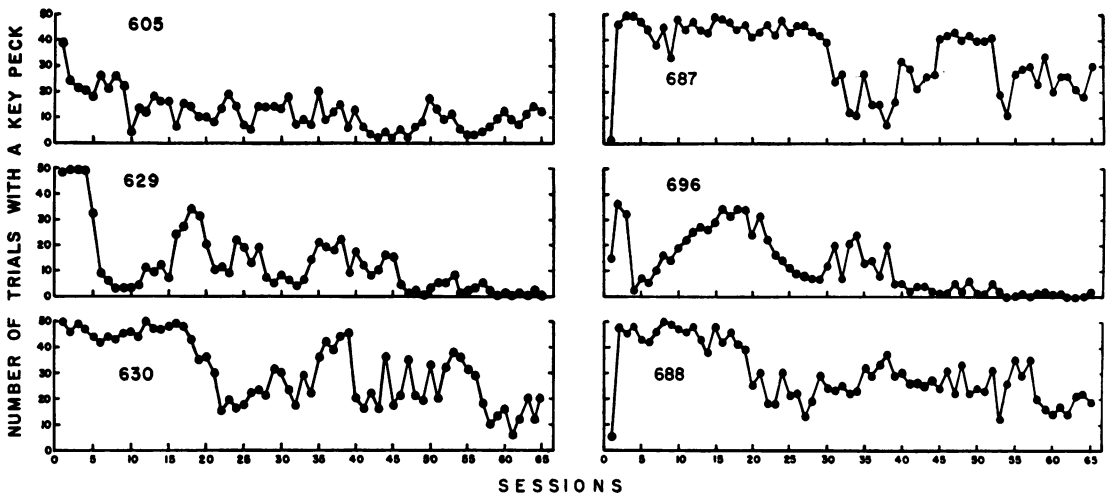
Fig. 1. Number of trials in which a key peck terminated the food signal and cancelled the delivery of food. Each session was composed of 50 trials. Data for experienced subjects are presented on the left and for naive subjects on the right.

in turn, were followed by erratic variations that in the long term tended toward clearly lower levels of key pecking. The key pecking of two birds (696 and 629), in fact, virtually disappeared within approximately 60 sessions.

By the end of the experiment, key pecking on more than 50% of the trials was not maintained for any bird and pecks terminated only a mean of about 25% of all trials. Although by the last 10 sessions mean key pecking during trials by experienced birds was less than the mean key pecking by naive ones, this difference was not statistically significant. No substantial differences in performance between the two groups of birds were otherwise evident, suggesting that the persistence of responding was unrelated to the initial mode of generating the key-peck response (*i.e.*, hand shaping or autoshaping).

The preceding results indicate, then, that with extended exposure to the food-omission contingency, key pecking consistently declined in all subjects and was nearly eliminated in some. However, although pecks on the keys decreased, all birds developed persistent rates of pecks that stopped short of the keys or that struck adjacent areas of the wall containing the keys. This offkey behavior during trials gradually came to predominate and developed into very idiosyncratic high-rate patterns. Table 1 presents data collected on these offkey

pecks by an observer for the last two or three sessions for each bird.[2]

High rates of offkey pecks characterized the terminal behavior of all subjects and appeared to be comparable across birds. The right-most column of Table 1 presents the percentages of total pecks that operated the keys during trials for sessions in which offkey pecks were recorded. These data illustrate the exceedingly small proportion of pecks that actually made contact with the keys. Although most birds pecked the wall and air very near to and around the keys, in no case did key pecks account for more than 2.5% of pecking; they averaged roughly only 1% of all pecking observed during trials.

Many of these offkey pecks struck the wall containing the keys, and carbon-paper scatter records (Bachrach, 1966) of their spatial distributions were obtained. Figure 2 presents

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[2]Interobserver reliability scores were computed by dividing the smaller by the larger count of pecks on each separate trial. All observers had experience recording pigeon behavior. Average reliabilities per session ranged between 0.903 and 0.946, and differed little across birds (0.923 to 0.925) or successive observing sessions (0.911 to 0.937). Response definition of pecks was done by direct demonstration, *i.e.*, before the observing session proper, pecks were pointed out to the auxiliary observers and differentiated from other nonpecking topographies (such as jerky head movements, bobbing or swaying) idiosyncratic to each bird.

Table 1

Proportion of offkey pecks during trial presentations (last two to three sessions).

Pigeon	Mean Pecks/ Session	% Key Pecks/ Session
605 (E)	807	1.57
687 (N)	1032	2.18
630 (E)	1479	1.10
688 (N)	805	2.48
629 (E)	1307	0.00
696 (N)	1200	0.08
Experienced Birds (E)	1198	0.89
Naive Birds (N)	1012	1.58
All Birds	1053	1.23

records collected on the day following the last experimental session for five of the six subjects. In general, direct perpendicular pecks at the wall are seen in Figure 2 as punctuate marks, whereas glancing pecks, *i.e.*, pecks made just short of the keys or wall that described a curved path and that struck the wall tangentially, are recorded as short lines. The records for Birds 605 and 688 were characterized by a predominance of the glancing type of peck, which corresponds to the offkey peck often described as "biting in thin air". In contrast, Birds 630 and 687 engaged mostly in direct pecks above the right key and differed from each other in the distance of the target area from the key and the breadth of area pecked. Bird 630 appeared to nibble on the edge of the key aperture or just above it; Bird 687, whose pattern was more variable, tended to peck higher above the key but with its beak more widely open, often hitting the top section of the key with its lower beak. Bird 696's record was punched at the site of the preferred location of pecking, a screw-head above and to the left of the left key. No record was obtainable for Bird 629, whose entire pecking during each trial was directed at the one-way mirror. Except for Bird 629, which nevertheless pecked close to the front wall, Figure 2 shows that all birds pecked very close to the keys, usually within a 3- to 4-cm radius, illustrating the narrow differentiation of the pecking response.

As do the offkey peck counts, the scatter records document the strong tendency of the birds to shift pecking away from the keys. This redirection of the pecking response shows that birds engaged predominantly in forms of
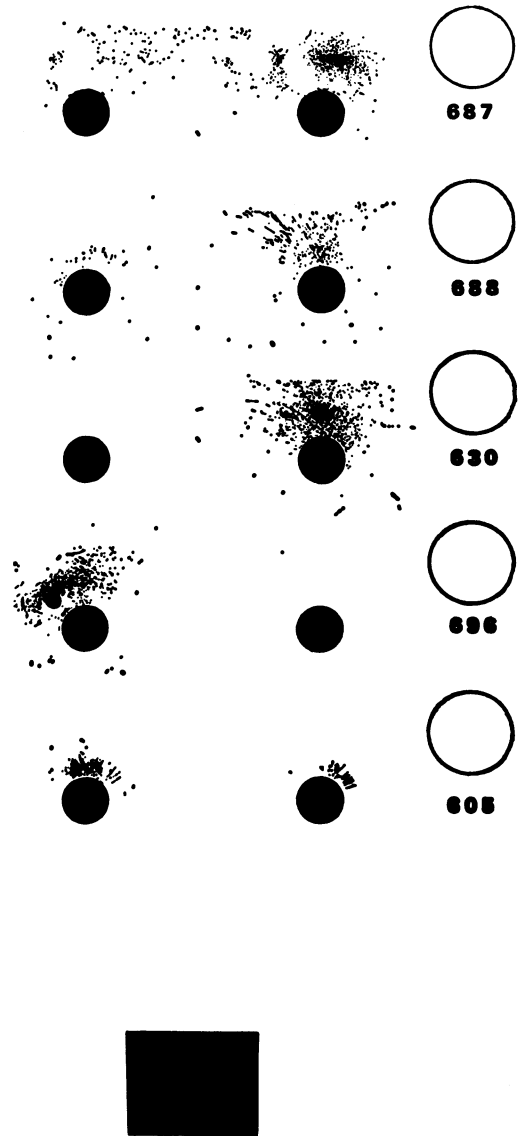

Fig. 2. Records of redirected offkey pecks that struck the wall containing the keys. The circle at the far right of each record shows the location of the houselight relative to the keys, and the dark square the location of the feeder aperture relative to the bottom record.

pecking other than those resulting in the cancellation of food. In addition, the scatter records illustrate the extent to which the terminal frequency of pecks that operated the keys depended closely upon each subject's offkey-pecking topography. For example, birds that pecked very close to the keys (*e.g.*, 630) operated them more often than birds that pecked at areas well removed from the keys (*e.g.*, 629). Similarly, birds with well differ-

entiated and stereotyped topographies (*e.g.,* 696) pecked the keys less often than birds with more variable patterns (*e.g.,* 688).

Figure 3 presents some typical examples of each bird's terminal pecking topography during the last 10 to 15 sessions of the experiment, illustrating the patterns that developed after protracted exposure to the food-omission contingency. The most successful pecking topographies, in terms of avoiding the keys, are shown by Birds 696 and 629. Bird 696 is shown pecking toward a screw-head; Bird 629, crouching and pecking the mirror. Birds 605 and 688 are both shown offkey pecking just short of the key. Bird 605 often pecked more than an inch short of the keys; Bird 688 usually stood much closer to the wall and pecked higher above the keys with very erratic patterns. Finally, Birds 630 and 687 are shown in the distinctive patterns that predominated in the later portion of the experiment, Bird 630 nibbling slightly above the right key, and Bird 687 pecking along the wall with its open beak. Both of these topographies often operated the keys, *i.e.,* by striking them with the closing motion of the lower beak, even though the birds were clearly not pecking directly at the keys.

In all subjects, offkey pecking underwent several changes before reaching the above described terminal stages. During the first five sessions, highly directed key pecking, *i.e.,* within 2 sec of trial onset, predominated in most subjects. On trials in which no key pecks occurred birds mostly paused, often looking first at one key, then at the other, and sometimes emitting weak intentional pecks in the direction of a specific key without contacting it. For one bird (696) offkey pecks preceded key pecking; for all naive subjects, the mean number of offkey pecks observed in the first two or three sessions was approximately 0.4 per trial. Although experienced birds did not initially peck offkey, by Session 10 all subjects were observed to do so with some regularity. Other responses (turning around, pausing, head swaying), however, were also noted to occur during trials and to be likewise followed by food presentations. By Session 10, the rapid and direct key pecks of earlier sessions no longer prevailed; for the remainder of the experiment, key-peck latencies were largely determined by each subject's specific offkey topographies. For example, Bird 629 for some time pecked the wall between and under the keys (Sessions 20 to 45), but drifted toward them in the second half of the trial; this resulted in somewhat long key-peck latencies. Similarly, Bird 696 engaged temporarily (Sessions 10 to 25) in air pecks that barely avoided the keys, with the result that its key pecks tended to be evenly distributed across the trial during these sessions. During the last portion of the experiment, two other birds (630 and 687) occasionally pecked the dark keys, *i.e.,* when food was presented; this delayed responding was also determined by topographical modifications. Thus, whereas Bird 630 usually pecked above the right key and then gradually approached it, in later sessions it tended to begin pecking at a point higher above the rim of the key aperture.

Topographical shifts of offkey pecking also resulted, to some extent, in shifts of pecking from one to the other key. Abrupt declines in pecking at a preferred key were often noted and, in some cases, accompanied by a shift of pecking to the other key. When these shifts between keys did occur, they were more likely than not to be preceded by several sessions
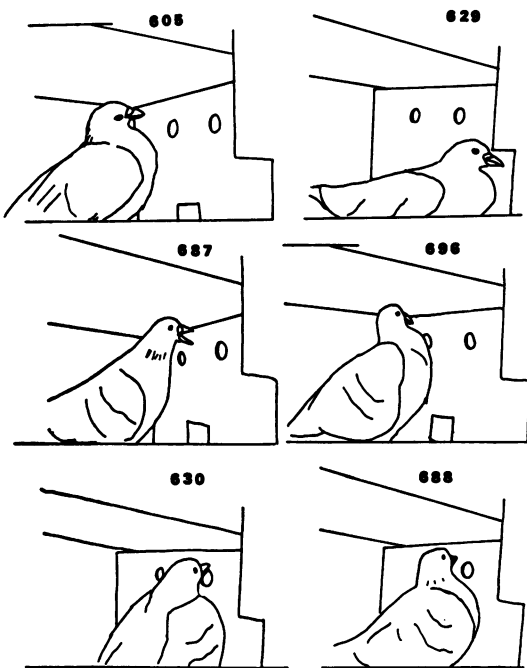

Fig. 3. Line tracings of photographs taken during the last 10 to 15 sessions of the experiment. Note that camera angle differed across subjects. Individual topographies are described in the text.

in which peck-terminated trials exceeded the proportion of food-terminated trials. In other cases (*e.g.*, Sessions 5 to 29 for Bird 687; Sessions 22 to 65 for Bird 630), however, sustained food cancellations on a single key led instead to changes in the pecking topography around that key, as partly evidenced by the marked instability and variability of such behavior (*cf.* Figure 1).

In summary, then, topographical changes across sessions entailed gradual as well as abrupt shifts, and many of the intervening pecking patterns were transitory and clearly unstable; novel peck topographies often appeared whenever extant or previous patterns became highly correlated with extensive food omissions. These results suggest that although avoidance of key contacts was frequently erratic, key-averting topographies were consistently selected in all birds.

DISCUSSION

When hungry pigeons' key pecks to a stimulus signalling the imminence of food resulted in the cancellation of food, key pecking gradually declined in all birds. The proportion of peck-terminated trials dropped from about 80% in initial sessions to levels ranging from only half to virtually none of the trials by the last 10 sessions. Although the decline of key pecking seems by itself sufficient to demonstrate its sensitivity to the food-omission contingency, this susceptibility was also evident in other aspects of the birds' responding. For example, the pigeons' tendency to shift from one key to another suggests that birds left a key on which a number of food presentations had been cancelled, even though pecking then increased on the other key.

Susceptibility to the response-dependent omission of food was more sharply evident, however, in the gradual predominance of pecks that did not contact the keys and thus successfully avoided the food-omission contingency. This selection of topographical variants that evolved away from those that caused food cancellations demonstrates clearly the pigeon's sensitivity to the contingency, and therefore questions the concept of automaintenance, insofar as this concept implies that key pecking is either unresponsive or unaffected by the food-omission contingency. Although offkey pecking, as a collateral measure of sensitivity, was first reported (Dunham,

Mariner, and Adams, 1969) for a shock-presentation procedure, the emergence of redirected pecking in the food-omission procedure seems to be well substantiated and has thus far been observed by Kirby (1968), Moore (1971), and Wasserman (1972). Similar abortive behavior was reported by Gamzu (1972) in his failure to obtain "auto-maintained" responding in the squirrel monkey, and by Radiker and Parker (1973) for the Japanese quail.

The observed redirection of pecking renders unlikely the possibility that the relative slowness in the decline of key pecking may in itself be due to some inherent unmodifiability of the pecking response. Rather, it appears that this slowness was primarily due to topographical variables such as the shifts of peck topographies (*e.g.*, of location or angle of peck) observed across sessions. The slow decline of pecking may thus be best characterized as a result of the gradual elimination of different variants of responding. This underscores the importance of prolonged exposure to the experimental contingencies, inasmuch as a greater number of sessions allowed a greater elimination of key-contacting variants. This indirect relation between length of exposure and reduction of key pecking appears to be already confirmed by two other studies (Herrnstein and Loveland, 1972, Experiment 4; Wasserman, 1972, Experiment 7). In the first of these studies, exposure to a larger number of sessions with a similar procedure reduced responding below the 25% reported here (to 10% of the trials); in the other, exposure to approximately half the sessions studied here reduced responding to slightly above the present average (to 35% of the trials).

The slow decline of key pecking also appeared related to some birds' characteristic pecking styles, *e.g.*, Bird 687's gaping topography, or the high-rate fluttering peculiar to Bird 630. Although such pecking styles remained largely unmodified during the experiment, and although the food-omission contingency succeeded in displacing them from the keys, such displacements typically required a large number of sessions. Since only a small proportion of these pecks actually struck the keys (*cf.* Table 1), it is possible that such slow drifts off the keys were influenced by the relatively low probability with which pecks "spilled" onto the keys and cancelled food presentations. Current research indicates that

intermittent food omissions may, under certain conditions, maintain key pecking relatively intact for longer periods.

In summary, the present results suggest that the main impact of the food-omission contingency consisted of topographical modifications, namely, ostensive changes in the modal loci and spatial distributions of pecking. As these distributions shifted, the likelihood of key pecks was accordingly modified, leading to greater or lesser levels of key-peck persistence. These results also suggest that the reduction of trials without food appeared alone sufficient to maintain key-pecking avoidance, and that therefore the basic mechanism of selection was the maintenance of offkey behavior by nontermination of the food signal. Thus, pecking at the food signal, once acquired, continued to be always generated and constrained by its normal causal factors (cf. Shettleworth, 1972), while the food-omission procedure directly affected, and eventually tended to eliminate, all pecks that came into contact with the contingency, i.e., pecking was moved off the keys.

EXPERIMENT II

In order to assess the extent to which offkey pecking in Experiment I was dependent only upon the consequences of key pecking, pigeons were exposed to identical conditions as in that study, except for the food-omission contingency. This comparison was deemed especially necessary because it has been observed that in some cases, offkey pecks appear to be part of the generalized approach-contact activity characteristic of autoshaping. In order to determine more clearly the effect of the food-omission contingency upon key pecking, the same pigeons were subsequently exposed to the food-omission procedure. Comparisons of baseline and food-omission performance could thus allow a more accurate determination of whether the contingency merely increased offkey pecking topographies already present before the food-omission contingency was introduced, or if the main action of the contingency was to redirect pecking away from the keys.

METHOD

Subjects and Apparatus

Six White Carneaux male pigeons served. Four of these were naive (Birds 689, 699, 700,

and 701), and the other two had histories of color discrimination training (Birds 611 and 608). Running weights and home-cage conditions were identical to those of Experiment I. The same apparatus and a similar schedule of observations were used.

Procedure

As in the previous study, experienced birds were retrained to peck the keys when transilluminated with green keylights, and naive birds were magazine trained. Next, all birds were exposed to the same procedure as in Experiment I, except that key pecking had no consequences, i.e., key pecks did not terminate the trial stimulus or cancel the delivery of food. After 40 sessions of 50 trials each with this response-independent procedure, the food-omission contingency for key pecking during trials was introduced as in Experiment I; i.e., the first peck when the keys were green changed the key color to white and cancelled food delivery. Twenty sessions later, the response-independent procedure was re-introduced for three sessions and followed by five extinction sessions, in which no food was delivered but the trial stimuli continued to be presented at intervals as before.

RESULTS

Performance in the last five sessions (36 to 40) of the response-independent procedure, during which offkey pecks were also recorded, is shown on the left panels of each individual subject in Figure 4. Total pecking rates, counting both pecks on and off the keys were relatively similar for all subjects, except that Bird 700 pecked at a somewhat lower rate. The proportion of pecks that closed the key switches was highly variable. At one extreme, almost all pecks were on the keys (Bird 699); at the other extreme, almost all pecks were offkey (Bird 608).

Direct observation revealed that pecking was oriented and directed at the keys in nearly all cases, whether or not the pecks struck the keys. The sole exception was Bird 689, whose pecking was divided throughout the trial between flicking (short, sideway pecks) at the wall near the feeder and pecking at the keys. For all other birds, offkey pecks consisted mostly of short, air pecks that were very close to and directly in front of the keys. Bird 608 tended predominantly to nibble near to or on
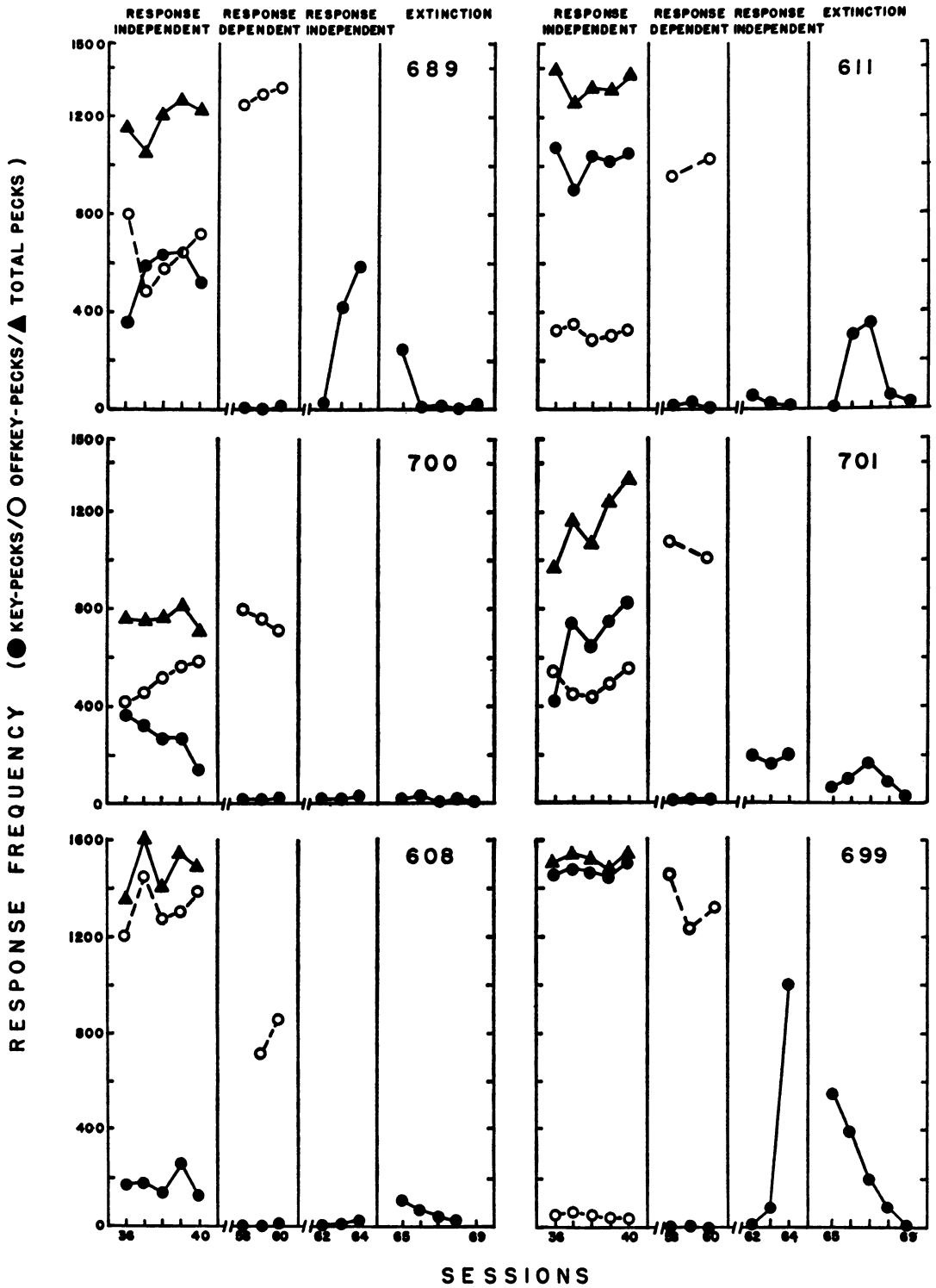
Fig. 4. Response frequencies of key pecks (solid circles), offkey pecks (unfilled circles) and sum of both (triangles), during portions of several experimental conditions. Total pecks are plotted only for the initial response-independent sessions (left panels). Offkey pecks were in some cases not recorded.

the keys' surface, rather than peck them with forward head movements. Bird 699, on the other hand, appeared to peck the key more vigorously toward the end of each trial and would then sometimes hit the rim of the key aperture rather than the key; these near misses constituted the only offkey pecks recorded for this subject. Birds pecked on an average of 92.4% of the trials.

On the day following the last response-independent session (*i.e.*, Session 40), the food-omission contingency was introduced. The effects of this manipulation are shown in Figure 5, which presents the number of trials in which the key was pecked during the last five response-independent sessions and the subsequent response-dependent food-cancellation sessions.

The effect of the food-omission contingency on key pecking was unequivocal and dramatic. Within approximately five sessions, key pecking dropped rapidly to an average of 10 trials per session and remained, for nearly all subjects, well below that level for the rest of the omission condition. By the last five sessions, nearly all birds had either stopped key pecking completely or key pecked at very low levels.

The effects of the abrupt introduction of the food-omission contingency upon birds' topographies were striking. Whereas in Experiment I offkey pecking remained confined to a narrow area around the keys, in this experiment most birds moved rapidly well away from the key area. Four birds withdrew almost completely from the front portion of the chamber; Bird 701 pecked the far-left corner of the front wall; and Bird 689 pecked the area between the magazine aperture and the keys (*i.e.*, the same site at which it pecked during the response-independent procedure). Bird 700 positioned itself in the middle of the chamber, whence it would flex its neck, pause and then slowly engage in deep thrusts toward the upper portion of the wall containing the keys. Bird 611 arched its head in a very pronounced manner, while walking backwards to the wall opposite the keys. In the last portion of each trial, Bird 611 emitted bowing movements combined with long, air pecks. Birds 699 and 608 quickly moved to the mirror at the onset of the food signal; with its back to the keys, Bird 699 pecked the mirror while moving away from the wall containing the keys; Bird 608 walked backwards pecking at

the mirror and pushing it with its body, and ended the trial pecking in the top rear corner of the chamber. (Of the three birds that pecked the mirror—including Subject 629 of Experiment I—only one, Bird 608, was positioned in a way that allowed pecking at reflections of the keys; however, it often stopped pecking the mirror to look at the keys. Hence, mirror pecks may have been directed at the birds' images, but clearly lacked all the intentional threat movements and vocalizations of agonistic behavior.)

In short, then, the overall effect of the food-omission contingency was a marked movement of the birds away from the keys immediately upon onset of the pretrial or trial stimuli, and a pronounced redirection of pecking. These topographies emerged abruptly—within one to six sessions, changed little in the remaining sessions, were highly successful in avoiding the contingency, and, for the most part, consisted of topographies never before observed in these birds. The rapid topographical differentiation obviously affected the persistence of key pecking and when key pecks did occur they were clearly related to the offkey behavior. For example, the relatively higher persistence of Bird 701 was related to the appearance of two distinct topographies: pecking at the wall in the extreme left-front corner alternated, in the last 10 sessions, with short offkey pecks at the right key.

Figure 4 shows that for four birds (689, 700, 701, and 699) the rate of offkey pecking during the food-omission phase roughly matched the total frequency of pecking in the prior response-independent condition. For the two other birds, offkey rates were lower because other, nonpecking responses (walking backwards, bowing, pausing while looking at the keys) were blended into the final offkey topography. Although these data suggest a simple increase of offkey pecking in the omission sessions relative to the preceding condition, almost none of the offkey topographies observed in either phase occurred during the other condition. Furthermore, no significant correlations were found between the extent of offkey pecking in the first phase and any of the parameters (*i.e.*, distance from keys, peck locus, key-peck persistence) of the subsequent differentiation. The relative permanence of offkey topographies was partly evident in the low key-peck rates observed during the sub-
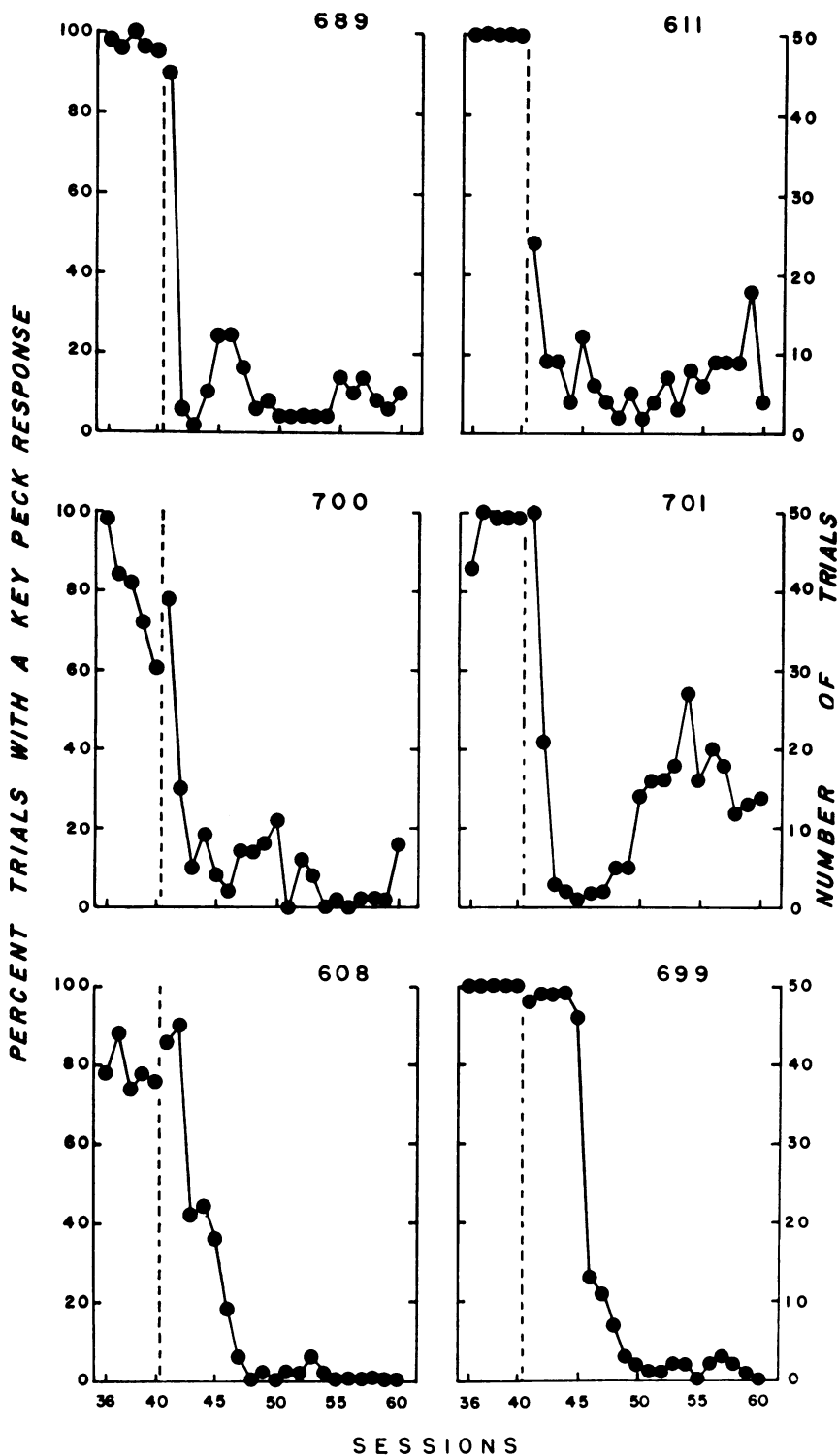
Fig. 5. Number of trials with a key peck during the last five sessions of the response-independent procedure (to the left of the dashed line), and during the response-dependent sessions in which key pecks terminated the food signal and cancelled the delivery of food.

sequent re-introduction of the response-inde-pendent procedure. Although most birds pecked the keys on a larger proportion of trials, the rates remained extremely low for most subjects. That is, recovery of the previous key-directed patterns, during this brief reversal period, was blocked by the incompatible off-key sequences.

Finally, in order to test whether the sharp decline of key pecking could have been due to an abrupt decrement in the rate of food pre-sentations, as might occur during the food-omission contingency, and not directly to the contingency between key pecking and food cancellation, birds were exposed to five extinc-tion sessions. During these sessions, most birds at first alternated between key pecking and their previous offkey patterns. As general activity diminished, key-averting patterns dropped out and most subjects tended to ap-proach the keys, resulting in moderate in-creases of actual key contacts (see, *e.g.,* data for Birds 701, 611, and 608 in the right-most panels of Figure 4). By the fourth and fifth sessions, birds were mostly inactive and fre-quently roosting, although some key pecks still occurred and birds often looked at the trial stimuli. The topographies differentiated during the food-omission sessions thus extinguished be-fore the decline of key contacts and other key-oriented behavior. In summary, then, the effects of a response-independent reduction in food presentations were opposite to those of the response-dependent food cancellations: birds moved away from the keys during the food-omission phase but approached and re-mained somewhat close to them during the extinction sessions.

DISCUSSION

When pigeons were exposed to a stimulus-correlated food schedule in which key pecking had no effect on the delivery of food, some offkey pecking appeared, but its extent varied greatly across subjects. This finding confirms the observations of other investigators that some offkey pecking is typical of autoshaping. All birds, however, pecked the keys on nearly all trials. Thus, although the number of key contacts varied across subjects, all birds ex-hibited unequivocal and sustained key-directed behavior. This uniform behavioral conver-gence upon the keys contrasted markedly with the performance of birds exposed from the

outset to the food-omission contingency (Ex-periment I). During Sessions 36 to 40, subjects in the response-independent procedure key pecked on a median average of 98.0% of the trials; during the same session, the same mea-sure for subjects exposed to the food-omission contingency from the outset amounted to only 34.0% of the trials.

The difference between groups of birds was even more marked in terms of the pecking topography: almost all birds in the response-independent procedure pecked directly at or in front of the keys; in the food-omission con-dition, almost no pecks were directed at the keys. Thus, whatever the reason for the appear-ance of offkey pecks under standard autoshap-ing conditions, it is clear that the predominance of offkey pecks in the food-omission condition was the result of the contingency. This was un-ambiguously confirmed by the marked re-direction of pecking observed when the re-sponse-independent procedure was replaced by the food-omission contingency. These results amply corroborate and extend the conclu-sions of the previous experiment, namely, that signal-directed pecking is sensitive to and clearly affected by the food-omission contin-gency, and that pigeons will tend to avoid contacting a food signal if such contacts result in the cancellation of food presentations.

Experiments I and II provide respective examples of gradual and rapid centrifugal response differentiations. Although the greater persistence of key pecking in Experiment I suggests that avoidance of the food-omission contingency was achieved only with great diffi-culty, Experiment II indicates that this specific difficulty cannot be accounted by attributing to the pecking response any sort of intrinsic limitations. Rather, the ease, or lack of it, with which the contingency was avoided indicates that a major determinant of key-peck persist-ence was the extent to which birds remained in the vicinity of the keys during trials. Thus, in Experiment I continued proximity to the keys placed birds in an unstable situation in which the probability of key pecks remained relatively high, if erratic, until antagonistic offkey variations were displaced sufficiently to override key-contacting topographies. On the other hand, the marked withdrawal from the keys of subjects in Experiment II, which was clearly the most effective response to the omission contingency, resulted in a swift de-

cline of key pecking and little or no subsequent persistence.

Topographical analyses of food-omission performance in both experiments suggest, then, that the fact to be accounted for is not so much the persistence of key pecking but the failure of subjects in Experiment I to engage from the outset in the appropriate withdrawal response. This failure may be seen as involving two components: one, the absence of rapid initial withdrawals from the keys, and two, the relative absence of marked displacements from the keys throughout the rest of the experiment. In Experiment II, introduction of the food-omission contingency following exposure to response-independent food allowed birds rapidly to discriminate the correlation between pecking at the keys and food omissions. In Experiment I, however, the only frame of reference was that provided by preceding performances, i.e., the effects of specific pecking patterns could be compared only with the outcomes of previous topographies. Hence, forms of pecking that minimally, rather than amply, avoided the contingency were the main types of topographies that tended to be differentiated.

This lack of a reference context may also partly explain why subjects in Experiment I did not withdraw rapidly from the keys at the beginning of that study. It is more likely, however, that other variables specifically affected early food-omission performance. For example, once pigeons began pecking the keys, the reliability of trial stimuli as food signals, as well as the rate of food presentations (i.e., the interfood intervals) were necessarily altered; this may have created enhanced stimulus conditions that commanded more attention. There already exists some evidence showing that a combination of unreliable predictors and food signals commands more responding than a food signal alone (Allaway, 1971), that food-omission pecking is initially much more key-directed than standard autoshaping (Wasserman, 1972, Experiment 8), and that autoshaping is acquired much faster with lengthier intertrial, and hence interfood, intervals (Smith, 1972).

Finally, failure to withdraw from the keys could conceivably be attributed to the adventitious reinforcement of nonkey pecking responses (Wessells, 1974). This convenient interpretation does not, however, seem to account why, even though a large variety of other responses were often followed by food early in the experiment, only offkey pecking increased or endured in all subjects. The often abrupt emergence of novel offkey pecking patterns and considerable topographical variability across sessions also seem inconsistent with the notion that specific topographies were strengthened by virtue of their contiguity with food. Thus, although there was an unequivocal correlation between nonkey pecking and food, a correlation that was defined by the contingency rather than by accident, the role of adventitious reinforcements in this correlation appears to be, at best, unclear.

The main difficulty, however, of resorting to an adventitious reinforcement account stems from the fact of autoshaping itself. As noted by Jenkins (in press), if this type of reinforcement had any serious effect in the autoshaping procedure, then keylight pecking would hardly ever be acquired—for many different kinds of responses precede the first peck and are followed by food. Wessells has, nevertheless, proposed that autoshaping, as well as the persistence of key pecking in the omission procedure, are both due to the fact that only "prepecking" responses appear to be selectively reinforced by their contiguity with food. It is not clear, however, if autoshaping actually depends on the food reinforcement of these "prepecking" responses (cf. Zentall and Hogan, 1973), or if an operant reinforcement account is even appropriate (cf. e.g., Catania, 1973, p. 40).

GENERAL DISCUSSION

Sustained key-directed pecking that is experimentally unmodifiable by and insensitive to its food-cancellation outcomes—the defining criteria of successful automaintenance—was not encountered in either of the experiments reported here. The present findings suggest, instead, that attempts to characterize signal-directed pecking as intractable, or the action of the food-omission contingency as ineffectual, must be questioned. These findings indicate clearly that the omission procedure affected all birds' key-pecking topographies.

The present results suggest that persistent key pecking in the food-omission procedure is predominantly the byproduct of an adjusting process, wherefrom redirected pecking grad-

ually prevails. Although key pecking persisted more in some subjects than in others, the extent of this persistence was closely related to antagonistic topographies. Thus, for most subjects, a major determinant of this persistence was the actual distance from the keys during trials. Although marked withdrawals from the keys did not necessarily preclude subjects from approaching the keys during trials and pecking them, most of these approaches were also clearly affected by the contingency: pecks at the keys would often be preceded by vacillation (Hearst, 1963; Hearst and Korensko, 1964), and birds would waver between engaging in their regular offkey sequences and directing their pecks at the keys. This conflict behavior (Hinde, 1970) was especially conspicuous in cases where the loci of offkey pecks were well removed from the keys. It is very likely, however, that less discernible instances of this behavior played a larger role when birds pecked very near to the keys, as this may have both physically limited the range of possible pecking variations and allowed food signals to compete more effectively with alternative pecking targets. Since redirected behavior is a familiar topographical outcome of conflicting approach-avoidance tendencies (Hess, 1962), it is clear that the redirected pecking reported here could well be considered an experimental instance of that phenomenon (*cf.* Burghardt, 1973).

The presence of such persistent responding has, however, been afforded a different standing by other investigators. Williams and Williams (1969) attributed the persistence of key pecking to a special insensitivity of signal-directed pecking to its consequences, and recent reports have in turn attempted to account for this insensitivity by proposing special types of responses (Schwartz and Williams, 1972*b;* Williams, 1972). These investigators have suggested, for example, that signal-directed pecking consists of certain units of behavior, released by food stimuli, which are identified by their short duration (*i.e.*, the "auto-pecks"). Evidence for the special nature of these pecks has been proposed in a threefold argument, according to which short-duration pecks (*a*) appear at the beginning of any appetitive experimental manipulation, which suggests that they are induced by food; (*b*) predominate in the food-omission procedure, which suggests they are insensitive to negative contingencies; and

(*c*) cannot be increased in their frequency of occurrence by differential reinforcement, which suggests that they are insensitive to positive contingencies too.

An alternative account of these findings is that the duration of key pecks does not directly identify the nature of a response but, more simply, its topography. Skinner (1938), for example, noted that brief-duration bar presses also typically occurred in early sessions, even though there is evidence that bar pressing is not a natural food response of hungry rats (Peterson, Ackil, Frommer, and Hearst, 1972). In addition, Ferster and Skinner (1957) noted that initial key pecks were of a light, exploratory kind, usually irrespective of the shaping procedure used—including withholding all food until the first peck occurred. The close relation between peck topography and duration is, however, more clearly brought out when one takes into account the predominance of short-duration pecks in the food-omission procedure. It is here that it becomes apparent that what other investigators recorded as brief pecks were in fact the endpoint of close offkey pecks, the birds' grazing and scratching the keys with the tips of their beaks, and other weak marginal variability of displaced pecking. The dependence of response duration on peck topography (*e.g.*, angle of peck, peck location, direction and depth of thrust) has been amply substantiated by Moore (1971, *e.g.*, p. 128; see also Moore, *in press*).

The strongest linkage, however, between offkey pecking and recorded peck duration is furnished by Schwartz and Williams's finding that short-duration pecks do not increase in standard operant reinforcement procedures, *i.e.*, when food is contingent on *key* pecking. Since it is reasonable to assume that under such conditions offkey pecking would be largely extinguished, it is not surprising that short-duration key pecks tend to disappear with positive key-peck contingencies, for it is unlikely that differential reinforcement of pecks on the key will generate many pecks that fall short of the key or that are redirected away from it. That short-duration key pecks disappear when food depends on key pecking, and that they appear when food depends on not key pecking, thus appears actually to confirm the disruptive effects of the food-omission contingency upon key pecking. If this is the case, then autopecks are not the members of a

special class of elementary and unmodifiable units of behavior; they simply substantiate the sensitivity and modifiability of signal-directed pecking.

In conclusion, the present studies suggest that it may be a serious error to assume that behavior, such as signal-directed pecking, that is ostensibly neither generated by nor dependent upon a strengthening effect of reinforcement, will remain necessarily unaffected when allowed to operate upon the environment. The presumed nature of a response cannot, by itself, determine whether or not that response will be affected by specific environmental consequences. A similar caution may be derived from two recent studies dealing with other stimulus-directed responses. In one (Hoffman, Stratton, and Newby, 1969), it was shown that a negative contingency selectively suppressed the released response of following an imprinted object, even though this response complex, too, has often been considered to be of a special nature (cf. e.g., Bateson, 1966). In the other case (Shinkman, 1973), stimulus-bound eating and drinking responses, which have also been described as species-specific consummatory actions (e.g., Valenstein, Cox, and Kakolewski, 1970), were shown to be actively inhibited when omission of the electrical stimulation that induced these responses was made contingent upon their occurrence. Such findings, in conjunction with those reported here, emphasize the need to examine closely, and directly, the effects and interactions of response-linked contingencies upon these behavioral phenomena, rather than prematurely to invoke special response classes to account for apparent peculiarities. These observations should not be taken to mean that nonoperant response classes, with special constraints and properties, are not to be postulated. Rather, they suggest a careful re-examination of the underlying assumption that there exists a separate and distinct *operant nature* in contradistinction to others. Although reference to an operant response entails only a specific condition, *i.e.*, the fact that the response at issue is related to the environment in a prescribed and conditional manner, it is nevertheless often assumed that a response's relation to the environment implies or creates a differential operant "nature". The present studies furnish evidence contradictory to this assumption, in that pecking at a food signal

was not originated by operant reinforcement, yet it was clearly affected by the imposed contingencies. That is, pecking was induced and maintained by the food signal but was simultaneously affected by its operant condition.

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