

*THE BASIS OF SUPERSTITIOUS BEHAVIOR:
CHANCE CONTINGENCY, STIMULUS SUBSTITUTION,
OR APPETITIVE BEHAVIOR?*

WILLIAM TIMBERLAKE AND GARY A. LUCAS

INDIANA UNIVERSITY

This research examined three explanations for the "superstitious" behavior of pigeons under frequent fixed-time delivery of food: accidental response-reward contingency, stimulus substitution, and elicited species-typical appetitive behavior. The behavior observed in these studies consisted of occasional postfood locomotion away from the food hopper, and a predominant pattern of activity directed toward the hopper wall (wall-directed behavior), including approaching, stepping side to side, scratching with the feet, bumping with the breast, pendulum movements of the extended neck, and head bobbing, though *not* pecking. The consistency of these behavior patterns argued against explanation by accidental response contingencies, and the complexity of behavior was incompatible with the classic stimulus-substitution account. These studies also showed that: (1) response contingencies and prior stimulus experience can modify wall-directed behavior, but within definable limits; (2) pecking sometimes can be obtained in birds of specific strains, and by providing extended training; (3) placing the hopper in the floor at the center of a large chamber replaces wall-directed behavior with circling in a manner that resembles ground foraging for food. We conclude that superstitious behavior under periodic delivery of food probably develops from components of species-typical patterns of appetitive behavior related to feeding. These patterns are elicited by a combination of frequent food presentations and the supporting stimuli present in the environment.

Key words: superstitious behavior, appetitive behavior, behavior systems, stimulus substitution, fixed-time schedules, wall-directed behavior, pecking, pigeons

When pigeons receive food at frequent fixed times independent of their behavior, they rapidly develop a set of relatively stereotyped responses. These responses are typically described as "superstitious" because they emerge in the absence of actual environmental contingencies, presumably like superstitious behavior in humans (Skinner, 1948). The point of the present studies was to explore the form and causation of such behavior in pigeons. We will use the term superstitious (without quotes) to refer to behavior that emerges under a response-independent schedule, but without presumption as to its causation.

The two predominant explanations of superstitious behavior in pigeons are the acci-

dental response-contingency hypothesis of Skinner (1948) and the stimulus-substitution hypothesis as outlined by Staddon and Simmelhag (1971). According to Skinner, superstitious behavior is an operant that occurs under the response-independent presentation of reward because accidental (unprogrammed) juxtapositions of reward and response establish a positive feedback loop. Initial accidental response-reward contingencies raise the probability of a response, thereby increasing the likelihood of further accidental response-reward contingencies, etc. The experimental situation Skinner used to demonstrate superstitious behavior involved the response-independent delivery of grain to a hungry pigeon once each 15 s. Skinner reported that pigeons rapidly developed a variety of characteristic individual patterns of behavior, summarized in Table 1. Most of these patterns were stable over time, although Skinner noted that some patterns drifted in topography, presumably as the result of continued feedback from accidental juxtapositions of food and behavior.

In contrast to Skinner's (1948) view, Staddon and Simmelhag (1971) argued that superstitious behavior patterns are members of

This research was supported in part by PHS Grants S07 RR 7031, MH 39345 and by NSF Grants 82-10139 and 84-11445. We thank Peter Harvey, Dean Hill, Robert Jeffers, and David Martino for their assistance and Don Gawley, Nancy Innis, and John Staddon for comments. We also thank Nancy Innis and Peter Balsam for sharing with us videotapes and films of their subjects. Reprints may be obtained from William Timberlake, Department of Psychology, Indiana University, Bloomington, Indiana 47405.

Table 1

Category comparison: Skinner (1948) and Staddon and Simmelhag (1971).

Skinner	Staddon & Simmelhag
Turn	Quarter circle
Head and neck pendulum	Head movements along magazine wall
Step, hop (dance)	Moving along magazine wall
Thrust head in upper corner	Beak to ceiling
Toss head	Dizzy motion
Brush at floor with beak	Pecking floor
Walk about chamber	Locomotion
	Magazine wall
	Pecking key
	Pecking (wall)
	Pecking window wall
	Flapping wings
	Window wall
	Preening
	Head in magazine
	Head to magazine

a class of terminal responses elicited in anticipation of food rather than accidentally reinforced. In support of this view, they reported that pigeons exposed to short fixed-time (FT) or variable-time (VT) schedules developed a common terminal response of pecking the magazine wall prior to the delivery of food. They argued that the commonality of the pecking response favored an explanation based on elicitation rather than on accidental response contingencies. They also noted that the occurrence of pecking was readily explained by the classic stimulus-substitution hypothesis (Pavlov, 1927), according to which conditioned responses are formed from components of the unconditioned reaction to the unconditioned stimulus (in this case, the food).¹ Prior to the terminal response of pecking, the pigeons also engaged in various interim behavior patterns apparently unrelated to food. The categories of behavior recorded by Staddon and Simmelhag are also noted in Table 1.

Both views have received further support. Herrnstein (1966), Morse and Skinner (1958),

¹ Although they favored stimulus substitution as an explanation for the majority of their data, Staddon and Simmelhag also noted that it was "not adequate as a universal account" (1971, p. 16). They suggested that a number of additional principles of behavioral variation were required to account for more complex behavior (see also Staddon, 1983).

and others have reported more general cases in which animals continued to behave as if a contingency existed between their behavior and reward after the contingency had been removed. On the other hand, Reberg, Mann, and Innis (1977), Reberg, Innis, Mann, and Eizenga (1978), Blaine, Innis, and Staddon (1980), Innis, Reberg, Mann, Jacobson, and Turton (1983), and Innis, Simmelhag-Grant, and Staddon (1983) reported data that extended the stimulus-substitution/elicited-behavior interpretation to longer interfood intervals, to water presentation, and to rats as subjects (although similar results were not found by Fenner, 1980, who reported very little pecking by pigeons on fixed-time schedules).

The main purpose of the present set of experiments was to investigate the obvious disparity between both the empirical results and the theoretical interpretations of Skinner (1948) and Staddon and Simmelhag (1971). The first experiment established the existence of a reliable form of superstitious behavior under a short fixed-time schedule of food presentation. Experiments 2 to 5 tested more directly the importance of response contingencies in determining superstitious behavior. Experiments 6 to 8 investigated the determinants of the terminal behavior of pecking reported by Staddon and Simmelhag. The results of these experiments strongly suggested the alternative hypothesis that superstitious behavior is comprised of elicited components of species-typical appetitive behavior related to feeding. The final study and discussion began an analysis of superstitious behavior from such an approach (Timberlake, 1983a, 1983b, 1983c, 1984; see also Staddon & Simmelhag, 1971; Staddon, 1983).

GENERAL METHOD

Subjects

Unless otherwise noted, pigeons in all experiments were naive female White Carneaux retired breeders (5 to 7 years old), obtained from the Palmetto Pigeon Plant. The birds were individually housed in 30.5 by 30.5 by 30.5-cm sheet-metal cages with 2.54 by 2.54-cm hardware cloth fronts and stainless steel mesh floors. A 12:12-hr light:dark cycle was in effect and water was freely available. During experiments the pigeons were maintained at 77.5% of their ad-lib body weights by sup-

plemental feeding in their home cages within 1 hr after their daily sessions.

Apparatus

The experimental area was contained in a large 81 by 76 by 45.7-cm sound-attenuating chamber. The floor, back, and right walls of the experimental area were the sheet-metal walls of the chamber. In the initial studies, the left wall consisted of a standard two-key Lehigh Valley Electronics pigeon panel centered in a 76-cm long piece of black plywood. In Experiments 4, 5, 7, 8, and 9, this wall was covered by a flat gray 0.32-cm layer of Masonite with an opening for the feeder. This modification made the surface of the wall more uniform and controlled for any effects of the reflectiveness of the aluminum panel. The front wall of the experimental area was the door of the sound-attenuating chamber and contained a double glass window, 61 by 30.5 cm, through which the birds were observed. Lighting was provided in the chamber by two overhead incandescent 60-W bulbs behind diffusing gratings. Masking noise and cooling were provided by two exhaust fans mounted directly over the lighting fixtures. The floor of the chamber was covered with newspaper.

Procedure

Adaptation to the food hopper was accomplished in 1 day by placing the pigeon in the chamber with the hopper raised and illuminated. As soon as the pigeon ate for 10 to 12 s, the hopper was lowered and raised again. Across the next 15 to 20 presentations, the duration of access to food was gradually reduced to 5 s and the time between food presentations was increased to 15 s. Each subject received a total of about 30 presentations on this day. Following feeder training the subjects typically received 20 days of training with 40 hopper presentations per day on a FT 15-s schedule. Each hopper presentation lasted 3 s, except as noted.

The behavior of the pigeons was observed directly by one or two experimenters seated in a dark room approximately 1.5 m from the chamber, and was coded into one of the categories defined in Table 2. The coding categories were developed by modifying the set of categories outlined by Staddon and Simmelhag (1971) and Skinner (1948). The stylized drawings in Figure 1 show examples of typ-

Table 2

Behavior categories, with subcategories indicating variations coded within the major categories.

PECKS—A discrete forward or sideways movement of the head in which the beak makes contact with a surface
PECKH—Peck inside or on the edge of the hopper opening
PECKW—Peck other wall areas
PECKF—Peck floor, either with sideways brushing motion or direct peck, most often related to picking up spilled grain
WALLD—Behavior directed to the wall nearest to or containing the hopper
BOB.W—Bob head in front of the hopper wall, either side to side or up and down, usually with head up and neck elongated, but includes low bob on wall as well
HIBOB—A further subdivision of Bob.W used in later studies that included only bobbing directed toward the top of the wall
LOBOB—A subdivision of Bob.W used in later studies that included only bobbing directed toward the bottom of the wall
WALKW—Bob and step back and forth in front of wall
HUG.W—Walk wall while pushing breast against it
SCRAW—Hug wall while scratching and climbing against wall with feet
STAWY—Remain nearly motionless (stand away), most often near a front corner. Posture varies from upright with neck slightly extended to body at 45° with neck less extended
HOPPR—Oriented waiting within 8 cm of hopper with head bobbing
BOB.H—Bob at wall hopper
BOBFH—Bob at hopper in floor
SQTFH—Squat over floor hopper with body horizontal, usually turning in tight arcs around it
ORMID—Active waiting while oriented toward middle of chamber
BOB.F—Bob with head toward floor and not within 8 cm of a wall
BOB.M—Bob toward middle, head up and not walking
LOCOM—Movement around the chamber in upright posture
WALKM—Walk around the chamber
URNS—Turn the body in at least quarter circle
EMOTN—Behavior apparently related to fear or escape
CROUC—Crouch, head low and not extended, tail high
TAILF—Tail flick, a pronounced downward flick of the tail feathers
FLAPP—Repeated wing flapping, sometimes with retraction of feet
GROOM—Preening behavior including wiping of face, nibbling and stroking of feathers with bill, and scratching of body or face with foot
NOMOV—A motionless almost horizontal posture resembling roosting, with head pulled against body; usually occurred only in extinction

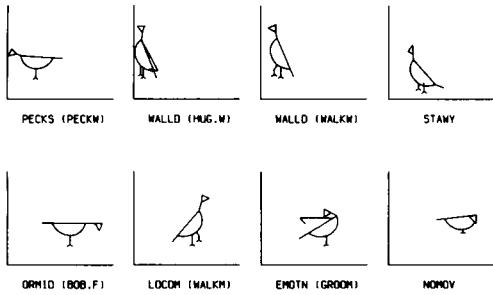


Fig. 1. Stylized drawings of typical postures in relation to the hopper wall (here assumed to be on the left) for most of the general behavior categories. See Table 2 for detailed descriptions.

ical postures for most of the major categories reported in this paper. A category of behavior was recorded when a click was produced every 3 s within the 15-s interfood interval. Additional notes were made on the scoring sheet to facilitate interpretation and recall of the session. In addition, a sample of each bird's behavior was filmed at asymptote. Unless otherwise noted, the data reported are averages based on the last 4 days of each experimental condition.

Four different primary observers were used singly in these experiments. The observers were undergraduates who received either course credit or pay for their work. Each observer read Skinner (1948) and selected parts of Staddon and Simmelhag (1971), and learned the list of behavior categories shown in Table 2. One of the authors (G.A.L.) then sat with each observer for 3 to 5 days while the observer coded each behavior pattern on a data sheet while calling it aloud. Immediate feedback was given for appropriate and inappropriate categorization. This form of guided coding continued until agreement on the major categories was close to 100%. Subsequent tests of interobserver agreement on the major categories listed in Table 2 have shown above 90% agreement (the agreement for three recent pairs of observers was 92%, 92%, and 93%). All coding was blind to the obtained outcome in the general sense that the observers could expect only results similar either to those of Staddon and Simmelhag (1971) or to those of Skinner (1948). In addition, Experiment 2 was run specifically blind as to which birds had been pretrained to turn and which to peck.

Table 3
Methodological differences between Skinner (1948) and Staddon & Simmelhag (1971).

Characteristic	Skinner	Staddon & Simmelhag
Deprivation weight	75% ad lib	80% ad lib
Intertrial interval	15 s	12 s
Feeder duration	5 s	2 s
Size of chamber	?	Standard
Experience of subjects	Naive?	Naive & experienced
Number of sessions	Few (1-2?)	Very large (>60)
Type of observation	Ad-lib inspection	Systematic categories

THE EMPIRICAL PHENOMENON OF SUPERSTITIOUS BEHAVIOR

EXPERIMENT 1

The purpose of the first experiment was to establish the nature of superstitious behavior in our experimental conditions. An important step in this process was the selection of procedures from the slightly different methodologies employed by Skinner (1948) and Staddon and Simmelhag (1971) that are summarized in Table 3. In this experiment we chose the 15-s interfood interval and 5-s hopper duration used by Skinner. We averaged the deprivation levels by using a 77.5% body weight. We also ran an intermediate number of sessions (20), and used a relatively large experimental area so that the orientation of the birds' behavior with respect to the food source was relatively unconstrained by adjacent walls. As noted above, the behavior of the pigeons was classified into the set of categories shown in Table 2 and was recorded at 3-s intervals during the interfood interval.

Method

The subjects were 4 pigeons maintained and housed as described in the General Method section. These birds had received prior auto-shaping training in standard pigeon boxes (Lehigh Valley). The apparatus, procedures, and recording techniques were those described in General Method, except that each hopper presentation lasted 5 s.

Results and Discussion

Figure 2 shows the temporal pattern of interfood behavior plotted by 3-s intervals and

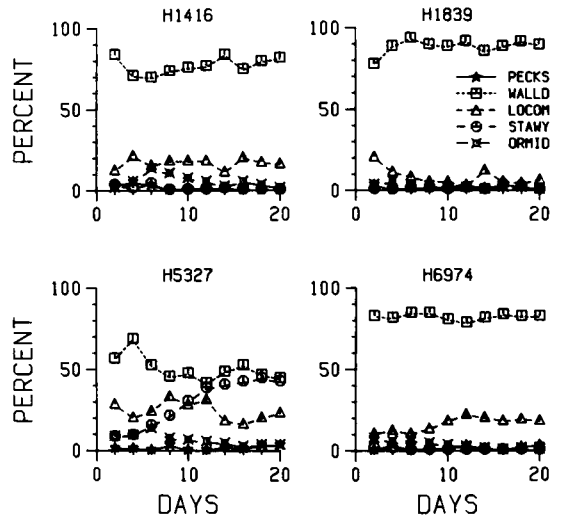
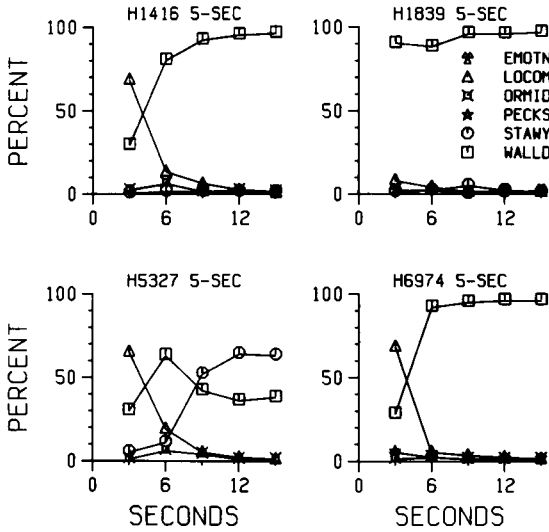


Fig. 2. Percentage of behavior categories recorded in Experiment 1 across 3-s observation points during the interfood interval. Data are means of all intervals for the last 4 days of training. Note that only the four most frequently occurring categories for each bird are plotted.

Fig. 3. Percentage of total behavior categories recorded in Experiment 1 plotted across 2-day blocks. Note that these averages are taken across all the observation intervals.

averaged over all trials in Sessions 17 to 20. In this and subsequent plots, only the four most frequently occurring categories of behavior are shown for each bird. There are two striking findings. The first is that all the birds quickly exhibited almost identical behavior, which could be divided into two broad classes, frequent circling away from the hopper immediately after it was lowered, followed or superseded by the predominant class of repetitive movements along the hopper wall until food was presented. The forms of wall-directed behavior included neck up, head bobbing, pendulum motions of the neck, slightly drawn wings, stepping back and forth, bumping the panel with the breast, and scratching the wall with the feet. An alternative pattern frequently shown by Subject H5327 included standing nearly motionless near the wall and about 20 to 30 cm to the side of the hopper (stand-away).

The overwhelming similarity of the behavior patterns of the different birds makes very unlikely Skinner's contention that accidental contingency is the cause of superstitious behavior. Although there was variation in the birds' behavior, it was definitely secondary to the high level of similarity. It might be argued that Skinner's (1948) observations were made

after a relatively few trials when the behavior was more variable. However, Figure 3 shows that wall-directed behavior emerged during the first block of two sessions. Wall-directed behavior was simply what pigeons did almost immediately in this situation when access to food was regularly presented independent of responding.

The second striking finding was that the topographies we obtained differed from those reported by either Staddon and Simmelhag (1971) or Skinner (1948) in important ways, though they resembled aspects of both. First, although behavior frequently appeared to be divided into two classes that could be described as interim (behavior away from the hopper) and terminal (behavior near the hopper), we never saw pecking of the magazine wall. Instead, the pigeons head-bobbed, stepped, and bumped, often throughout the entire interfood interval. On the other hand, although we saw elements of most of the topographies reported by Skinner, typically these were components of overall behavior directed away from or toward the hopper wall. For example, although head-bobbing (one of the patterns Skinner reported to be accidentally reinforced) increased over trials, all the animals did it in some form. Further, it was typically directed along the wall above the hop-

per, and was accompanied by bumping, stepping, and neck and head motions.

In summary, the results resembled those of Staddon and Simmelhag (1971) in showing a common set of terminal behavior patterns, and often a sequence of different types of behavior within a trial. However, the absence of pecking appeared to rule out the operation of the stimulus-substitution mechanism invoked by Staddon and Simmelhag to explain their pecking results. Similarly, the results resembled those of Skinner (1948) in showing increases in a variety of individual response components. But the overall similarity and patterning of the obtained behavior appeared to violate Skinner's argument that superstitious behavior was produced by accidental response-reward contingencies, and supported elicitation rather than operant response conditioning as the primary causal mechanism.

Although the consistency of these results strongly suggests the importance of elicited, preorganized patterns in superstitious behavior, the data do not rule out a contribution of response-reward contingencies, or the potential importance of pecking. The next group of experiments analyzed more carefully the potential role of accidental response contingencies in producing the obtained behavior. The subsequent group of experiments explored the determinants of pecking in the superstition paradigm.

THE ROLE OF RESPONSE CONTINGENCIES

The experiments in this section explored the importance of response-food contingencies in producing and controlling the behavior obtained in the superstition paradigm. Experiment 2 manipulated the initial probability of particular responses by imposing prior response-contingent food deliveries. Experiment 3 extinguished previously acquired superstitious behavior, and then examined the results of reacquisition. Experiments 4 and 5 assessed the effects of explicit positive and negative response contingencies on wall-directed behavior.

EXPERIMENT 2

In this experiment we modified the initial distribution of behavior by briefly shaping two

responses by means of response-contingent food delivery prior to exposure to the response-independent fixed-time schedule. Our strategy was to develop a response of initial high probability (either wall-pecking or turning) to increase the likelihood of accidental juxtapositions of that response with food. Two birds were trained to peck the magazine wall, and 2 birds were trained to turn in circles. The birds were then introduced to an FT 15-s schedule. During 3 days of response-contingent training, we gradually extended the contingent interfood interval to 15 s so that the animal would less readily discriminate the subsequent transition to a response-independent schedule (Herrnstein, 1966). It should be noted that naive birds were used in this experiment to evaluate the possibility that previous autoshaped training had contributed to the results of Experiment 1.

Method

The subjects were 4 naive pigeons. Housing, feeding, apparatus, and initial pretraining were the same as in Experiment 1. On the first day of training, 2 birds were randomly assigned to a "pecking" condition and the other 2 to a "turning" condition. Coincident with the completion of hopper training, reinforcement of successive approximations was used to shape either pecking at the magazine wall or turning in a circle. On the second day of training, the interfood interval was gradually increased to approximate an FI 15-s schedule with 3-s hopper duration. On the third day of training, each subject received one full session of forty 3-s food deliveries on an FI 15 schedule. On the next day, the birds were transferred to an FT 15 schedule with the same hopper duration; this procedure was continued for 20 sessions. The observer was not informed of the subjects' pretraining.

Results

Figure 4 shows the acquisition of superstitious behavior plotted by two-session blocks. It can be seen that the level of the trained behavior (either pecking or turning), although initially high, declined rapidly as wall-directed behavior emerged. Figure 5 shows that at asymptote the behavior patterns of the birds were similar and resembled those of the pigeons in Experiment 1. The responses of

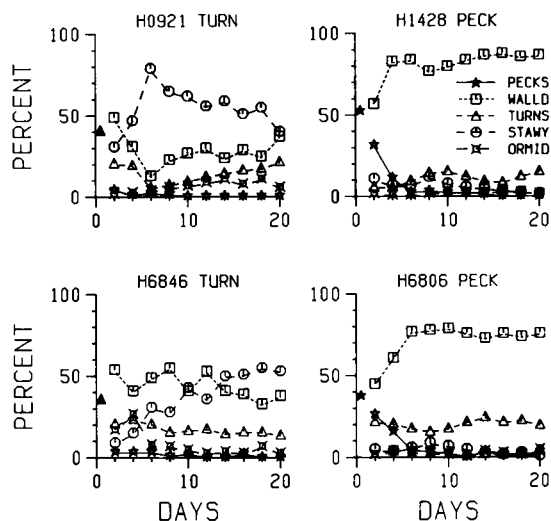


Fig. 4. Percentage of total behavior categories recorded in Experiment 2 plotted across 2-day blocks. The solid points to the left of the first block of days in each graph represent the level of performance of the pretrained behavior on the last day of FI 15-s training.

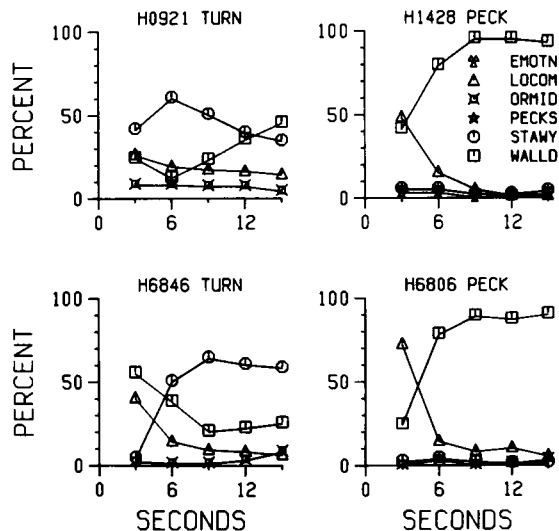


Fig. 5. Percentage of behavior categories recorded in Experiment 2 across 3-s observation points during the interfood interval, during the final 4 days of the FT 15-s schedule of food delivery.

pecking the hopper wall and turning, despite their initial high probabilities, were superseded by a basic set of wall-directed patterns. However, there appeared to be an indirect effect of prior response-contingent training on the components of superstitious behavior that emerged. The birds trained initially to turn rather than peck showed a greater variety of locomotor behavior and more of the stand-away form of wall-directed behavior. Even with these minor differences, the outcome again supports the view that superstitious behavior is basically elicited rather than reinforced, although the elicitation does not fit the classic stimulus-substitution model.

EXPERIMENT 3

In this experiment birds previously trained on an FT 15 schedule were thoroughly exposed to an extinction procedure and then placed again on the FT 15 schedule. Skinner (1948) reported using this procedure with a single bird and finding different responses the second time. He cited this result as proof of the effects of accidental contingencies between responses and food under the FT schedule. When food was reintroduced, simply by chance the contingencies favored a response other than the one just extinguished. It follows that if

accidental response contingencies were at work in our situation, the present birds should show different responses during reacquisition.

Method

The subjects were 4 experienced pigeons. Housing, feeding, apparatus, and initial procedures were identical to the previous experiment. Acquisition for these birds is reported in Figure 11 (Experiment 6b). Following acquisition, no hopper presentations occurred for 12 sessions. Food was then presented again on an FT 15 schedule for 8 days. The hopper duration used in this condition was 2 s.

Results

The data in Figure 6 indicate quite thorough extinction after 12 days of no reward. The birds remained motionless in a single position during nearly the entire session. However, Figure 7 shows that when food was reintroduced, the birds rapidly resumed the typical patterns of wall-directed behavior (see also Figure 11). Thus, on the basis of Skinner's argument, accidental contingencies of response and reward appear to have had little to do with the particular behavior that occurred. The alteration of behavior Skinner (1948) reported may have reflected the devel-

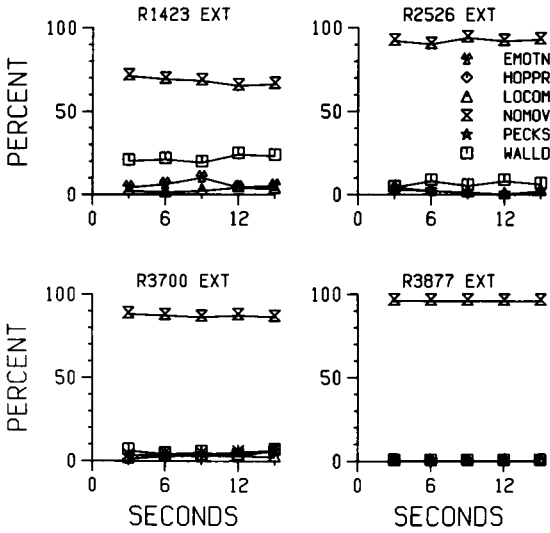


Fig. 6. Percentage of behavior categories recorded during the final four sessions of extinction in Experiment 3, across 3-s observation points corresponding to periods within the interfood interval during the prior and subsequent FT 15-s schedule.

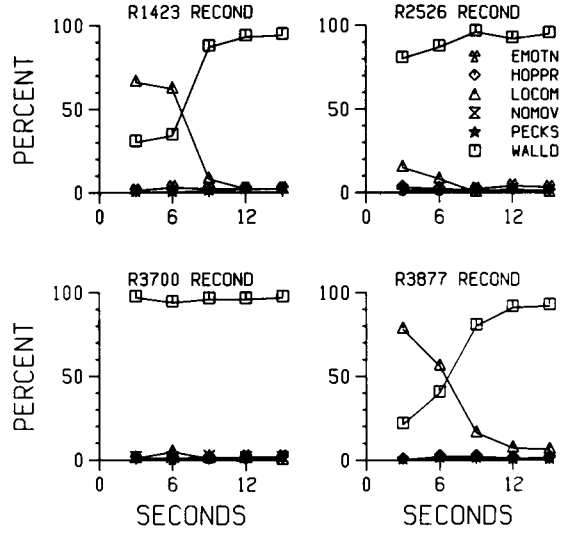


Fig. 7. Percentage of behavior categories recorded after the FT 15-s schedule was reintroduced in Experiment 3, plotted across 3-s observation points during the interfood interval. Data are means based on the final four sessions of the experiment.

opment of alternative forms of wall-directed behavior or a decrease in locomotor patterns as a function of repeated extinction and reconditioning.

EXPERIMENT 4

Although the previous experiments strongly indicate that behavior in the superstition paradigm is based on preorganized rather than newly shaped response patterns, nonetheless, there still may be a role for response-reward contingencies in maintaining and modifying superstitious behavior. In the next two experiments we attempted to modify behavior by making food presentations contingent on responding. In the present experiment, access to food was contingent upon experienced birds' wall-directed behavior (defined as remaining within 8 cm of the panel and within 8 cm of either side of the hopper). In the first operant condition, food was presented immediately when the bird had remained in this area for 3 s. Thus, birds were able to decrease the time to food (and increase the frequency of food deliveries) by returning to the hopper more quickly, or by never leaving the area. In the second operant condition, frequency was held constant by imposing the additional rule that only one food delivery could be produced in each 15-s interval. In both conditions, if the

wall-directed behavior of the birds on the FT 15 schedule was being maintained by accidental response contingencies, the addition of actual response contingencies should produce a rapid increase in the relative frequency and intensity of wall-directed behavior because it now more consistently led to food. However, to the extent that components of superstitious behavior were elicited, the behavior should prove less amenable to easy modification by response-food contingencies.

Method

The subjects were 4 experienced pigeons that had demonstrated moderate to high levels of wall-directed behavior under 20 days of FT 15 delivery of food. In this and all of the following studies (except Experiment 6), the apparatus was modified so that the hopper wall that held the feeder was covered by a flat gray 0.32-cm layer of Masonite. This change made the hopper wall more uniform, thus controlling for the possibility that wall-directed behavior was related to the reflectiveness of the aluminum panel. The experiment had four phases: baseline (FT 15), fixed-duration 3 s, contiguity-promoting 15 s, and baseline (FT 15). Each phase was maintained until responding stabilized and a minimum of 6 days passed.

As discussed above, the fixed-duration 3-s (FD 3) schedule rewarded any approach to the wall that was maintained for a minimum of 3 s. The contiguity-promoting (CP) procedure was an alternative FD 3/FT 15 schedule that provided one 3-s hopper presentation during each 18-s cycle. The first time the pigeon maintained wall-directed behavior for a minimum of 3 s during each 18-s cycle, grain was presented immediately; otherwise, grain was presented during the last 3 s of the cycle. Thus, this schedule promoted contiguity between wall-directed behavior and food delivery while maintaining a constant rate of food delivery.

Results

Figure 8 shows the mean percentage of wall-directed behavior maintained at asymptote under each schedule condition (the two FT 15 baseline conditions produced similar results and were averaged). Under the fixed-duration procedure, 3 of the subjects actually showed a slight decrease in percentage of wall-directed behavior. This decrease appeared to occur because, although the contingency shortened the intertrial interval, the pigeons still walked away from the magazine after eating. Thus, wall-directed behavior made up a smaller portion of the interfood interval. In the case of a subject that previously showed no locomotor behavior (P1186), there was a slight increase in percentage of wall-directed behavior. However, when the length of the intertrial interval was controlled by using the contiguity-promoting schedule, there was no consistent change from the percentage of wall-directed behavior under the fixed-time condition.

The basic topography of the behavior patterns observed under all conditions remained similar. However, for 2 of the birds the mean onset of wall-directed behavior occurred slightly earlier in the interval under the response-contingent procedures. These birds simply shortened the duration of the walk-away pattern.

In sum, explicit response contingencies modified the superstitious behavior of 3 of the birds in some way, but not to the extent or with the consistency one would expect if superstitious behavior were maintained primarily by accidental reinforcing consequences. It might be argued that a ceiling on responding

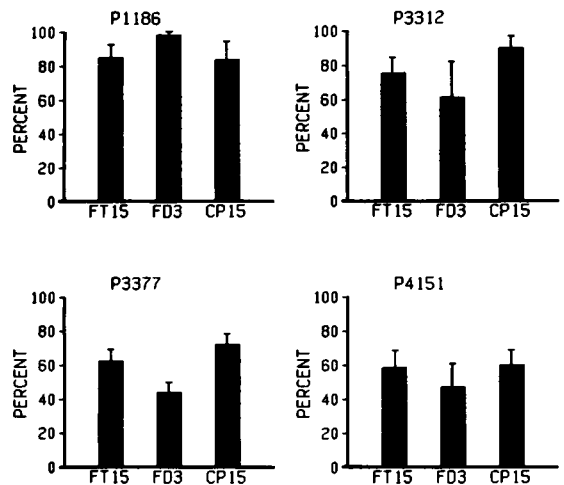


Fig. 8. Percentage of wall-directed behavior obtained under three reinforcement contingencies in Experiment 4. Bars show standard errors of the mean. Data are means based on the final four sessions of the condition.

prevented a marked effect of the response contingencies in one bird; however, this does not account for the maintenance of response topography, nor for the failure of the other birds' rewarded behavior to increase markedly or consistently.

EXPERIMENT 5

In this experiment we trained naive animals on an omission procedure contingent upon active wall-directed behavior. Response-based omission of reward has been a classic method in testing for elicited behavior (Sheffield, 1965; Williams & Williams, 1969). To the extent that wall-directed behavior or related interim components emerge and continue under an omission contingency, an elicited basis for superstitious behavior is better supported. To the extent that wall-directed behavior becomes less frequent, a role for response contingencies in superstitious behavior is better supported. We note that these arguments are not entirely conclusive as to causation of responding (e.g., Jenkins, 1977), but we consider the results of the omission procedure potentially instructive.

Method

The subjects were 4 naive pigeons. The housing, apparatus, and preliminary procedures were identical to those of Experiment

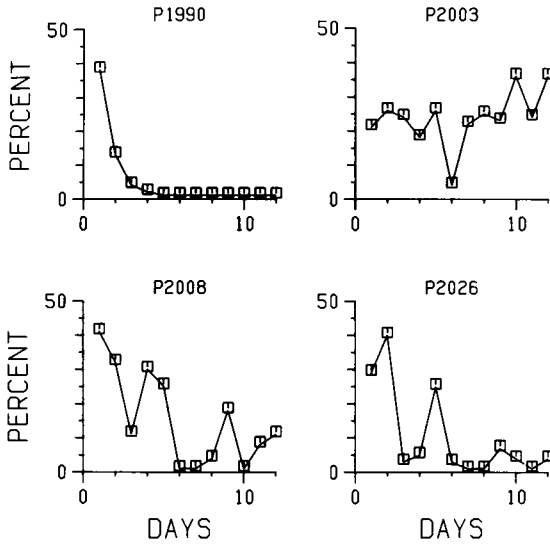


Fig. 9. Percentage of wall-directed behavior obtained in Experiment 5 during successive sessions of an FT 15-s schedule that omitted food deliveries when wall-directed behavior occurred.

4. Food was presented on an FT 15 schedule so long as the bird was not within an area extending 8 cm from the front wall and 8 cm on either side of the hopper during any of the 3-s periods in the interfood interval. An exception was made during the first 3-s interval to allow the birds an opportunity to leave the hopper area after the hopper was lowered.

Results

The percentages of wall-directed behavior recorded across days for each subject are shown in Figure 9. Despite the presence of an omission contingency, all 4 pigeons initially developed a strong tendency to step, bump, and head-bob along the feeder wall. For one Subject, P1990, this wall-directed pattern was quickly replaced by the stand-away pattern. However, another subject, P2003, continued wall-directed stepping and bobbing despite the omission procedure. For the other 2 pigeons, wall-directed responding decreased over days, and the wall-directed patterns were replaced mainly by increased circling and bobbing directed toward the middle of the chamber. Thus, a negative response contingency decreased wall-directed behavior in most birds, but the initial emergence and continued occurrence of active wall-directed behavior still

suggest control by elicitation. Further, that the birds engaged in behavior patterns already observed under response-independent food delivery (e.g., stand away and turn) suggests the possibility that omission had its effect by altering the forms of elicited food-related behavior, rather than by rewarding some arbitrary new responses.

DISCUSSION OF EXPERIMENTS 2 TO 5

These experiments support the view that behavior in the superstition paradigm does not depend primarily on accidental response contingencies, nor is it dominated by pecking, as expected from a stimulus-substitution account. Apparently the behavior depends on the elicitation of preorganized behavior patterns by the frequent presentation of food. Limited forms of wall-directed and interim behavior occurred whether they were previously extinguished, whether pecking or turning had previously been reinforced, whether food deliveries were contingent upon remaining near the hopper, or whether food was contingent upon staying away from the hopper.

However, there were effects of response contingencies on behavior. Although pretraining birds to peck or turn did not produce pecking or turning as terminal behavior patterns, the pretraining did modify the subsequent distribution of responding. Also, making food deliveries contingent upon the birds' standing near the hopper wall affected some aspect of the wall-directed behavior of 3 birds. Finally, an omission contingency for the birds' remaining near the wall markedly decreased the initial level of wall-directed behavior in 1 of the birds and produced a decreasing trend in wall-directed behavior in 2 others.

An interesting discovery in the omission experiment was that when food was omitted for standing near the wall, the birds did not engage in random alternatives. Instead, 1 bird engaged in a stand-away pattern, while the other 2 circled. Both of these types of behavior had been observed previously. Stand-away was typically a much less probable alternative to active wall-directed behavior. Circling away was a predominant pattern following food and preceding wall-directed behavior. Thus, even when the omission contingency was successful in reducing wall-directed behavior, the nature

of the replacement patterns still suggested the existence of preorganized species-typical patterns elicited by the repeated delivery of food. Thus, the results can be used to argue for the existence of a limited hierarchy of behavior patterns related to feeding: If one is punished, another of predictable topography will take its place (cf. Murray, 1973, cited in Williams, 1981).

A final issue was the apparent contradiction of previous data showing that pigeons that were transferred from response-contingent to response-independent schedules continued to peck (e.g., Herrnstein, 1966). In Experiment 2, 2 pigeons stopped pecking and engaged in wall-directed behavior when exposed to this transition. We suggest: (1) Extensive training may markedly increase the dominance of pecking as an appetitive behavior pattern; (2) extensive responding to a lighted key may increase its salience as a target; (3) direct observation of birds in previous studies might have revealed the development of considerable wall-directed behavior accompanying the pecking that was recorded.

Having established the likelihood that behavior in the superstition paradigm is primarily elicited rather than controlled by accidental response contingencies, it is important to begin to analyze what controls the complex set of wall-directed behavior patterns. The experiments in the next section attempted to explore the reasons for differences between the set of elicited behavior patterns we obtained and the apparently simpler pattern of pecking the hopper wall reported by Staddon and Simmelhag (1971) and others.

FACTORS THAT INFLUENCE THE ELICITATION OF SUPERSTITIOUS PECKING

The next several experiments were an attempt to discover what variables might account for the absence of pecking of the wall near the hopper (e.g., Staddon & Simmelhag, 1971). A careful reading of the many articles reporting terminal pecking revealed several possibilities. First, birds that had previous experience in working on schedules were more likely to peck than were naive birds. Only about 50% of naive birds pecked consistently. It should be noted, however, that in Experi-

ment 1 we used birds previously trained on an autoshaping procedure and this previous experience did not result in pecking during our experiment. Whether different or additional schedule experience would have an effect must remain conjecture. Second, there may be strain or gender differences in likelihood of producing pecking (e.g., Fenner, 1980). Third, the shorter, 12-s interfood intervals used by Staddon and Simmelhag increased the frequency of food deliveries and thus may have increased the likelihood of pecking (see Innis, Reberg, Mann, Jacobson, & Turton, 1983; Innis, Simmelhag-Grant, & Staddon, 1983). Fourth, the use of a 2-s hopper presentation may have forced greater attention to the magazine area to avoid missing the food, and this may have indirectly promoted pecking. Fifth, most of the experiments that reported pecking ran for great lengths of time, often 4 to 6 months, instead of the 20 days we typically ran. Pecking may be late-emerging behavior. Sixth, some investigators have included in their pecking category head-bobbing movements that did not actually involve beak contacts. Head bobbing is pigeons' normal pattern of visual scanning (they have very limited eye movement), and may or may not lead to pecking (see Zweers, 1982). It is important, though, to stress that counting head bobs as pecks cannot be the entire story, because there is no question that considerable actual pecking has been obtained. Finally, it might seem that the occurrence of pecking could have been underestimated in the present data because a brief peck would be likely to be missed under a 3-s sampling scheme. However, we removed this possibility after the first experiment by asking the observers to note *any* pecking in an interval, regardless of whether it occurred at the sample point. The experiments reported below explored the contributions of many of the above circumstances to the elicitation of pecking.

EXPERIMENTS 6A AND 6B

Experiments 6a and 6b tested the possibility that a short, 2-s hopper presentation would result in terminal pecking. A short hopper duration might cause the birds to remain close to the hopper and thus increase the likelihood of their pecking the wall. In Experiment 6a birds with previous experience with a 5-s

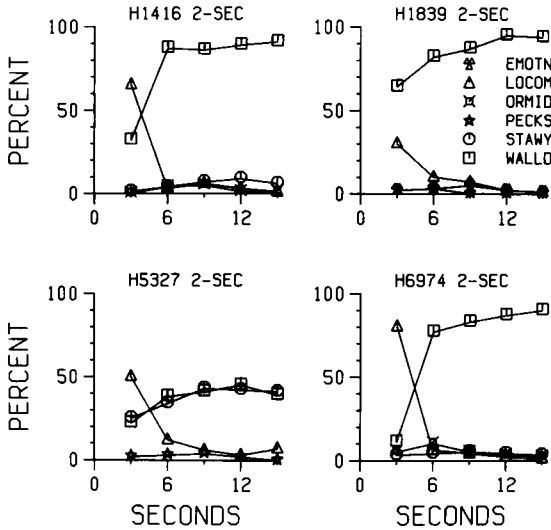


Fig. 10. Percentage of behavior categories recorded for the experienced birds in Experiment 6, plotted across 3-s observation points during the interfood interval. Data are means based on the final four sessions of the experiment.

hopper duration on an FT 15-s schedule were shifted to a 2-s duration. Experiment 6b continued this investigation by exposing naive birds to an FT 15-s schedule with a 2-s duration from the beginning of training.

Method

The subjects for Experiment 6a were the birds used in Experiment 1. The subjects for Experiment 6b were 4 naive birds. Housing, feeding, apparatus, and basic procedures were the same as in Experiment 1. Each set of animals received 40 2-s hopper presentations each day. The experienced birds received 10 daily sessions of this procedure; the naive birds received 20 sessions.

Results

The results for both sets of birds were similar and are shown in Figures 10 and 11. The subjects showed little behavior that resembled pecking of the hopper wall. Instead, they showed the now familiar sequence of some locomotor behavior after obtaining food, followed by wall-directed behavior until the next delivery of food. Again, the wall-directed behavior was predominantly wall "hugging," including bumping, stepping, pendulum motions of the head and neck, and bobbing of the head. Only a few birds showed the passive

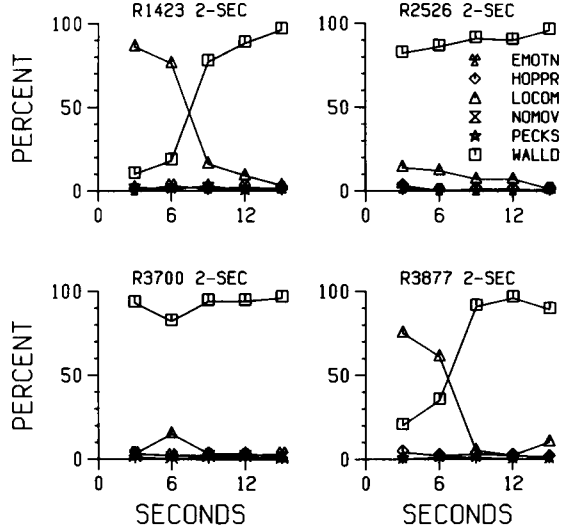


Fig. 11. Percentage of behavior categories recorded for the naive birds in Experiment 6, plotted across 3-s observation points during the interfood interval. Data are means based on the final four sessions of the experiment.

stand-away form, and only one, H5327, showed it more than occasionally. Thus, the 2-s hopper duration did not by itself increase the likelihood of pecking.

EXPERIMENT 7

Experiment 7 explored the possibility that differences in strains of birds may account for differences in the elicitation of pecking the hopper wall as a type of terminal behavior. For example, Fenner (1980) reported very little pecking in White Carneaux pigeons in a superstition paradigm, but more pecking by White King and Silver King pigeons. Thus, Experiment 7 used female White Kings as subjects in an attempt to increase the likelihood of pecking. Innis, Simmelhag-Grant, and Staddon (1983) reported that pecking almost never occurred at intervals greater than 12 s, although wall-directed behavior continued to occur at intervals up to 300 s. Interfood intervals as short as 6 s appeared to increase the likelihood of pecking (see also Innis, Reberg, Mann, Jacobson, & Turton, 1983). Thus, in a second phase of Experiment 7 we decreased the interfood interval from 15 to 9 s.

Method

The subjects were 4 female White King pigeons. Housing, feeding, apparatus, and pretraining procedures were similar to Ex-

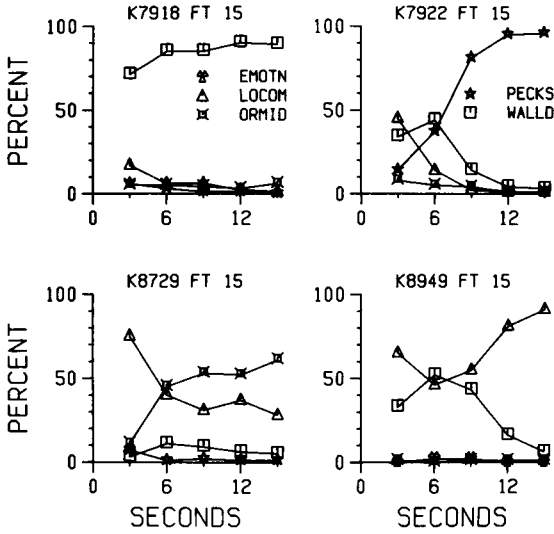


Fig. 12. Percentage of behavior categories recorded for the White King pigeons in Experiment 7, recorded across 3-s observation points during the interfood interval under an FT 15-s schedule. Data are means based on the final four sessions of the condition.

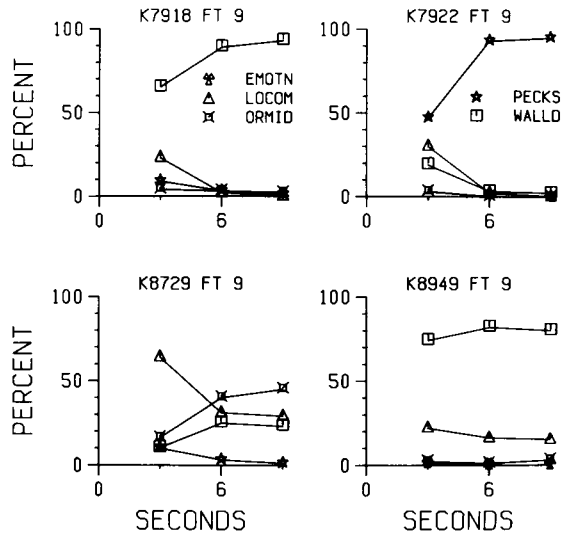


Fig. 13. Percentage of behavior categories for the White King pigeons in Experiment 7, across 3-s observation points during the interfood interval under an FT 9-s schedule. Data are means based on the final four sessions of the condition.

periment 1, except for an initial exposure to an FT 15-s schedule with a 3-s hopper presentation through a hole in the floor of the chamber, 20.3 cm from the plywood wall. Following 16 sessions of this condition, the birds were switched to the usual wall-mounted feeder for the 8 sessions reported here. Following this procedure the schedule was changed to an FT 9-s schedule for an additional 8 sessions. Data are reported from the last 4 days of each of the two conditions with the hopper in the wall.

Results

As shown in Figure 12, for one of the birds (K7918) the results were very similar to those obtained before. Behavior was largely divided into a moderately probable leaving of the hopper area, followed by wall-directed behavior that continued until the delivery of food. However, 2 birds showed considerably more locomotor behavior, and the fourth, K7922, developed a persistent pattern of pecking the wall below the hopper. Pecking in this bird emerged when the feeder was in the floor and was directed at the rim of the floor-hopper aperture. When food was delivered from the wall, the pecking moved to the area below that hopper. Changing the interfood interval to 9 s, as shown in Figure 13, increased the percent-

age of pecking for K7922 and the percentage of wall-directed behavior for the other birds.

Although not definitive, our results are consistent with Fenner's (1980) demonstration of small strain differences in the amount of superstitious pecking, and suggest that a reason pecking has been reported more frequently in some previous experiments is that these experimenters typically used strains other than Carneau, such as Silver King or White King. Further, the results indicate that a 9-s interfood interval produces a greater proportion of wall-directed behavior of all kinds than does a 15-s interval. These results may have been highlighted in the present data because the prior training with the hopper in the floor appeared to produce an unusually large amount of locomotor and orient-to-the-middle behavior. However, this behavior is unlikely to represent a strain difference because similar behavior was obtained using a floor hopper with Carneau pigeons in Experiment 9.

EXPERIMENT 8

The final possible factor affecting pecking that we explored was the large number of sessions typically used in experiments reporting pecking. Although we had previously run birds in Experiments 1 and 6a for a combined total of 40 days without obtaining pecking, none-

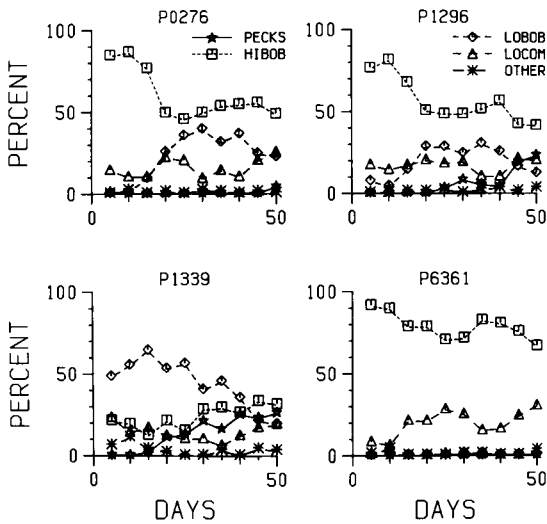


Fig. 14. Percentage of total behavior categories recorded in Experiment 8 plotted across 5-day blocks.

theless, experiments in which pecking is typically obtained use an even greater number of trials and no change in conditions. In this experiment we observed 4 naive female White Carneaux pigeons for a total of 50 sessions.

Method

The subjects were 4 naive pigeons. The housing, feeding, apparatus, and pretraining were similar to Experiment 1. The birds were exposed to 50 sessions with an FT 15-s schedule with a 3-s hopper duration.

Results

As shown in Figure 14, the results support the importance of extent of training as a variable contributing to pecking. Two birds eventually pecked on approximately 20% of the sample intervals. Subject P1339 began pecking the hopper wall frequently around Session 20, and Subject P1296 around Session 45. However, it is important to note that even for these 2 birds, pecking was not the dominant pattern of behavior. They engaged in non-pecking wall-directed behavior more often than they pecked.

An interesting aspect of the results was the occurrence of characteristic sequences of topographies that preceded the development of pecking. Both birds began with the components of typical wall-directed behavior, body and head erect, bumping, stepping, neck pen-

dulum movements, and head bobbing. The birds began to peck only after assuming a more horizontal posture for a number of days while continuing to head bob in front of the panel (low bob). The subject that began pecking earliest, P1339, also showed the earliest emergence of this low-bob posture. Stepping, pendulum motions, and bumping decreased at this point. After a variable number of days in this low-bob posture, the birds began to peck the hopper wall, typically within several inches of the top of the hopper opening, but not inside it.

DISCUSSION OF EXPERIMENTS 6 TO 8

These results supported our previous conclusion that a relatively small and consistent number of interim and terminal behavior patterns dominate the superstition situation. Under nearly all conditions, the pigeons engaged primarily in wall-directed behavior of the typical form. It remains difficult to argue that the overall reliability of this behavior arises from accidental response-reward contingencies. Although there were variations in response topography, these variations occurred in a context of similarity that suggests that components of a preorganized set of behavior patterns is readily elicited in the present stimulus circumstances by the periodic presentation of food.

We were able to obtain a small amount of pecking of the sort reported by Staddon and Simmelhag (1971) and others, but it required using more sessions or a different strain of pigeons. Even under these conditions, pecking was not common, and it clearly emerged from the context of general wall-directed behavior. It should also be noted that one of the Carneaux pigeons that pecked was unique in that she pecked before Trial 20, something we had observed in no prior bird of this strain and gender. That we found pecking so difficult to obtain speaks against accounting for superstitious behavior in terms of a stimulus-substitution mechanism of elicitation (cited by Staddon & Simmelhag, 1971). It speaks for the importance of a more general view of the patterns of appetitive behavior available for conditioning (Timberlake, 1983b; see also Staddon, 1983; Staddon & Simmelhag, 1971).

Our initial inability to obtain pecking may be seen as fortunate in that it called attention

to the reliable matrix of behavior that precedes food delivery without allowing it to be dismissed as part of an immediate ingestive sequence. Inspection of the reports by Staddon and Simmelhag (1971), Reberg, Innis, and their co-workers, and especially Innis, Reberg, Mann, Jacobson, and Turton (1983), and Innis, Simmelhag-Grant, and Staddon (1983) shows results comparable to our wall-directed behavior. This pattern was simply deemphasized in their reports in favor of the focus on pecking. In our estimation the larger matrix of appetitive behavior patterns is more likely to hold the key to explaining superstitious behavior than an account focused on pecking.

APPETITIVE STRUCTURE AND SUPERSTITIOUS BEHAVIOR

EXPERIMENT 9

The final experiment to be reported here briefly explored some ramifications of the hypothesis that wall-directed behavior consists of elicited components of species-typical appetitive behavior ordinarily related to obtaining food. This hypothesis stems from the assumption that learned behavior is based on species-typical units (modules) of appetitive response tendencies and stimulus sensitivities organized within larger functional system related to survival (Timberlake, 1983a, 1983b, 1983c; Timberlake, Wahl, & King, 1982; see also Baerends, 1976; Hogan & Roper, 1978; Hollis, 1982; Scott, 1958; Tinbergen, 1951). The emergence of common behavior patterns in the superstition paradigm suggests that the superstition procedure contacts such a set of appetitive modules related to food, and that these modules are expressed in the patterns of circling away and wall-directed behavior.

Although it is not yet clear how wall-directed behavior fits into the pigeon's natural repertoire of obtaining food, the circling away seems closely related to components of ground foraging. Observation of ground-feeding pigeons shows that pigeons typically move away from a location where they have found food (personal observation; see also Murton, 1965). The appetitive-structure view of conditioning can be tested indirectly in these circumstances because it predicts that behavior produced by response-independent procedures should be

influenced by ecologically relevant stimulus conditions (Timberlake, 1983b; Timberlake et al., 1982). Thus, we should be able to change the stimulus conditions to support more readily interpretable forms of food-getting behavior. To this end the final experiment involved moving the hopper away from its location in the wall and into the floor at the center of the chamber, thus providing a ground-foraging context that ecologically is more typical for the adult pigeon.

Method

The subjects were 4 naive pigeons. The chamber was identical to that described in Experiment 1 except that a feeder was installed beneath the wooden floor in the center of the area, 38.1 cm from each wall. The feeder aperture was a funnel-shaped opening approximately 5 cm in diameter at the top and tapering to a 1.6-cm opening about 3 cm below the surface of the floor. When operated, the feeder solenoid raised a food tray flush with the bottom of the funnel opening. When raised, the food was clearly visible. No additional hopper light was presented. As in the previous studies, the floor of the chamber was covered with newspaper. A 5-cm hole was cut in the paper to accommodate the hopper opening. The pigeons were trained for 12 sessions under a FT 15-s schedule with a 3-s hopper duration.

Results and Discussion

As shown in Figure 15, the location of the feeder had a marked effect on the patterns of behavior generated by the periodic feeding schedule. Two subjects, D3312 and D3377, developed a predominant pattern of locomotion and head bobbing directed toward the center of the chamber. Following the offset of food, each subject began to walk about the center of the chamber, head oriented toward the floor, in the circling pattern typical of pigeons foraging for scattered food on the ground. The main difference between behavior patterns of these 2 birds was the extent of circling while bobbing toward the floor. In contrast, Subject D4151 initially circled away from the feeder and then spent most of the remainder of the interval engaged in stepping and bobbing toward the side wall, while Subject D1186 showed a mixture of wall-directed bobbing and circling.

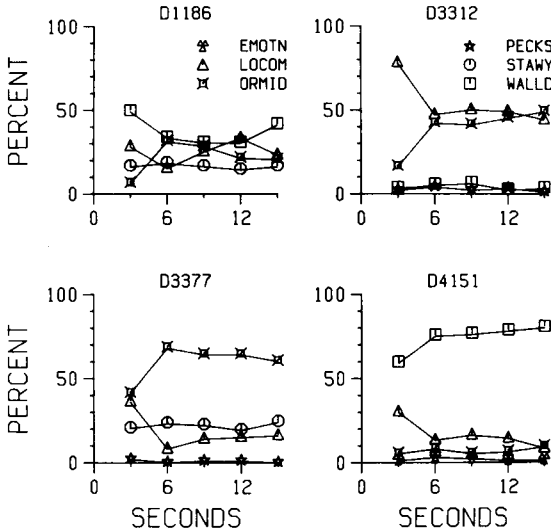


Fig. 15. Percentage of behavior categories recorded across 3-s observation points during the interfood interval in Experiment 9 when the food hopper was located in the center of the floor. Data are means based on the final four sessions of the experiment.

Thus, the patterns of behavior that appeared when food was presented in the center of the chamber contained distinct nonarbitrary sets of locomotor and visual search patterns clearly related to foraging for ground sources of food. However, 2 birds also showed wall-directed behavior. Although these results do not illuminate further the precise functional role of the wall-directed behavior observed in the previous experiments, they suggest that something about the wall itself supports stepping, bobbing, and bumping in the context of food, whether or not food is located in it.

GENERAL DISCUSSION

Chance Contingency versus Elicitation

On the basis of these experiments, we conclude that Skinner's explanation for the occurrence of superstitious behavior on short fixed-time schedules is incorrect. Nearly all of our birds showed a common set of wall-directed behavior, including bumping, scratching, head bobbing, and neck movements in front of the hopper. Skinner (1948) reported almost all these patterns but his description did not capture their uniformity of topography, relatedness, or location. There is no doubt that the present birds showed recognizable in-

dividual styles congruent with Skinner's report. Some birds scratched more than others, some swung their necks more, some head-bobbed more intensely. But all showed most of the components we have identified as wall-directed behavior, and patterns typically occurred along the wall containing the hopper. The large experimental chamber we used probably made the focus on the hopper wall more obvious. In a smaller chamber, or in one with the hopper in a corner (e.g., Innis, Simmelhag-Grant, & Staddon, 1983), the orientation of these behavior patterns might be more varied and/or appear less directed.

Other reasons for our differences with Skinner (1948) are probably related to his focus on the diversity rather than the commonalities of behavior patterns. First, he reported any increase in a single response regardless of its temporal location in the interval. For example, circling, which typically occurs early in the interfood interval, was cited by Skinner as "superstitious" behavior on a par with head bobbing, a pattern that occurs most frequently at the end of the interfood interval. Second, it is probable that the majority of Skinner's observations were taken very early in training when diversity in behavior may have been more apparent (though we have no strong empirical evidence that this diversity persists for any period of time). Finally, it may be that because Skinner did not systematically categorize the birds' behavior, he was drawn to emphasize increases in the frequency of individual motor acts that fit his conception of causation by response-reward contingencies, rather than noting the larger organization of predictable behavior change.

Our results clearly support Staddon and Simmelhag's (1971) assumption that in a fundamental way behavior in the superstition paradigm is elicited by the periodic presentation of food. Response contingencies, while potentially affecting behavior, appear unlikely to have been the primary basis of behavior change. Preliminary procedures that increased the a priori probability of pecking or turning did not produce more pecking or turning in the behavior that subsequently emerged. When wall-directed behavior was explicitly rewarded or punished, similar behavior continued to occur. When other behavior patterns did emerge under the omission contingency, they consisted of response forms previously

observed in this paradigm, rather than arbitrary new patterns. In general, it appears that what has been called superstitious behavior in the pigeon actually represents expression of preorganized response patterns elicited by periodic delivery of food.

However, it should be emphasized again that the final form of superstitious behavior can be modified by previous stimulus conditions and response-reward contingencies. In the present experiments the components of superstitious behavior were seen to vary with pretraining (Experiment 2), with positive and negative response contingencies (Experiments 4 and 5), and with previous experience (Experiments 7 and 8). Because of these effects it might be tempting to argue that response contingencies, although not producing initial wall-directed behavior, are responsible for its maintenance. While one cannot disprove this contention with certainty, there are elements of this position that are not attractive.

If wall-directed behavior is originally elicited as a species-typical appetitive pattern and then is shaped and maintained by accidental response contingencies, behavior patterns should develop in two stages. Behavior in the initial elicited stage should be common across all subjects, while behavior in the subsequent reinforced stage should show large, unpredictable variation across subjects as accidental contingencies begin to modify the patterns. Although we cannot provide a precise evaluation of this prediction, it is not congruent with our impressions. If anything, the behavioral topography initially is more variable and subsequently settles into the typical wall-directed patterns. The failure of a continuing positive contingency for remaining near the hopper wall to affect behavior systematically also speaks against maintenance of wall-directed behavior by response contingencies.

One might still argue for a fundamental role of response contingencies if one assumed that superstitious behavior were based on a common precise response-reward contingency that nearly all birds were programmed to "fall into" under a variety of different procedures. However, this argument, in addition to being untestable, makes essentially the same point we wish to make with an elicitation approach. Basically, superstitious behavior must be explained either by elicitation through pairing of food with the passage of time, or

by a truly remarkable commonality of sensitivities to infrequent accidental contingencies that somehow resist the effects of much more explicit programmed contingencies (Experiments 4 and 5). Both explanations point to our conclusions that superstitious behavior comes from a specific evolved system selected to produce species-typical appetitive behavior patterns in the presence of food.

Finally, some readers may agree that the behavior we obtained in the superstition paradigm is fundamentally elicited, but argue that phenomena such as the persistence of key pecking in birds transferred from response-dependent to response-independent schedules (e.g., Herrnstein, 1966) still point to the effect of "superstitious" contingencies on behavior. It has been argued in such cases that the continued "accidental" juxtaposition of key pecking and food maintains pecking in the absence of an actual contingency. However, our data from Experiment 2 suggest that such accidental contingencies do not work that simply. Apparently there is something unique about training of pigeons' key pecking that produces persistence of this response under fixed-time schedules. We think it likely that these results occur because training a pigeon to peck a lighted key produces an integrated response related to natural food-getting behavior. Once trained, key pecking is readily elicited by the combination of frequent food presentation and a salient target. In the absence of changes in the supporting stimuli or the frequency of food presentation that more strongly support other species-typical forms of food-getting behavior, key pecking should remain a dominant response.

Pecking

One concern regarding the present results, given those of Staddon and Simmelhag (1971) and others, is the very limited amount of pecking we obtained. Although an elicitation analysis of superstitious behavior does not require that pecking occur (Staddon, 1983; Staddon & Simmelhag, 1971), any appeal to classic stimulus-substitution processes to explain superstitious behavior argues that it should. In the present experiment, pecking did not occur with short hopper durations, with short inter-food times, or even with food deliveries made contingent upon the birds' remaining near the wall. We were able to obtain some pecking by

selecting a different strain of bird and by training Carneau pigeons over a longer period of time. In the Carneau there appeared to be a particular acquisition sequence. Pecking emerged after the bird developed a consistent low-bob posture along the hopper wall. The significance of this sequence is not yet clear.

Considering all the evidence, a likely conclusion is that wall pecking has been over-emphasized in superstition paradigms (Fenner, 1980; Innis, Simmelhag-Grant, and Staddon, 1983). A careful review of the literature shows that pecking is a frequent pattern for no more than half of naive birds of the more peck-oriented strains, and apparently emerges primarily at relatively short interreward intervals and after a large number of sessions. Innis, Simmelhag-Grant, and Staddon (1983) reported little pecking in Carneau pigeons at any interval above 6 s, and this even though they apparently counted some examples of head bobbing as pecking. It could be argued from these data that wall pecking is just one potential component of wall-directed behavior, and frequently a minor one.

Finally, there is some question whether the pecking we did obtain was attributable to stimulus substitution. In many ways it appeared more related to search than to ingestion. In the present experiments, pecking consisted of a mixture of downward angled, glancing contacts along the lower part of the wall, and occasional strong sideways swiping of the beak along the floor. The latter movement typically occurs in digging and rearranging the substrate when foraging (Lucas, 1981; Schorger, 1955; Whitman, 1919). Skinner (1948; see our Table 1) also reported these "brush-type" pecking movements. The wall pecking in films by Reberg and Innis is more of the driving open-beak variety that has been observed directed toward lighted keys (e.g., Jenkins & Moore, 1973). Even this pecking can be considered more manipulative than consummatory (cf. Delius, 1983), inasmuch as a peck of this force would be more likely to scatter food than pick it up (J. D. Deich & H. P. Zeigler, personal communication, April, 1984; see also LaMon, 1981; Zweers, 1982). In sum, although the control of pecking in the superstition paradigm remains of interest, we feel that it is a more complex and variable

behavior than typically has been acknowledged.

Interim Behavior

The present data did support the temporal organization of behavior reported by Staddon and Simmelhag (1971). However, their categorization into exclusive interim and terminal patterns (or interim, terminal, and facultative patterns; see Staddon, 1977) appears problematic. For example, our dominant category of wall-directed behavior was classified as interim behavior in Staddon and Simmelhag's (1971) study. Further, the circling response, classified as interim behavior, sometimes did not occur (the bird immediately began wall-directed behavior), or occupied the entire interfood interval (when the hopper was in the floor). Thus, the behavioral organization underlying superstitious behavior appears to be more complex and flexible than the interim-terminal categorization suggests. Similar points have been made by Reberg et al. (1978), Innis, Reberg, Mann, Jacobson, and Turton (1983), and Innis, Simmelhag-Grant, and Staddon (1983).

An additional problem with the analysis of Staddon and Simmelhag (1971) is their assumption that interim behavior patterns are unrelated to the reward. In the present results, the only consistent interim pattern was circling away from the hopper and returning. Observation of pigeons in small flocks and individual feeding situations reveals that a pigeon frequently feeds for short periods at a particular location and then moves away from that point continuing to search for other food items (personal observation; Murton, 1965). Such immediate postfood searching would be expected from a seed eater like the pigeon that feeds in patches of closely distributed food items (Murton, 1965).

Circling appears to be an adjustment of the species-typical postfood search pattern to laboratory situations in which food periodically reappears at the same point. When the hopper was in the center of the floor approximating a ground-foraging situation, circling was a dominant pattern for most birds. Thus, the interim pattern of circling away after feeding from the hopper appears to be directly related to the spatial and temporal organization of the pigeon's feeding rather than to motivationally

irrelevant behavior. Further support for this view is provided by evidence that pigeons receiving water presentations do not circle away following drinking, but remain near the water source (Reberg et al., 1978; Innis, Reberg, Mann, Jacobson, & Turton, 1983; Innis, Simmelhag-Grant, & Staddon, 1983). Such behavior would be expected in the case of a commodity that is found most often at concentrated spaced locations (e.g., sources of water) rather than distributed in small packages (e.g., seeds).

A Behavior-System Approach

A more parsimonious account of superstitious behavior may be provided within the framework of the appetitive structure of behavior systems (Timberlake, 1983a, 1983b, 1983c, 1984; see also Davey & Cleland, 1984; Davey, Cleland, & Oakley, 1982; Jenkins, Barrera, Ireland, & Woodside, 1978; Staddon, 1983). This approach suggests that the organization of behavior depends on functional systems related to important ecological variables. These "behavior systems" can be viewed as collections of organized modules (units of stimulus sensitivities and related motor patterns) that can be collectively primed by contact with a reward. When such a behavior system is activated, these modules provide a substrate of preorganized behavioral components and stimulus sensitivities from which an ecologically adaptive sequence of behavior is likely to emerge. The selection and integration of modules into an organized pattern of behavior appear to depend on a number of factors, including elicitation by the physical characteristics of predictive and supporting stimuli in the environment, the repetition of a response sequence in particular stimulus conditions, and the instigating role of one module with respect to another, as well as the spatial and temporal contingencies imposed by the environment (or the experimenter).

The traditional stimulus-substitution account of Pavlovian conditioning (Pavlov, 1927) has assumed that predictive stimuli elicit the same behavior elicited by the rewarding stimulus (e.g., consummatory pecking in the case of pigeons and food). In contrast to this focus on consummatory behavior, the appetitive-structure view of elicitation assumes the possibility of conditioning a more complex and

complete repertoire of food-related behavior patterns that range from searching, through capture and preparatory handling, to ingestion (see Timberlake, 1983b, 1983c). For example, as the probability of food increases in the presence of appropriate predictive and supporting stimuli, we would expect to be able to condition pigeons to: (1) land near groups of pigeons in foraging postures (e.g., with exposed neck feathers [Murton, 1965]); (2) approach areas where pecking sounds and movements are displayed; (3) walk about a food area in patterns and postures that ordinarily would facilitate locating further food items; (4) search visually for predictive features in the substrate; (5) brush and poke at ground cover, thus exposing new search areas (Whitman, 1919); (6) grasp certain-sized items in the beak; (7) mandibulate these items in predictable ways that test their suitability as food before swallowing (Zweers, 1982); and (8) reject or accept objects with particular textures and tastes.

The emergence of each of these patterns should depend both upon the physical characteristic of the stimuli available and the temporal relation of these stimuli to food. The closer in time to food presentation a particular stimulus occurs, the more likely that the stimulus will elicit preconsummatory or ingestive forms of appetitive behavior based more on its close temporal relation to food and less on its unique physical characteristics. Such results would be compatible with, although they do not require, a stimulus-substitution account (Timberlake, 1983c). On the other hand, the further away from food in time a predictive stimulus occurs (up to a point), the more likely it will be to elicit patterns of search and approach behavior that are highly dependent on the physical characteristics of the stimulus. Such results are not compatible with stimulus-substitution accounts (see also Konorski, 1967).

It may be worth noting that within the present behavior-system view there is no sharp distinction between appetitive and consummatory behavior. All complex behavior patterns are appetitive in that components vary with stimulus conditions (see Zweers, 1982, for a particularly pretty analysis of the appetitive nature of "consummatory" pecking in pigeons). On the other hand, nearly all be-

havior patterns have fixed aspects. What should be of interest to learning researchers is how the variable and fixed aspects of behavior interact in producing integrated performance (e.g., Hailman, 1967).

From an ecological viewpoint it is very important that an animal be able to produce adaptive organized sequences of behavior in the presence of incomplete, novel, and intermittent cues. The availability of systems of preorganized stimulus sensitivities and response tendencies should facilitate adaptive behavior in these environments. In the superstition paradigm there are no specific predictive stimuli, but the pigeon still shows a sequence of searching and preconsummatory behavior loosely organized around the presentation of food. Locomotor searching is shown early in the interfood interval, especially when the interval is long (Innis, Simmelhag-Grant, & Staddon, 1983) or when omission of food occurs within a periodic sequence. More vigorous wall-directed behavior, including pecking when conditions are suitable, occurs more frequently toward the end of the interfood interval when the overall probability of food is high (see also Staddon, 1977; Staddon & Simmelhag, 1971).

Presumably, modules and behavior systems evolved that produce learning of adaptive behavior within particular ranges of ecologically relevant conditions (Johnston, 1982). If an unusual or incomplete behavioral context is presented (as may easily occur in the laboratory and may also happen in the field), the structure of appetitive patterns may promote the learning of behavior that appears maladaptive, nonoptimal, or "superstitious." For example, circling away from the feeder in the present studies was not adaptive because food was not available elsewhere.

A number of questions remain unanswered within the present approach. For example, over what interfood intervals and durations of feeding can one expect interim behavior to be related to obtaining food? Innis, Simmelhag-Grant, and Staddon (1983) reported similar interim behavior in interfood intervals of up to 300 s. Roper (1980) has shown similar interreward behavior under both experimenter-terminated and subject-terminated bouts of eating and drinking. It seems reasonable to assume that the extent of food-related interim behavior should depend upon the range of meal lengths available to the species, and upon

the relation of postfood behavior to locating additional sources of food.

A second critical question concerns the functional basis for wall-directed behavior in the present experiments. Although we cannot answer definitely, we note that wall-directed behavior involves components of food begging by young squab (cf. Delius, 1983), including stepping, bumping, directed head bobbing, and slightly raised wings. A few such patterns also may be seen in female pigeons soliciting courtship feeding from males. Whether these components can account completely for wall-directed behavior must await the outcome of further research.

In summary, our results support a view of superstitious behavior as elicited in a broad sense. It seems likely to us that superstitious behavior is based on species-typical components of food-getting behavior, although their exact functional basis can be inferred readily only for circling and pecking. Such an assumption may be difficult to prove, but we consider it a more productive path of investigation than the assumption that such behavior patterns are accidentally reinforced, or elicited as conditioned consummatory behavior.

REFERENCES

- Baerends, G. P. (1976). On drive, conflict, and instinct, and the functional organization of behavior. In M. A. Corner & D. F. Swaab (Eds.), *Perspectives in brain research* (Vol. 45, pp. 427-447). Amsterdam: Elsevier/North-Holland Biomedical Press.
- Blaine, C., Innis, N. K., & Staddon, J. E. R. (1980). Stimulus control of behavior induced by a periodic schedule of food presentation in pigeons. *Bulletin of the Psychonomic Society*, **16**, 131-134.
- Davey, G. C. L., & Cleland, G. G. (1984). Food anticipation and lever-directed activities in rats. *Learning and Motivation*, **15**, 12-36.
- Davey, G. C. L., Cleland, G. G., & Oakley, D. A. (1982). Applying Konorski's model of classical conditioning to signal-centered behavior in the rat: Some functional similarities between hunger CRs and sign-tracking. *Animal Learning & Behavior*, **10**, 257-262.
- Delius, J. D. (1983). Learning. In M. Abs (Ed.), *Physiology and behaviour of the pigeon* (pp. 327-355). London: Academic Press.
- Fenner, D. (1980). The role of contingencies and "principles of behavioral variation" in pigeons' pecking. *Journal of the Experimental Analysis of Behavior*, **34**, 1-12.
- Hailman, J. P. (1967). The ontogeny of an instinct. *Behaviour* (Suppl. No. 15).
- Herrnstein, R. J. (1966). Superstition: A corollary of the principles of operant conditioning. In W. K. Honig (Ed.), *Operant behavior: Areas of research and application* (pp. 33-51). New York: Appleton-Century-Crofts.

- Hogan, J. A., & Roper, T. J. (1978). A comparison of the properties of different reinforcers. In J. S. Rosenblatt, R. A. Hinde, C. Beer, & M.-C. Busnel (Eds.), *Advances in the study of behavior* (Vol. 8, pp. 155-255). New York: Academic Press.
- Hollis, K. L. (1982). Pavlovian conditioning of signal-centered action patterns and autonomic behavior: A biological analysis of function. In J. S. Rosenblatt, R. A. Hinde, C. Beer, & M.-C. Busnel (Eds.), *Advances in the study of behavior* (Vol. 12, pp. 1-64). New York: Academic Press.
- Innis, N. K., Reberg, D., Mann, B., Jacobson, J., & Turton, D. (1983). Schedule-induced behavior for food and water: Effects of interval duration. *Behaviour Analysis Letters*, 3, 191-200.
- Innis, N. K., Simmelhag-Grant, V. L., & Staddon, J. E. R. (1983). Behavior induced by periodic food delivery: The effects of interfood interval. *Journal of the Experimental Analysis of Behavior*, 39, 309-322.
- Jenkins, H. M. (1977). Sensitivity of different response systems to stimulus-reinforcer and response-reinforcer relations. In H. Davis & H. M. B. Hurwitz (Eds.), *Operant-Pavlovian interactions* (pp. 47-66). Hillsdale, NJ: Erlbaum.
- Jenkins, H. M., Barrera, F. J., Ireland, C., & Woodside, B. (1978). Signal-centered action patterns of dogs in appetitive classical conditioning. *Learning and Motivation*, 9, 272-296.
- Jenkins, H. M., & Moore, B. R. (1973). The form of the auto-shaped response with food or water reinforcers. *Journal of the Experimental Analysis of Behavior*, 20, 163-181.
- Johnston, T. D. (1982). Selective costs and benefits in the evolution of learning. In J. S. Rosenblatt, R. A. Hinde, C. Beer, & M.-C. Busnel (Eds.), *Advances in the study of behavior* (Vol. 12, pp. 65-106). New York: Academic Press.
- Konorski, J. (1967). *Integrative activity of the brain*. Chicago: University of Chicago Press.
- LaMon, B. C. (1981). *Conditioned and consummatory grasping in the pigeon*. Unpublished doctoral dissertation, Hunter College, City University of New York.
- Lucas, G. A. (1981). Some effects of reinforcer availability on the pigeon's responding in 24-hour sessions. *Animal Learning & Behavior*, 9, 411-424.
- Morse, W. H., & Skinner, B. F. (1958). Some factors involved in the stimulus control of operant behavior. *Journal of the Experimental Analysis of Behavior*, 1, 103-107.
- Murray, C. S. (1973). *Conditioning in Betta splendens*. Unpublished doctoral dissertation, University of Pennsylvania.
- Murton, R. K. (1965). *The wood-pigeon*. London: Collins.
- Pavlov, I. P. (1927). *Conditioned reflexes*. (G. V. Anrep, Trans.). London: Oxford University Press.
- Reberg, D., Innis, N. K., Mann, B., & Eizenga, C. (1978). "Superstitious" behavior resulting from periodic response-independent presentations of food or water. *Animal Behaviour*, 26, 507-519.
- Reberg, D., Mann, B., & Innis, N. K. (1977). Superstitious behavior for food and water in the rat. *Physiology & Behavior*, 19, 803-806.
- Roper, T. J. (1980). Behaviour of rats during self-initiated pauses in feeding and drinking, and during periodic response-independent delivery of food and water. *Quarterly Journal of Experimental Psychology*, 32, 459-472.
- Schorger, A. W. (1955). *The passenger pigeon: Its natural history and extinction*. Madison: University of Wisconsin Press.
- Scott, J. P. (1958). *Animal behavior*. Chicago: University of Chicago Press.
- Sheffield, F. D. (1965). Relation between classical conditioning and instrumental learning. In W. F. Prokasy (Ed.), *Classical conditioning* (pp. 302-322). New York: Appleton-Century-Crofts.
- Skinner, B. F. (1948). "Superstition" in the pigeon. *Journal of Experimental Psychology*, 38, 168-172.
- Staddon, J. E. R. (1977). Schedule-induced behavior. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior* (pp. 125-152). Englewood Cliffs, NJ: Prentice-Hall.
- Staddon, J. E. R. (1983). *Adaptive behavior and learning*. Cambridge: Cambridge University Press.
- Staddon, J. E. R., & Simmelhag, V. L. (1971). The "superstition" experiment: A reexamination of its implications for the principles of adaptive behavior. *Psychological Review*, 78, 3-43.
- Timberlake, W. (1983a). Appetitive structure and straight alley running. In R. L. Mellgren (Ed.), *Animal cognition and behavior* (pp. 165-222). Amsterdam: North Holland Press.
- Timberlake, W. (1983b). The functional organization of appetitive behavior: Behavior systems and learning. In M. D. Zeiler & P. Harzem (Eds.), *Advances in analysis of behaviour: Vol. 3. Biological factors in learning* (pp. 177-221). Chichester, England: Wiley.
- Timberlake, W. (1983c). Rats' responses to a moving object related to food or water: A behavior-systems analysis. *Animal Learning & Behavior*, 11, 309-320.
- Timberlake, W. (1984). An ecological approach to learning. *Learning and Motivation*, 15, 321-333.
- Timberlake, W., Wahl, G., & King, D. (1982). Stimulus and response contingencies in the misbehavior of rats. *Journal of Experimental Psychology: Animal Behavior Processes*, 8, 62-85.
- Tinbergen, N. (1951). *The study of instinct*. Oxford: Clarendon Press.
- Whitman, C. O. (1919). *The behavior of pigeons*. In H. A. Carr (Ed.), *Posthumous Works of Charles Otis Whitman* (Carnegie Institution of Washington, Publication No. 257, Vol. 3). Philadelphia: Lippincott.
- Williams, D. R. (1981). Biconditional behavior: Conditioning without constraint. In C. M. Locurto, H. S. Terrace, & J. Gibbon (Eds.), *Autoshaping and conditioning theory* (pp. 55-99). New York: Academic Press.
- Williams, D. R., & Williams H. (1969). Auto-maintenance in the pigeon: Sustained pecking despite contingent non-reinforcement. *Journal of the Experimental Analysis of Behavior*, 12, 511-520.
- Zweers, G. A. (1982). Pecking of the pigeon (*Columba livia L.*). *Behaviour*, 81, 173-230.

Received September 21, 1984
Final acceptance July 22, 1985