Behavioural Processes 170 (2020) 103979

Contents lists available at ScienceDirect

Behavioural Processes

journal homepage: www.elsevier.com/locate/behavproc

Superstition revisited: Sex, species, and adventitious reinforcement

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ARTICLE INFO

Keywords:
Superstitious behavior
Adventitious reinforcement
Stimulus substitution
Behavior systems
Appetitive behavior
Fixed-time schedules

ABSTRACT

Skinner's (1948) 'Superstition' in the Pigeon paper proposed that accidental response-reward contingencies, via adventitious reinforcement, could operantly condition the behaviors of pigeons under fixed-time (response-independent) schedules of food delivery. Skinner likened the behavior of pigeons under these fixed-time schedules to the superstitious behavior of humans and proposed that both response patterns were the result of contiguous pairings of rewards following some response. Alternative explanations of superstitious behavior have included Staddon and Simmelhag's (1971) stimulus substitution account and Timberlake and Lucas's (1985) elicited species-typical appetitive behavior account. Under both these alternative explanations of superstitious behavior, observations of pigeons under fixed-time schedules revealed a lack of idiosyncratic responding, which is a critical element in Skinner's explanation of superstitious behavior via adventitious reinforcement. The following study implemented 4 fixed-time schedule experiments to further study superstition. In Experiment 1, male and female pigeons were compared, which provided support for the disparity in response patterns observed in previous studies. Experiments 2–4 examined the behavior of roller pigeons, ring-necked doves, and bantam chickens. In all the above studies, a lack of idiosyncratic responding and emergence of species-typical foraging behavior was observed. The results provide additional evidence that the 'superstitious' behavior that emerges in pigeons and other organisms under response-independent food schedules is the result of elicited species-typical food getting behaviors, and that these behaviors emerge as a result of frequent food deliveries in environments that support such foraging repertoires.

1. Introduction

Skinner (1948) applied the term "superstition" to stereotyped, idiosyncratic behaviors of pigeons that emerged when a wall hopper filled with grain was briefly presented for 2–4 s on a Fixed-Time 15 s (FT-15 s) schedule. According to Skinner's informal account, after less than an hour of exposure to such a schedule, six out of eight pigeons developed a dominant, idiosyncratic response during the inter-food interval. These responses included circling, pendulum movements of the neck and head, and head tossing. Skinner (1948) labeled these responses superstitious because they appeared in the absence of a programmed response contingency between the behavior and the reward. He compared them to the behavior of a bowler applying "body English" after they released the ball as if trying to guide the ball into the pins from a distance, and to people engaged in rituals that have been related to success at card games in the past.

Three explanations have been used to account for the superstitious behavior of pigeons. Skinner (1948) argued that each contiguous pairing between a behavior and a reward increased the future probability of that response, thereby increasing the likelihood that the future presentations of the hopper would follow or overlap that response again. In other words, Skinner posited the existence of a feedback effect whereby an "accidental" reward contingency (i.e., adventitious reinforcement) increased the strength of any response it followed, and a feedforward loop whereby the increase in the reinforced response increased the likelihood it would be followed by food again.

Although, several other investigators have reported similar behaviors in pigeons produced by FT schedules (Eldridge et al., 1988; Justice and Looney, 1990; Neuringer, 1970), none have directly tested Skinner's model of how superstitious behavior arose as a function of the adventitious reward proximity (i.e., contiguity) and the resultant increase in the likelihood of more adventitiously reinforced responding. In most studies of superstition in pigeons, response-dependent fixed- or variable-interval (FI; VI) schedules are first introduced, and only one response topography is examined: key pecking. Additionally, in most of those studies, the response-dependent schedules for key pecking are

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https://doi.org/10.1016/j.beproc.2019.103979
Received 4 September 2019; Received in revised form 27 September 2019; Accepted 27 September 2019

then transitioned to similar response-independent fixed- or variable-time (FT; VT) schedules. However, in most the aforementioned studies, key pecking is rarely if ever able to be maintained (Appel and Hiss, 1962; Herrnstein and Morse, 1957; Lachter et al., 1971; Morse and Skinner, 1957; Zeiler, 1968) The closest researchers have come to empirically establishing the relation between responding and the delivery of rewards on response-independent schedules occurred in the investigation of autoshaping of key pecking in pigeons. Rachlin (1969) took pictures of pigeons in front of the lighted key at the exact moment food was delivered. Rachlin was testing the suggestion of Brown and Jenkins (1968) that key pecking in autoshaping was superstitiously reinforced by the feedback process of successive adventitious reinforcement of pecking-like responses and the feedforward increase in likelihood that such reinforced responses would occur through an increase in the probability of pecking the lighted key. The results suggested neither obvious incremental response feedback nor feedforward effects. Instead the pigeons tended to go from key pecking to not key pecking very quickly.

Alternative explanations of the behavior of pigeons on fixed-time (FT) schedules were offered by Staddon and Simmelhag (1971) and Timberlake and Lucas (1985). Staddon and Simmelhag (1971) coded pigeons over multiple days of FT presentations and described two predominant classes of responding: interim and terminal behaviors. Interim behaviors, such as circling, pecking at the floor, and moving along the front panel, peaked in the middle of the inter-food interval, before food was made available. Terminal behaviors, such as orienting at the food hopper and pecking in and around it, were observed primarily at the end of the inter-food interval, just before food appeared. Staddon and Simmelhag argued that the behaviors displayed by the pigeons were more like adjunctive behaviors emitted rather than directly controlled by adventitious reinforcement. They also concluded that the preponderance of pecking in their animals was related to the Pavlovian process of stimulus/response substitution in which the temporal CS substituted for the food (the US) in eliciting pecking (the UR).

Timberlake and Lucas (1985) also coded the behavior of pigeons in 9 experiments and found results more consistent with the account of Staddon and Simmelhag (1971) than Skinner (1948). They reported that nearly all the birds turned and circled away from the hopper following the delivery of food, returning to the hopper area partway through the interval. However, instead of the response of pecking emphasized by Staddon and Simmelhag, they found stepping, head-bobbing, and pressing the breast against the wall around the hopper. The surprising similarity of the behaviors that emerged in individual pigeons casted considerable doubt on the accidental operant contingency explanation of Skinner (1948). Further questions of the accidental contingency account were raised by experiments in which pigeons were trained briefly either to peck or turn on fixed-interval 15 s (FI-15 s) schedules and released into fixed-time 15 s (FT-15 s) schedules, or were placed on an omission contingency from the beginning of acquisition that omitted food deliveries if the bird was near the hopper during the last 3 s of the schedule. In both cases the pigeons tended to show similar wall-directed behavior.

The theoretical account offered by Timberlake and Lucas (1985) (see also Timberlake, 1997; Timberlake and Lucas, 1989; Timberlake and Silva, 1994) was that the behavior that emerged under fixed-time (FT) schedules represented a compressed form of naturally-occurring food seeking (foraging) bouts on the part of the pigeons with most of the components that occurred related to focal search behavior. The turning and circling behaviors resembled the behavior of pigeons searching in a field for seeds and grain. However, the wall-directed behavior was more difficult to describe. When food was delivered in a floor hopper located in the center of the chamber (50 cm from the wall) the pigeons showed only the turning, circling, and bent over scanning and occasional beak sweeps shown by pigeons foraging in a field. In contrast, when the floor hopper was moved to within 22 cm of the wall, the pigeons showed the typical wall-directed behavior between deliveries. Based on considerable observation of pigeons in a variety of circumstances, Timberlake and Lucas (1985) suggested that the wall-directed behaviors most resembled the food-begging behaviors shown by mobile squab (12–19 days of age; see also Mondloch and Timberlake, 1991). When a returning parent arrived, these birds rapidly approach, standing upright in front of them, stepping, pressing against them, head bobbing in front of their beaks, and often wing flapping until the parents regurgitated food from their crops.

In short, the three explanations of superstitious behavior differ considerably. Skinner (1948) argued that superstitious behavior was operantly conditioned via adventitious reinforcement. As a result, Skinner emphasized the largely arbitrary nature of the superstitious behavior he anecdotally observed, and as such, the idiosyncratic properties of such responses. Staddon and Simmelhag (1971) and Timberlake and Lucas (1985) agreed that the responses that emerged were neither arbitrary nor idiosyncratic. Further, a sequence of more than one type of response typically occurred. Staddon and Simmelhag divided these responses temporally into two types: interim and terminal behaviors. The interim responses were like adjunctive behaviors shown under inter-food intervals, and the predominant terminal response of pecking was due to stimulus substitution involving pecking the food. Timberlake and Lucas also reported the emergence of different classes of behavior, which they attributed to different forms of niche-related naturally occurring foraging behavior of pigeons entrained by the regular delivery of food. The responses were predominantly behaviors related to a focal search mode suitable for foraging in the near vicinity of food. They emphasized the importance of the environmental support rather than the form of the UR in determining the specific behaviors that were expressed by showing that wall-directed behaviors emerged when food was delivered in or up to 22 cm from a wall, and field-foraging scanning and circular search emerged when food was delivered from a floor-hopper in the middle of the experimental chamber.

The purpose of the present experiments was to examine the fit between these explanations and the “superstitious” behavior of male and female pigeons (Experiment 1), roller pigeons (Experiment 2), ring-necked doves (Experiment 3), and bantam chickens (Experiment 4). Skinner’s (1948) explanation predicts idiosyncratic behaviors in all cases. Staddon and Simmelhag (1971) should predict interim and terminal behavior and predominant pecking because all the animals readily peck grain in the hopper. Timberlake and Lucas (1985) should predict classes of behavior related to typical foraging bouts and expressed as a function of the environmental support for naturally occurring (niche-related) behavioral repertoires.

2. General method

2.1. Subjects

Subjects in all 4 experiments included 3–12 White Carneau pigeons (*Columba livia*), roller pigeons (*Columba livia*), ring-necked doves (*Streptopelia capicola)*, or bantam chickens (*Gallus gallus*). 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.

2.2. Apparatus

The experimental area was contained in a large 68 × 74 × 42 cm sound-attenuating chamber. The floor, back, and right walls of the experimental area were either sheet-metal or particle board walls of the chamber. The left wall consisted of a standard two-key Lehigh Valley Electronics pigeon panel centered in a 76 cm long piece of black plywood. The front wall of the experimental area was the door of the sound attenuating chamber and contained a double glass window, 75 by 40.5 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 black rubber matting or newspaper.

2.3. Procedure

Adaptation to the food hopper was accomplished in 1 day by placing the bird in the chamber with the hopper raised and illuminated. As soon as the bird ate for 10–12 s, the hopper was lowered and raised again. Across the next 15–20 presentations, the duration of access to food was gradually reduced to approximately 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 16–25 days of training with 30–40 hopper presentations per day on a FT 15 s schedule. Each hopper presentation lasted 3–4 s.

The behavior of the pigeons was observed directly by one experimenter or observed from video by a single experimenter. When observed directly, the experimenter sat in the dark experimental room approximately 1.5 m from the chamber, and coded behavior into one of several categories adapted from Timberlake and Lucas (1985) and adjusted for each species/experiment (see Fig. 1 for behavior examples). Tables 1–3 show the behavioral codes used for all four experiments. Behaviors were coded every 3 s during the 15 s interval, starting with second 3. A repeatable countdown timer or a permanent timecode placed on the video were used to determine when to code. Unless otherwise noted, the data reported are averages based on the last 2–4 days of the experiments.

One primary observer was used to code all four experiments. The observer was an undergraduate student gaining research experience and course credit in the lab by participating in these projects. The observer read Skinner (1948) and Timberlake and Lucas (1985) and learned the list of behavior categories for all 4 experiments.

3. Experiment 1

An interesting conflict that arises in comparing the data of Staddon and Simmelhag (1971) with those of Timberlake and Lucas (1985) is the difference in pecking. A closer look at the data of Staddon and Simmelhag (1971) suggests that they overemphasized the importance of pecking. While all four of their pigeons displayed some level of terminal pecking, other studies examining pigeons under response-independent schedules found pecking at any area in the experimental chamber to occur significantly less (Reberg et al., 1978), or rarely at all (Innis et al., 1983). Nonetheless, there seems little doubt that 3 of Staddon and Simmelhag's pigeons showed a notable amount of pecking at asymptote, while none of the 45 birds run by Timberlake and Lucas showed pecking.

The problem with never or rarely getting an important outcome is that the failure can't be attributed to any one set of circumstances. However, during a lengthy conversation between Nancy Innis and the second author (W. Timberlake, personal communication, Midwestern Psychological Association, 1986), we were able to eliminate as a sole reason for the lack of pecking in Timberlake and Lucas (1985) differences in either coding categories, perspective of the observer, pretraining, breed, environmental specifics, or length of training. The only difference identified that could not be ruled out was the sex of the pigeons. Apparently, Staddon and Simmelhag (1971); Reberg et al. (1978), and Innis et al. (1983) used predominantly, if not exclusively, male pigeons, which came from a variety of sources. Timberlake and Lucas used retired female breeders from the Palmetto Pigeon Plant. Both male and female pigeons show begging behavior as squabs, but females continue to show begging behavior as adults when they direct begging to courting males as part of the mating process (Fabricius and Jansson, 1963; Timberlake and Silva, 1995). Based on their ontogenetic behavior, we would expect both males and female pigeons to show wall-directed behavior, but based on differences during courtship, we could expect males to show less begging and perhaps more pecking (i.e., courtship-related food-giving behavior; see General Discussion).

The purpose of the first experiment was to compare the behavior of male and female White Carneau pigeons under FT-15 s schedules. To the extent that the difference between the pecking reported by Staddon and Simmelhag (1971) and Timberlake and Lucas (1985) was due to the sex of the pigeon, we would expect more pecking in the males than the females, but otherwise similar wall-directed behavior for both.

3.1. Method

The subjects were 6 female and 6 male White Carneau pigeons obtained from the Palmetto Pigeon Plant in Columbia, SC. They were maintained and housed as described in the General Method section. All birds were maintained at 77.5 % of their free-feeding weight. Table 1 shows the coding scheme used to record the behaviors of each bird. The apparatus, procedures, and recording techniques were those described in the General Method, with the following caveats: all birds were run

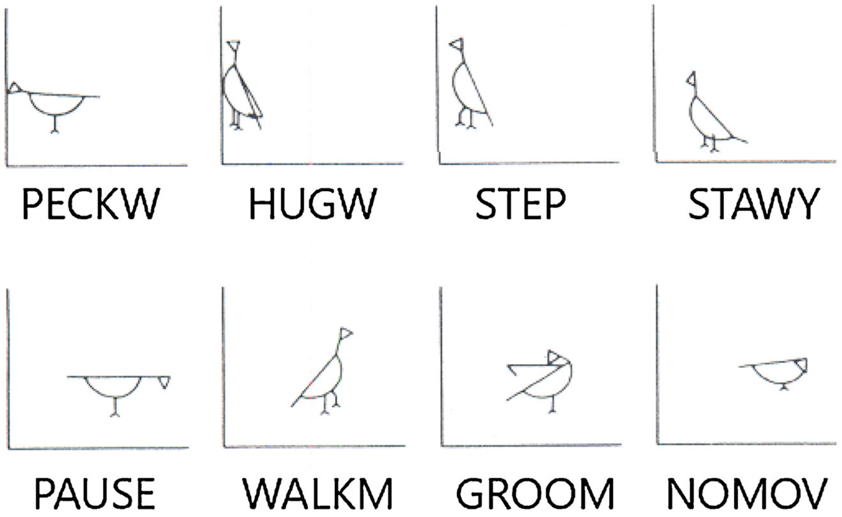

Fig. 1. Stylized drawings of typical postures in relation to the hopper wall (here assumed to be on the left) for most of the general behavior categories (adapted from Timberlake and Lucas, 1985). See Table 1 for detailed descriptions of the behaviors and their abbreviations.

Table 1
Behaviors, classes of behaviors, abbreviations, and definitions for the White Carneaux pigeons in Experiment 1.

CLASS	BEHAVIOR	DEFINITION
WALLD (hopper wall)	FLAPSCRA (FS)	Flapping while doing SCRAW (SC) [must include hugging wall].
	SCRAW (SC)	Hug wall while scratching and climbing against wall with feet.
	HUG.W (HW)	Walk wall while pushing breast against it (front wall).
	STEP (ST)	Bob and step back and forth in front of wall w/o contact (at least 2 steps).
	BOB (BO)	Bob head in front of the hopper wall, either side to side or up and down, and directed toward the wall.
	HEADFEED (HiF)	Head in feeder, but no pecking.
WALLG WALLS WALLO (wall-directed glass, side, opposite, respectively)	HUG.G (HG; HS; HO)	Hug glass (or other) while pushing breast against it.
	SCRAWG (SG; SS; SO)	Hug glass (or other) while scratching and climbing against the glass with feet.
	STEPG (StG; StS; StO)	Bob and step back and forth in front of glass (or other) w/o contact (at least 2 steps).
	BOBGL (BG; BS; BOO)	Bob head in front of the glass (or other).
LOCOM	WALKM (WM)	Walk around the chamber.
	TURNS (TU)	Turn the body in at least a quarter circle, (within 4" of same spot).
PECK (both pecks and/or thrusts of head toward an object)	PECKH (PH)	Peck inside or on the edge of the hopper opening (or head in hopper).
	PEKEY (PK)	Peck on the key.
	PECKW (PW)	Peck other wall area.
	PECKF (PF)	Peck floor.
NON-MOVEMENT	STAWY (SA)	Remaining nearly motionless (stand away), most often near a front corner. Posture varies from upright with neck slightly extended to body at 45 degrees with neck less extended.
	PAUSE (PA)	Not moving and breast away from a wall. This is a temporary pause in movement.
	LOOKARO (LA)	Just as pause, but with head moving around in non-bob fashion.
	NOMOV (NM)	A motionless almost horizontal posture resembling roosting, with head pulled against body.
GROOM	GROOM (GM)	Preening behavior including wiping of face, nibbling and stroking of feathers with bill, and scratching of body or face with foot.
EMOT	FLAPP (FL)	Repeated wing flapping, sometimes with retraction of feet.
	TAILF (TF)	Tail flick, a pronounced downward flick of the tail feathers.
ORIENT ("oriented" towards wall W/O defined wall-directed behaviors)	ORHOP (OH)	Breast towards hopper, and within 8 cm of the wall.
	ORGLA (OG)	Breast towards door wall, and within 8 cm of the wall.
	ORSIDE (OS)	Breast towards wall opposite of door, and within 8 cm of the wall.
	OROPP (OO)	Breast towards wall opposite of the hopper, and within 8 cm of the wall.

for 25 days, were run for 40 trials each day, and received 4 s food hopper deliveries.

3.2. Results/Discussion

Figs. 2–4 show the temporal patterns of all 12 pigeons plotted every 3 s of the inter-food interval averaged over 2 days (day 20 and 25) of the experiment. Most of the birds (5 out of 6 females; 4 out of 6 males) primarily displayed wall-directed behaviors (e.g., WALLD) from 6 to 15 s, just prior to a food delivery. Most of these behaviors consisted of moving back and forth against the wall while hugging and/or occasionally scratching the wall, stepping back and forth in front of the wall, and bobbing their heads in front of the wall. For most of the birds, these behaviors were preceded by quickly circling away from the wall (e.g., LOCOM) at second 3. For 2 of the males, pecking at or around the food hopper (e.g., PECK) replaced wall-directed behaviors for seconds 6–15 (Male5) or seconds 12–15 (Male 6). Two interesting exceptions were Female2, Male3, and Female5, who engaged in wall-directed behaviors at the glass panel entrance of the chamber (e.g., WALLG) for most of the observational intervals (Female2) or during second 3 (Male3; Female5). These behaviors were still the same wall-directed behaviors noted above but directed towards the glass entrance of the chamber.

The results were consistent with Timberlake and Lucas (1985) in that most of the behaviors were the same across individuals, primarily consisting of wall-directed responses, with occasional moving away from the hopper wall immediately following a food delivery. For 2 of the 6 males and none of the females observed, pecking in or around the food hopper occurred consistent with Staddon and Simmelhag (1971). While this was only a third of all males observed, as opposed to all four birds observed in Staddon and Simmelhag, it provides at least partial

Table 2
Behaviors, classes of behaviors, abbreviations, and definitions for the roller pigeons and ring-necked doves in Experiment.2–3.

CLASS	BEHAVIOR	DEFINITION
WALLD (hopper wall)	SCRAW (SC)	Hug wall while scratching and climbing against wall with feet.
	HUG.W (HW)	Walk wall while pushing breast against it (front wall).
	STEP (WW)	Bob and step back and forth in front of wall w/o contact (at least 2 steps).
	BOB (BH/BW)	Bob head in front of the hopper wall, either side to side or up and down, and directed toward the wall.
LOCOM	WALKM (WM)	Walk around the chamber.
	TURNS (TU)	Turn the body in at least a quarter circle, (within 4" of same spot).
PECK (both pecks and/or thrusts of head toward an object)	PECKH (PH)	Peck inside or on the edge of the hopper opening (or head in hopper).
	PECKW (PW)	Peck other wall area.
	PECKF (PF)	Peck floor.
NON-MOVEMENT	STAWY (SA)	Remaining nearly motionless (stand away), most often near a front corner. Posture varies from upright with neck slightly extended to body at 45 degrees with neck less extended.
	PAUSE/LOOKARO (P/L)	Not moving and breast away from a wall. This is a temporary pause in movement. Head can be moving around, but not in bobbing motion as seen in WALLD behaviors.
GROOM	GROOM (GM)	Preening behavior including wiping of face, nibbling and stroking of feathers with bill, and scratching of body or face with foot.
EMOT	FLAPP (FL)	Repeated wing flapping, sometimes with retraction of feet.
	TAILF (TF)	Tail flick, a pronounced downward flick of the tail feathers.

Table 3
Behaviors, classes of behaviors, abbreviations, and definitions for the chickens in Experiment 4.

CLASS	BEHAVIOR	DEFINITION
WALLD (hopper wall)	FLAPSCRA (FS)	Flapping while doing SCRAW (SC) [must include hugging wall].
	SCRAW (SC)	Hug wall while scratching and climbing against wall with feet.
	HUG.W (HW)	Walk wall while pushing breast against it (front wall).
	STEP (ST)	Bob and step back and forth in front of wall w/o contact (at least 2 steps).
	BOB (BO)	Bob head in front of the hopper wall, either side to side or up and down, and directed toward the wall.
	HEADFEED (HiF)	Head in feeder, but no pecking.
LOCOM	WALKM (WM)	Walk around the chamber.
	TURNS (TU)	Turn the body in at least a quarter circle, (within 4" of same spot).
PECK (both pecks and/or thrusts of head toward an object)	PECKH (PH)	Peck inside or on the edge of the hopper opening (or head in hopper).
	PEKEY (PK)	Peck on the key.
	PECKW (PW)	Peck other wall area.
	PECKF (PF)	Peck floor.
SCRATCH	SCRAH (SH)	Scratching at hopper wall.
	SCRAF (SF)	Scratching floor.
NON-MOVEMENT	STAWY (SA)	Remaining nearly motionless (stand away), most often near a front corner. Posture varies from upright with neck slightly extended to body at 45 degrees with neck less extended.
	PAUSE (PA)	Not moving and breast away from a wall. This is a temporary pause in movement.
	LOOKARO (LA)	Just as pause, but with head moving around in non-bob fashion.
	NOMOV (NM)	A motionless almost horizontal posture resembling roosting, with head pulled against body.
GROOM	GROOM (GM)	Preening behavior including wiping of face, nibbling and stroking of feathers with bill, and scratching of body or face with foot.
EMOT	FLAPP (FL)	Repeated wing flapping, sometimes with retraction of feet.
	DUSTB (DB)	A sweeping motion, where the bird lowers body and does a quick ruffle. This is dustbathing.
	RUFFLE (RF)	Ruffling of feathers while standing upright.
	HOP (HP)	Both feet leaving ground without flapping.
ORIENT ("oriented" towards wall W/O defined wall-directed behaviors)	ORHOP (OH)	Breast towards hopper, and within 8 cm of the wall.
	ORGLA (OG)	Breast towards door wall, and within 8 cm of the wall.
	ORSIDE (OS)	Breast towards wall opposite of door, and within 8 cm of the wall.
	OROPP (OO)	Breast towards wall opposite of the hopper, and within 8 cm of the wall.

support, in conjunction with the less frequent pecking responses observed for Reberg et al. (1978), and Innis et al. (1983) that the hopper pecking responses of pigeons during response-independent food schedules is linked to the sex of the bird, with only male pigeons engaging in such pecking responses.

4. Experiment 2

Given the view that behavior in the superstition paradigm is related to niche-related foraging behavior in pigeons, two things follow. Our best expectation is that different pigeon breeds will show basically the same foraging patterns because the selection that established them was not based on foraging patterns, but rather on unique features of plumage or behavior (e.g., rollers, tumblers). However, we would expect some deviation in the relative form or frequency of the responses that emerge, as a result of the breed artificial selection process itself.

The second experiment examined the behaviors of roller pigeons, a breed of the common pigeon used in all prior superstition studies. We expected the results to be similar to that of Timberlake and Lucas (1985) under the same FT-15 s schedules.

4.1. Method

The subjects were 3 roller pigeons maintained and housed as described in the General Method section. All birds were maintained at 82.5–85% of their free-feeding weight. Table 2 shows the coding scheme used to record the behaviors of each bird. The apparatus, procedures, and recording techniques were those described in the General Method, with the following caveats: all birds were run for 20 days, were run for 30 trials each day, and received 3 s food hopper deliveries.

4.2. Results/Discussion

Fig. 5 show the temporal patterns of all 3 roller pigeons plotted every 3 s of the inter-food interval averaged over the final 4 days of the 20-day experiment. All 3 of the birds primarily showed wall-directed behaviors (e.g., WALLD) during all observational intervals. Again, as in Experiment 1, most of these behaviors consisted of moving back and forth against the wall while hugging and/or occasionally scratching the wall, stepping back and forth in front of the wall, and bobbing their heads in front of the wall. One of the roller pigeons (R2) spent approximately 10 % of all observational intervals standing away from the hopper while remaining motionless and facing the hopper (e.g., STAWY). A similar behavior was observed in one of the pigeons of Experiment 1 of Timberlake and Lucas (1985).

As predicted, roller pigeons, which are a separate breed of the common laboratory pigeon, displayed similar levels of wall-directed behaviors as the birds observed in both Timberlake and Lucas (1985) and Experiment 1. Interestingly, all 3 of the birds in this experiment remained in wall-directed behaviors throughout all observational intervals, as opposed to moving away from the hopper (e.g., LOCOM) at second 3. It's not clear if this was somehow related to breed characteristics of roller pigeons, or just a chance result of the limited number of roller pigeons in this experiment.

5. Experiment 3

If superstitious behavior under fixed-time schedules is based on niche-related foraging mechanisms and their resultant expression in behavior, we would expect the superstitious behavior of ring-necked doves to resemble that of pigeons. Ring-necked doves belong to the same taxonomic family as pigeons (Columbidae) and, thus, are one of the few other species to employ crop milk as a means of feeding their young (Kierończyk et al., 2016). It would seem reasonable that their foraging behavior should be similar to that of pigeons. In other words, we should see moving away from the hopper immediately after a food delivery, followed by wall-directed behavior around the target, and little or no pecking. In contrast, the stimulus substitution hypothesis should predict considerable terminal pecking responses in or around the hopper. The third experiment examined the behaviors of three ring-necked doves. We expected the results to be similar to that of Timberlake and Lucas (1985) under the same FT-15 s schedules.

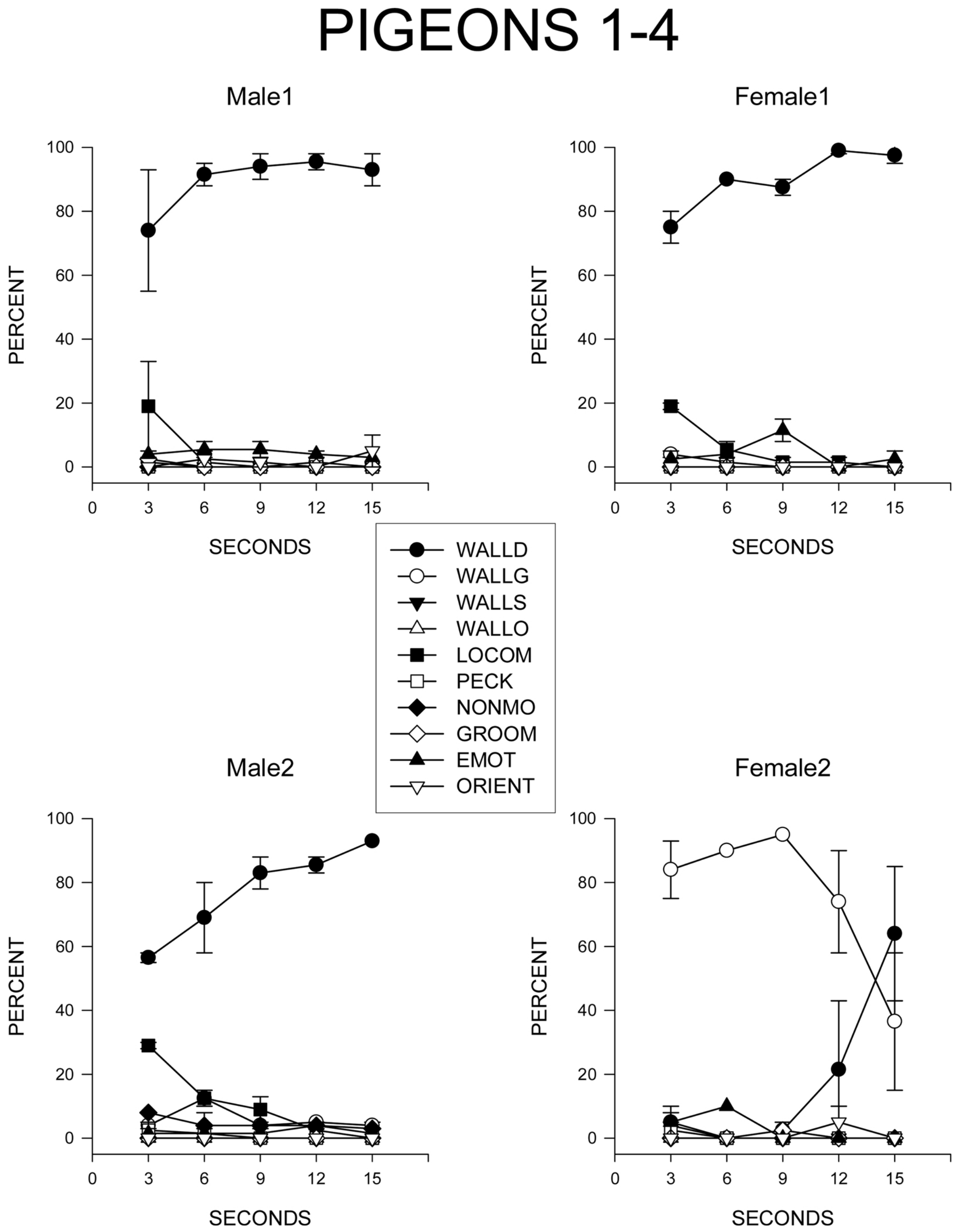

Fig. 2. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the White Carneau pigeons 1–4 in Experiment 1. Male pigeons are presented on the left, and female pigeons on the right. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on 2 days of the final 25 days of the experiment (day 20 & 25).

5.1. Method

The subjects were 3 ring-necked doves approximately 7 months of age maintained and housed as described in the General Method section. All birds were maintained at 85–87.5% of their free-feeding weight. Table 3 shows the coding scheme used to record the behaviors of each bird. The apparatus, procedures, and recording techniques were those described in General Method, with the following caveats: all birds were run for 20 days, were run for 30 trials each day, and received 3 s food hopper deliveries.

5.2. Results/Discussion

Fig. 6 show the temporal patterns of all 3 ring-necked doves plotted every 3 s of the inter-food interval averaged over the final 4 days of the 20-day experiment. All 3 of the birds primarily showed wall-directed behaviors (e.g., WALLD) during all observational intervals. Again, as in Experiment 1, most of these behaviors consisted of moving back and forth against the wall while hugging and/or occasionally scratching the wall, stepping back and forth in front of the wall, and bobbing their heads in front of the wall. Only 1 of the doves (D3) would move away from the hopper at second 3, and all 3 of the doves exhibited some level of emotional responding (e.g., EMOT) during all observational intervals, which primarily consisted of wing flapping in and around the food

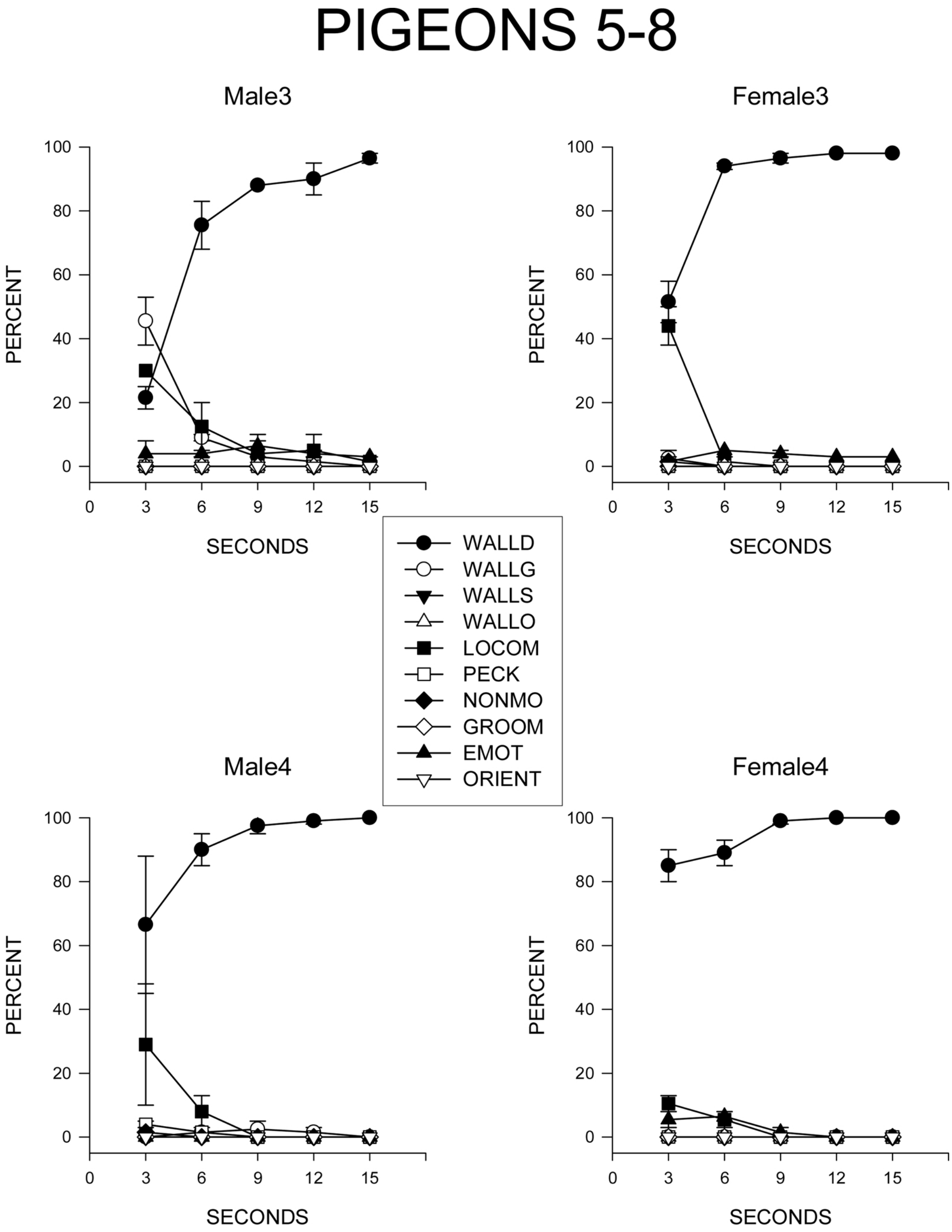

Fig. 3. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the White Carneau pigeons 5–8 in Experiment 1. Male pigeons are presented on the left, and female pigeons on the right. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on 2 days of the final 25 days of the experiment (day 20 & 25).

hopper.

As predicted, ring-necked doves, which belong to the same taxonomic family (Columbidae) as the common laboratory pigeon, displayed high levels of wall-directed behaviors similar to the birds observed in both Timberlake and Lucas (1985) and Experiment 1 and 2. However, all three doves also exhibited high levels of wing flapping directed towards the food hopper and/or food hopper wall, with two of the birds' wing flapping increasing in frequency toward the delivery of food. This may in part have been due to the smaller size of the doves compared to pigeons, and the increase in wing flapping may have been a result of the birds attempting to reach the food hopper.

6. Experiment 4

As noted previously, if superstitious behavior under fixed-time schedules is based on niche-related foraging mechanisms and resultant behavior, it follows that a different species, even another ground feeding bird species, like chickens, should show a different set of behavior than pigeons. Chickens are omnivorous, unlike pigeons and doves, which in the wild are considered granivorous (Klasing, 2005; Murton and Westwood, 1966). During development chickens do learn to peck at the location and substances the mother hen pecks at, but they are precocial animals and do not learn to beg for food regurgitated from the mouth of their parent (Nicol, 2004). As a result, we would not expect chickens to show wall-directed stepping, head bobbing, and other wall-directed responses. Instead we would anticipate their showing

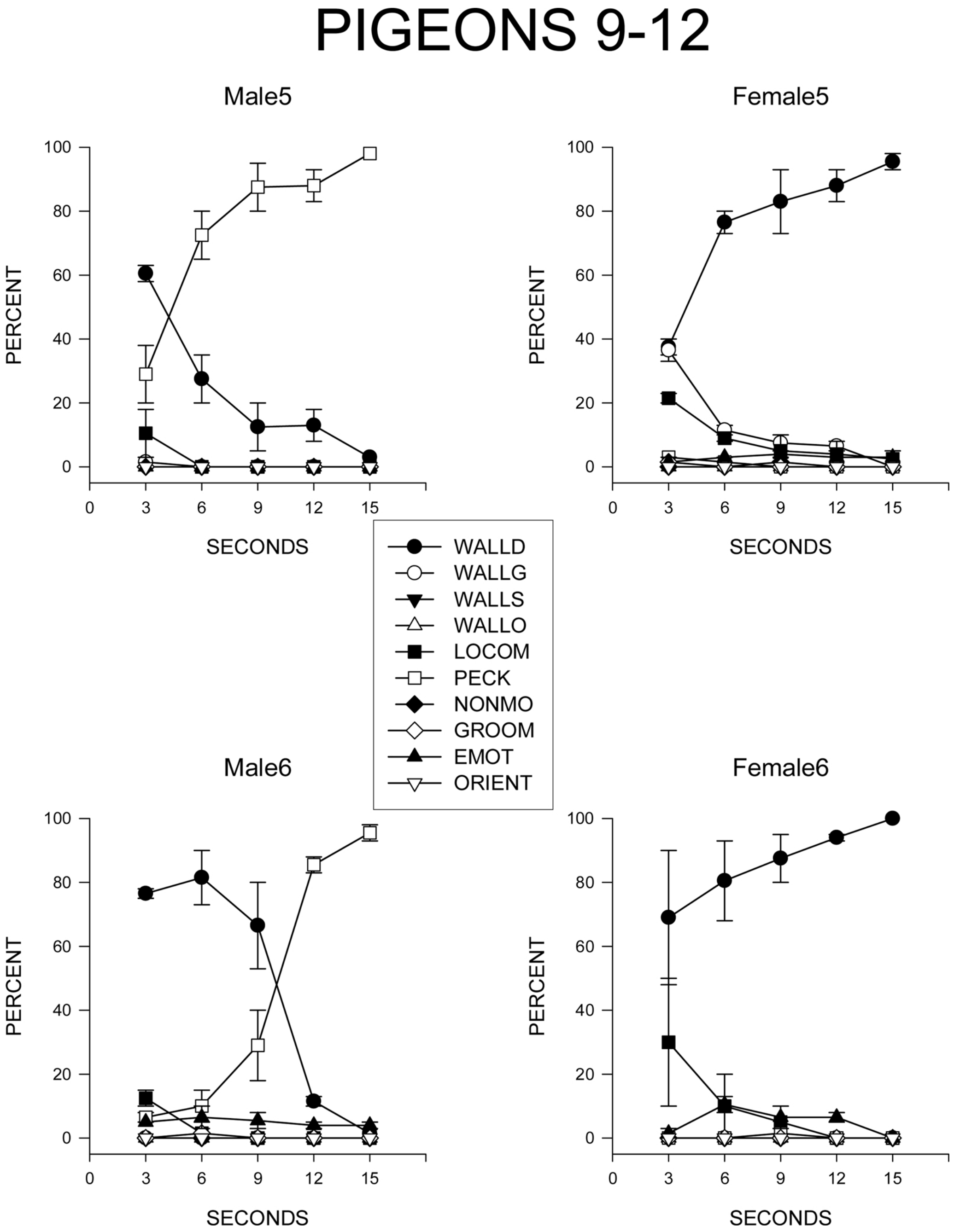

Fig. 4. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the White Carneau pigeons 9–12 in Experiment 1. Male pigeons are presented on the left, and female pigeons on the right. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on 2 days of the final 25 days of the experiment (day 20 & 25).

primarily focal search/handling behaviors of scratching and pecking of the floor and wall. Similarly, Staddon & Simmelhag's (1971) stimulus substitution hypothesis would predict considerable terminal pecking and scratching responses in chickens. However, pecking and scratching should be concentrated around the hopper, which would be paired directly with food.

The fourth experiment examined the behaviors of eight bantam chickens. We expected the results to be considerably different from either Timberlake and Lucas (1985) or Staddon and Simmelhag (1971) under the same FT-15 s schedules.

6.1. Method

The subjects were 8 bantam chickens obtained from a commercial supplier. They were maintained and housed as described in the General Method section. All birds were maintained at 80 % of their free-feeding weight. Table 3 shows the coding scheme used to record the behaviors of each bird. The apparatus, procedures, and recording techniques were those described in General Method, with the following caveats: all birds were run for 16 days, were run for 40 trials each day, and received 4 s food hopper deliveries.

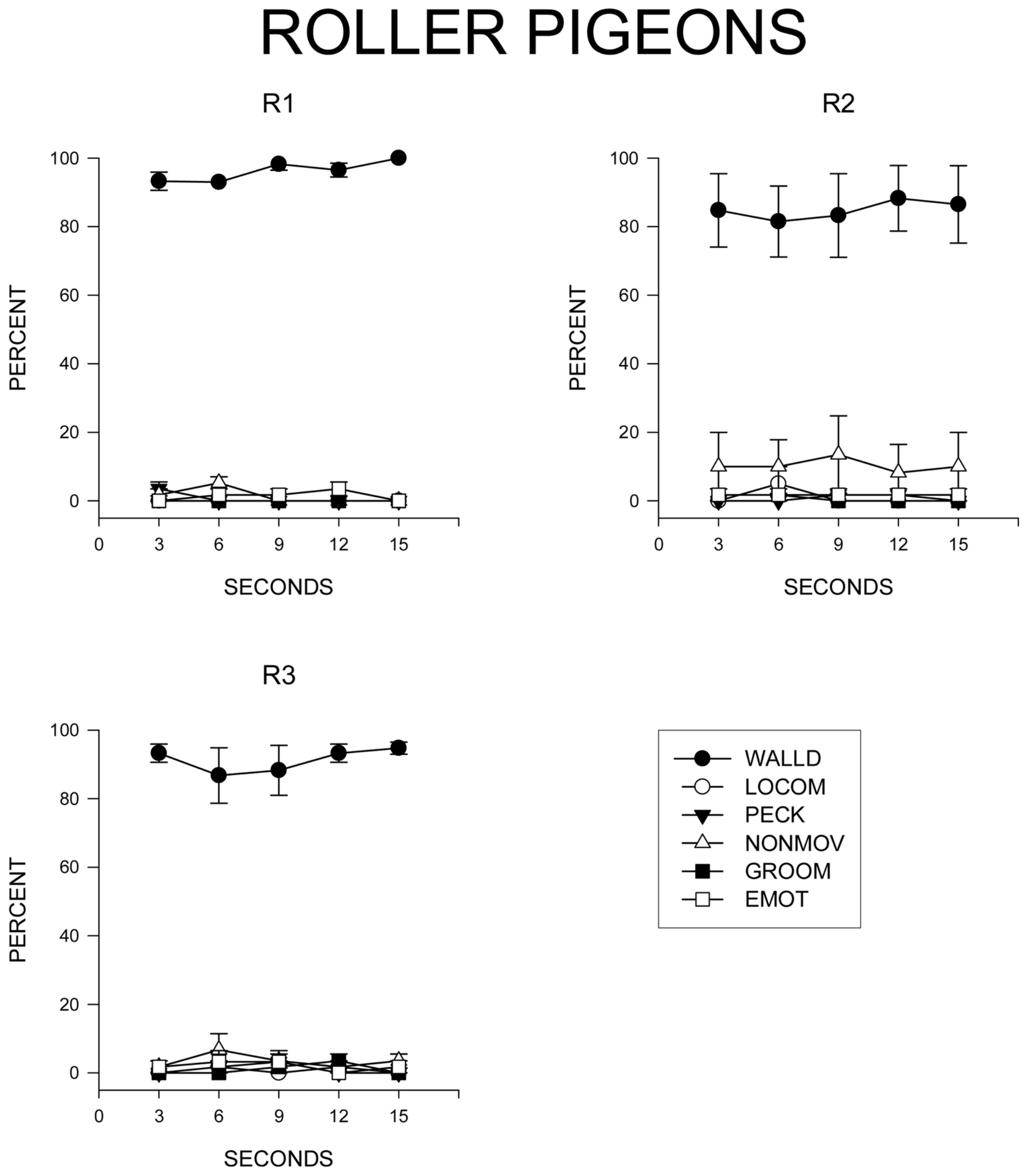

Fig. 5. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the roller pigeons 1–3 in Experiment 2. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on the final 4 days of the 20-day experiment.

6.2. Results/Discussion

Figs. 7, 8 show the temporal patterns of all 8 bantam chickens plotted every 3 s of the inter-food interval averaged over the final 4 days of the 16-day experiment. All 8 of the birds showed at least moderate levels of orienting toward the food hopper (e.g., ORIENT) at second 3 and 15, immediately before and following a food delivery. For 5 of the 8 chickens, scratching at the floor (e.g., SCRATCH) occurred for most the interim intervals (e.g., second 6–12). For 2 of the 8 chickens, pecking at either the floor or the hopper (e.g., PECK) occurred for most of the interim intervals. For 1 of the 8 chickens (C5), both scratching at the floor and pecking at either the floor or hopper occurred frequently during all observational intervals, and for another chicken (C8), orienting toward the hopper without moving occurred frequently during all intervals.

Fig. 9 shows the temporal patterns of all 8 bantam chickens combined and plotted every 3 s of the inter-food interval, and again for the final 4 days of the 16-day experiment. The plot on the right combines both PECK and SCRATCH behaviors (e.g., PECK + SCR). Both graphs display the regularity with which orienting toward the hopper occurs immediately before and following a food delivery, while scratching at the floor or pecking at the hopper or floor appear to happen as interim responses to the food interval. Thus, Staddon and Simmelhag (1971) might describe such scratching/pecking as interim adjunctive behaviors, although under their stimulus substitution explanation, one would expect such pecking/scratching responses to occur as terminal responses. A behavior systems approach to this behavior (see Timberlake, 1997, 2000; Timberlake and Silva, 1994) would suggest that orienting, scratching, and pecking are a function of appetitive, species-typical foraging responses elicited by the schedule of food delivery. Orienting responses should approximate proximate search responses, while scratching and pecking responses are more distally related to general search patterns of foraging.

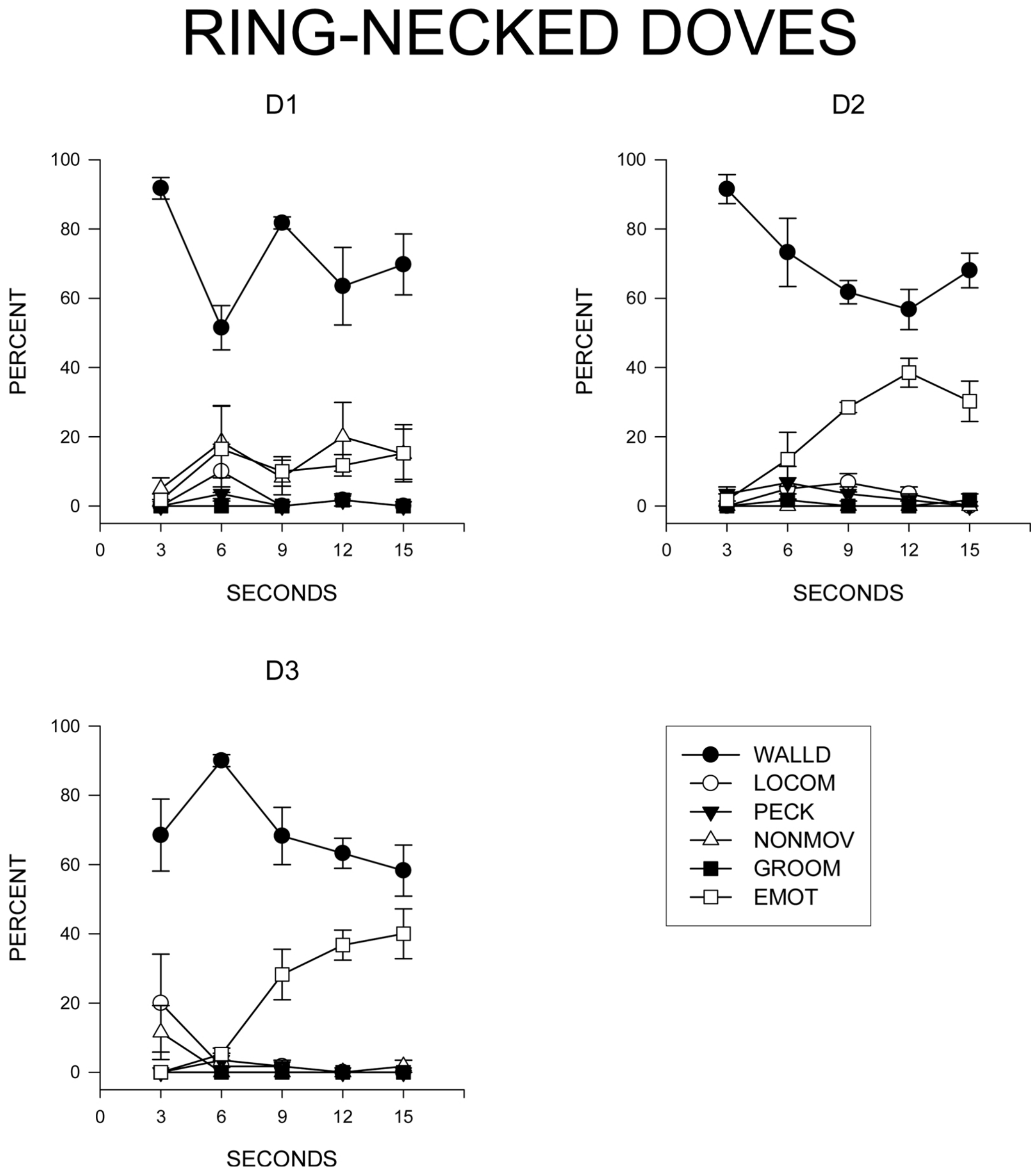

Fig. 6. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the ring-necked doves 1–3 in Experiment 3. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on the final 4 days of the 20-day experiment.

7. General discussion

7.1. Sex and breed differences in pigeon pecking

One of the difficulties in comparing both Staddon and Simmelhag's (1971) and Timberlake and Lucas' (1985) findings is that in one study, all birds pecked as a terminal response, while in the other study, few of the birds pecked. Timberlake and Lucas examined this in greater detail by presenting a shorter, 2 s access to the food (similar to that used by Staddon and Simmelhag), decreasing the interval to 9 s, and increasing the number of days a bird was exposed to an FT schedule. They also tested White King pigeons, a strain of pigeon observed to peck more often in superstitious conditioning studies (Fenner, 1980). While the food access and interval length had little effect on pecking, 1 of the 4 White King pigeons displayed a significant portion of pecking as a terminal activity, and 2 of the 4 pigeons on the extended trials pecked during approximately 20 % of the intervals sampled. Still, with the exception 1 of the White King pigeon, none of the pigeons displayed terminal pecking activity like that observed in Staddon and Simmelhag.

As noted previously, other studies examining response-independent food schedules with pigeons found considerably less pecking than Staddon and Simmelhag (1971) (Innis et al., 1983; Reberg et al., 1978). Additionally, many of the studies that did involve pecking used male pigeons as their subjects, whereas Timberlake and Lucas (1985) exclusively used female pigeons. Experiment 1 helped confirm that at least some of the disparity between the Staddon and Simmelhag and Timberlake and Lucas studies were due to the sex of the bird. These results provide further evidence that the pecking observed was a result of species-typical foraging and courtship behavior, rather than stimulus substitution, since female pigeons engage in more food-begging responses and less potential food-giving (e.g., pecking) activity (Timberlake and Silva, 1995). In addition, pecking as a foraging and courtship response, as opposed to as a result of stimulus substitution, compliments previous research examining the basis of stimulus substitution itself (Timberlake and Grant, 1975).

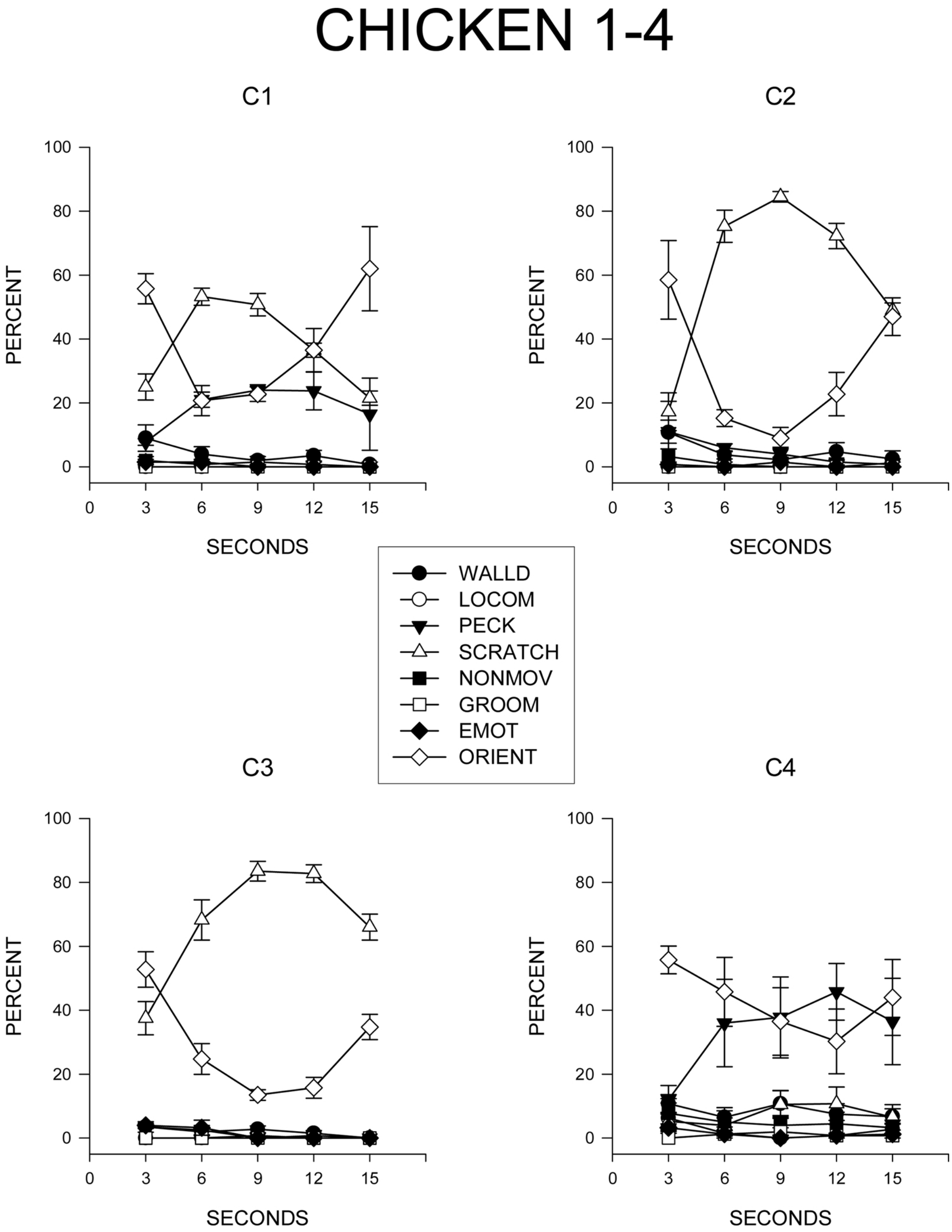

Fig. 7. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the chickens 1–4 in Experiment 4. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on the final 4 days of the 16-day experiment.

7.2. Species differences

Experiments 2–4 examined the similarities and differences of a different breed of the laboratory White Carneau pigeon species (Exp. 2, roller pigeons; *Columba livia*), a different species but same taxonomic family of the laboratory pigeon (Exp. 3, ring-necked doves; *Streptopelia capicola)*, and a species of bird in a different taxonomic order (Exp. 4, bantam chickens; *Gallus gallus*). We expected both the roller pigeons and ring-necked doves to have similar enough natural foraging strategies to the laboratory pigeon to exhibit predominantly wall-directed activity under response-independent food schedules, while the chickens, who are omnivorous and precocial, should deviate substantially from wall-directed behaviors. Additionally, we expected these differences to provide further support that the behaviors of these birds observed under response-independent food schedules are a function of elicited, species-typical food-getting behavior, as opposed to either stimulus substitution or adventitious reinforcement. Our results confirmed this, with the pigeons and doves in our experiments exhibiting primarily wall-directed behaviors, while the chickens displayed no wall-directed behaviors, and instead oriented toward the hopper wall as a terminal response, and scratched and/or pecked at the floor or hopper as an interim response. It is additionally worth noting that Breland and Breland (1961) observed similar floor scratching behaviors in chickens made to wait on a platform for 12–15 s. Neither stimulus substitution nor adventitious reinforcement explanations could account for the predominantly non-pecking, non-idiosyncratic responding we observed

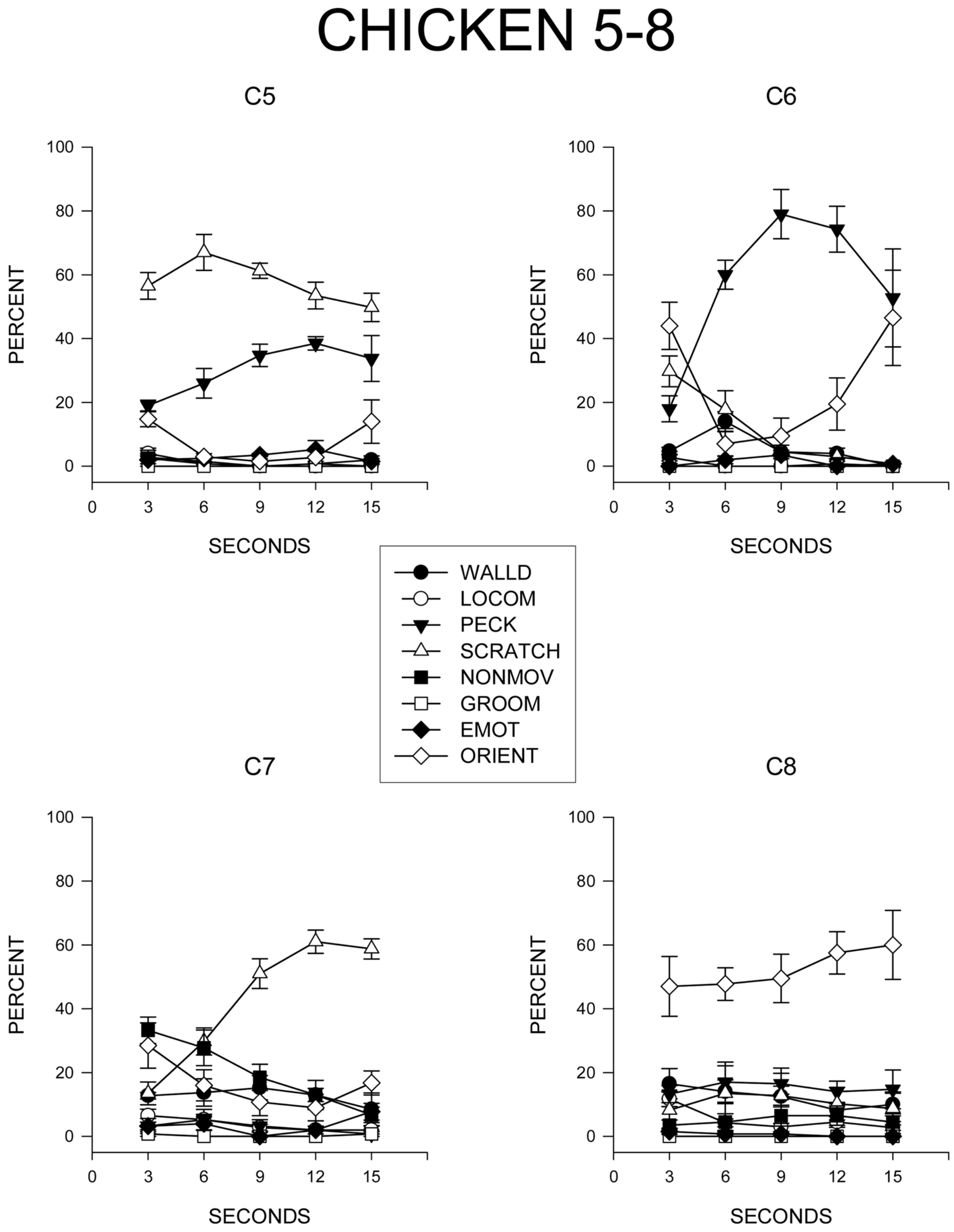

Fig. 8. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for the chickens 5–8 in Experiment 4. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). Average number of responses with standard errors of the mean (SE) are graphed based on the final 4 days of the 16-day experiment.

in all our experiments.

7.3. Mechanical measurement and direct observation

Much of the research on superstition has used as its subjects laboratory pigeons, and focused exclusively on one response topography: key pecking (Appel and Hiss, 1962; Herrnstein and Morse, 1957; Killeen, 1978; Lachter et al., 1971; Morse and Skinner, 1957; Neuringer, 1970; Zeiler, 1968). In most cases, maintaining key pecking when shifting from response-dependent to response-independent schedules has either failed or required additional stimulus support to maintain pecking. Similarly, laboratory studies on superstition in rats have been conducted, with some studies measuring multiple response topographies (Davis and Hubbard, 1972; Reberg et al., 1977; Rescorla and Skucy, 1969; see also Eldridge et al., 1988, for multiple measures of superstitious behaviors in pigeons). In some cases, lack of responding on one topography, or even the existence of only that response topography occurring, have been used as proof for or against adventitious reinforcement as an adequate explanation of superstitious behavior. However, Skinner's (1948) initial paper on superstition focused on direct observation of multiple response topographies in his pigeons. Anecdotal as those observations may have been, it illustrated the need for systematic measurement of behaviors beyond one mechanically recorded response topography (Davis et al., 1973). Put simply, the study of superstitious behavior requires systematic observation and recording of multiple response topographies (Fernandez and Timberlake, 2008).

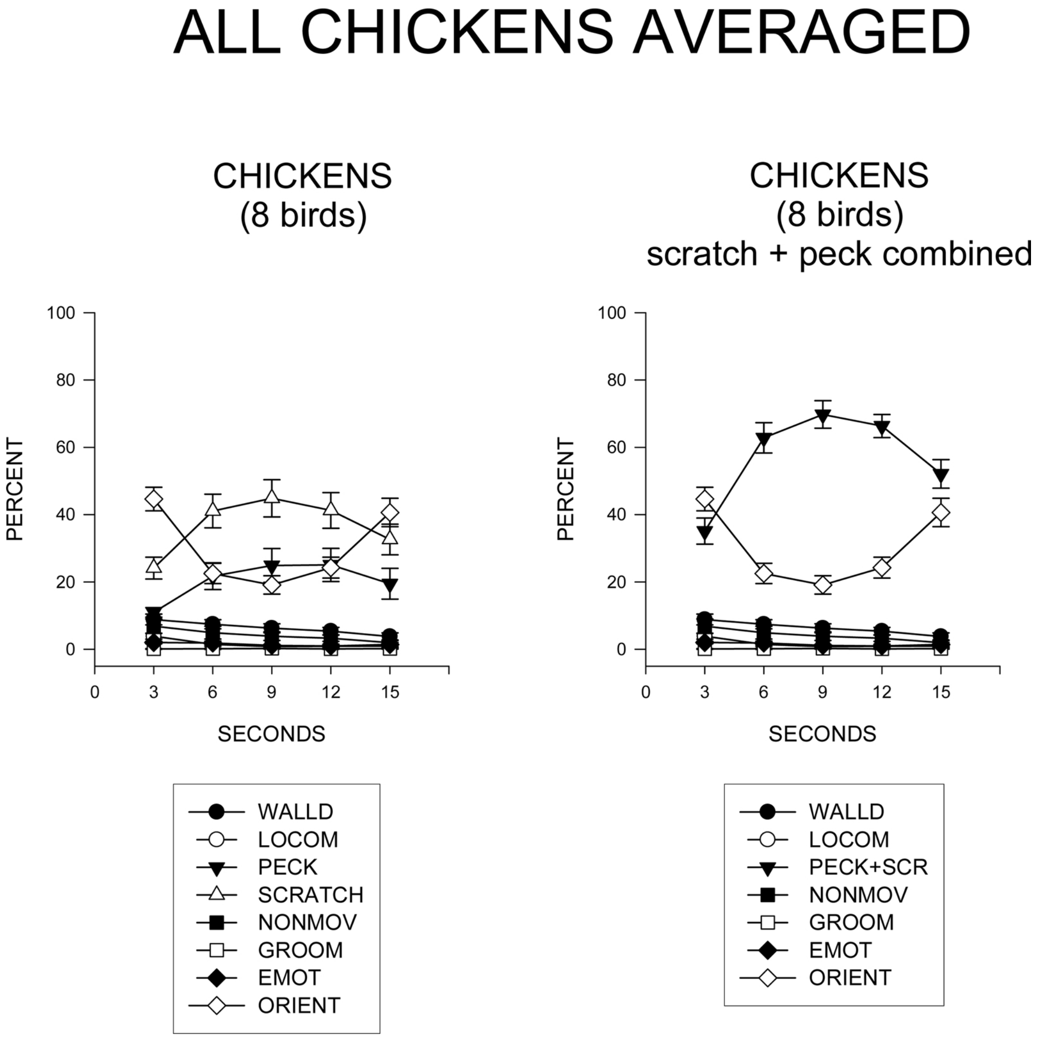

Fig. 9. Percentage of occurrence for each of the behavioral categories (classes) of behaviors possible for all 8 chickens averaged in Experiment 4. Behaviors were coded every 3 s for the 15 s between food deliveries (FT-15 s). The graph on the left is the average performance across all 8 classes of behavior, while the graph on the right represents 7 classes of behavior, with Pecking and Scratching combined as 1 class. Average number of responses with standard errors of the mean (SE) are graphed based on the final 4 days of the 16-day experiment.

7.4. Reinforcement, contingency, and contiguity

Over the past several decades, response-independent schedules (i.e., “noncontingent” reinforcement) have been effectively used for applied purposes, primarily to reduce undesired behaviors. While a review of such techniques is beyond the scope of this paper (see Carr et al., 2000), it is worth mentioning for two reasons: (1) it has brought attention to the reinforcement/contiguity dilemma, and (2) it has promoted examinations of the function of response-independent schedules that go beyond adventitious reinforcement.

With respect to the reinforcement/contiguity dilemma, others have previously noted that contiguity alone is not sufficient for defining either respondent or operant conditioning procedures (Rescorla, 1967; Staddon, 1992). Reinforcement, by definition, is contingent upon some response occurring (Carr, 1996; Poling and Normand, 1999; Vollmer, 1999). However, adventitious reinforcement defies such a necessary requirement, as it relies exclusively on temporal contiguity between an accidental reward and the response that precedes it. As such, superstition as a result of adventitious reinforcement should be as much of a theoretical conundrum as “noncontingent reinforcement”. With respect to examining non-adventitious reinforcement functions related to response-independent schedules, much of the human-oriented research suggests operant-related functions, such as satiation or response extinction (Carr et al., 2000; Kahng et al., 2000). Other research implementing response-independent schedules for applied purposes have examined their effects on stereotypic pacing in captive bears (Andrews and Ha, 2014; Carlstead et al., 1991; Fernandez, 2010). Future research could benefit directly from examinations of the potential environmental enrichment functions related to eliciting species-typical appetitive behavior as a result of fixed- and variable-time schedules.

7.5. Superstition revisited: an appetitive, ecological approach

The concept of adventitious reinforcement and superstition provided a useful heuristic for the promotion of operant conditioning principles. As Skinner (1987) noted, “The effect of an accidentally contingent reinforcer offers some of the best evidence of the power of operant conditioning, and possibly for that reason it has been challenged – as, for example, by Staddon and Simmelhag (1971). The behavior is said to drift toward phylogenic forms. I am quite sure of my original observation. I have repeated it many times, often as a surefire lecture demonstration. Deliver food every twenty seconds to a hungry pigeon and it will soon exhibit a food-getting ritual of unpredictable topography. I see no reason why there should not be a drift toward phylogenic behavior. It would be something like the Breland Effect unopposed by operant contingencies.” (p. 163–164).

Nevertheless, several difficulties exist in attempting to use adventitious reinforcement as an explanation for the occurrence of behavior under response-independent schedules. First, pigeons previously trained to peck a key under response-dependent schedules generally do not continue to do so when placed on similar response-independent schedules. The argument that ‘other’ behavior is being reinforced holds little empirical value when those other behaviors are not directly measured, and therefore provides no support. Second, when multiple behaviors are directly measured under response-independent schedules, the topographies of those responses in pigeons are not idiosyncratic. The production of idiosyncratic responses under response-independent schedules is an essential argument for the demonstration of adventitious reinforcement, since the lack of varying topographies suggests that the behaviors observed are not arbitrary, and therefore a result of events other than accidental rewards.

Stimulus substitution accounts of behavior under response-independent schedules appear to have several difficulties as well. The crux of the stimulus substitution account of superstitious behaviors in pigeons relies on the occurrence of terminal pecking activity at areas near or on the food delivery system. Since these areas may be paired with the delivery of food (as in a traditional respondent conditioning procedure), the stimulus substitution account suggests that a pigeon would respond to these areas as if responding to food. However, this and other studies have demonstrated that many pigeons spend little to no time pecking as a terminal activity under response-independent schedules. Many of the responses that do occur as terminal activity, such as wall-directed hugging or pacing (in pigeons) or orienting toward the hopper (in chickens), appear to have few similarities to how those birds contact food immediately before consumption.

Of the three theoretical accounts for understanding the function of behavior under response-independent schedules, the behavior systems account appears to best explain the behaviors that emerge. According to a behavior systems account, behaviors observed under response-independent food schedules should reflect species-typical food-getting behaviors, supported by the length of the interval and characteristics of the chamber (Timberlake and Lucas, 1989). That is, response-independent food schedules should elicit appetitive search behaviors related to the species involved and modulated by the environmental support provided. As in the quote above, Skinner readily acknowledged the importance of natural selection and an organism’s species-typical behavior in relation to what is and can be learned (Skinner, 1981, 1987; Timberlake, 2004). Superstition, and learning in general, should be placed within this ecologically relevant framework. Superstitious behavior, if we choose to call it that, is behavior afforded by both the environment and the organism. Both are indispensable for an appropriate functional description of superstition.

Acknowledgements

These studies were conducted as several different projects between 1984 – 1990. Much of the experiments were then coded and analyzed by the first author between 2003 – 2004. The authors would like to thank Kathryn Kalafut for countless hours spent coding pigeon, dove, and chicken videos.

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