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Behavioural Processes 43 (1998) 219–228

BEHAVIOURAL PROCESSES

External factors and causation of dustbathing in domestic hens

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Received 1 April 1997; received in revised form 18 February 1998; accepted 18 February 1998

Abstract

Dustbathing is known to be motivated by complex interactions between internal factors which build up over time and external factors, such as the sight of a dusty substrate. In this study, the effects of other external factors were investigated. Environmental temperature was shown to be important; frequencies of dustbathing were greater when hens were held at 22 than at 10°C ($P < 0.01$). In a second experiment, a radiant heat source or a radiant heat + light source, balanced to give the same radiant heat, resulted in more dustbathing behaviour during a 1-h stimulus period than during the same period with no stimulus ($P < 0.05$). Components of dustbathing were increased more by the heat + light stimulus than by the heat stimulus alone ($P < 0.03$). In a third experiment, the amount of dustbathing performed by individual hens in cages with dustbaths was increased by the presence of a group of hens dustbathing in an adjoining pen with a dustbath compared with the amount occurring when the hens were absent from the pen.

Keywords: Dustbathing; Illumination; Laying hens; Radiant heat; Social facilitation; Temperature

1. Introduction

Dustbathing in poultry is controlled by complex interactions between internal, peripheral and external factors. With regard to internal factors, it is known that the tendency to dustbathe fluctuates according to time of day, with more dustbathing occurring in the middle of the day (Vestergaard, 1982; Vestergaard et al., 1990), which suggests some type of endogenous circadian rhythm of motivation. If birds are denied the opportunity to dustbathe, the tendency to dustbathe increases with time, suggesting a Lorenzian build-up of motivation (Vestergaard, 1980, 1982).

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0376-6357/98/$19.00
PII S0376-6357(98)00017-5

Table 1
Schedules of temperature and substrate treatments for Experiment 1

Time table	Chamber A Trial 1 (three groups of ten hens)	Chamber B Trial 1 (three groups of ten hens)	Chamber B Trial 2 (three groups of ten hens)
1 Week	16°C Peat	16°C Peat	16°C Peat
9 Days	22°C Peat	10°C Peat	22°C Peat
9 Days	10°C Peat	22°C Peat	10°C Peat
1 Week	16°C Sand	16°C Sand	16°C Sand
9 Days	22°C Sand	10°C Sand	10°C Sand
9 Days	10°C Sand	22°C Sand	22°C Sand

Surprisingly, peripheral factors seem relatively unimportant in controlling the occurrence of dustbathing. Deprivation of dustbathing results in an increase in lipids on the feathers and a subsequent increase in dustbathing activity when this is allowed (van Liere and Bockma, 1987). However, although it can be speculated that the function of dustbathing is probably removal of excess lipids on the feathers (van Liere, 1992), lipid accumulation as a major cause of dustbathing has not been proved. van Liere et al. (1991) could only increase the duration of dustbathing bouts marginally by spreading lipids, equivalent to 1–2 month's accumulation, on birds' feathers. Moreover, extirpation of the oil gland in chicks, which eliminated the main source of lipids, had no effect on subsequent dustbathing (Nørgaard-Nielsen and Vestergaard, 1981). It therefore seems that the main effects of deprivation of dustbathing act through a central mechanism and not a peripheral one.

With regard to external factors, visual stimuli emanating from the substrate have been shown to be very important in triggering dustbathing behaviour (Petherick et al., 1995). The results of Petherick et al. (1995) also suggested that domestic fowl may hatch with a predisposition that enables them to 'recognize' a substrate suitable for dustbathing. In addition, Hogan and van Boxel (1993) have shown that a light/heat stimulus can control the time of day at which dustbathing is shown.

The experiments described here were designed to investigate more closely the effects of environmental temperature, radiant heat, light, and social stimulation on dustbathing behaviour.

2. Experiment 1: Effects of ambient temperature and type of substrate on occurrence of dustbathing

2.1. Materials and methods

2.1.1. Animals and housing

Ninety, mature, litter-reared, medium bodyweight, laying hens (ISA Browns) were used in this experiment. The hens were kept in groups of ten in floor pens (1.8 × 1.8 m) covered in wood shavings. There were three pens in each of two environmentally-controlled chambers. Each pen was furnished with one tube feeder, one gravity flow drinker, one perch and two nest boxes. In the centre of each pen was a wooden box (0.8 × 0.8 × 0.08 m) for dustbathing substrate. The chambers were illuminated by incandescent lights maintained on a 14:10 h light/dark cycle (lights on 06:00–20:00 h) and giving an average illumination of 45 Lux in the pens.

2.1.2. Experimental procedure

Hens were exposed to the schedule of treatments listed in Table 1. The hens were given 1 week of moderate temperature of 16°C to adjust to the pens. Following the adjustment period, environmental temperature was maintained at either 10°C (cool) or 22°C (warm) for a period of 9 days. The hens were allowed 3 days to acclimate to the temperature and video-recorded for the final 6 days. Then, temperatures in the chambers were switched so that hens experiencing the warm environment in the first phase of the experiment, experienced the cool in the second, and vice versa. Again the hens were allowed three days to acclimate to the new temperature, and then behaviour was video-taped for 6 days. The entire cycle of temperatures was imposed twice. Peat was available in the dustbath during the first cycle while sand was provided as a dustbathing substrate during the second. During Trial 2, hens in Chamber A (three pens of ten hens) developed severe feather-pecking and had to be eliminated from the study.

2.1.3. Data collection and analysis

Video recordings were made by sequentially switching input from three cameras so that each pen was videotaped for a period of 90 s every 270 s. Videotapes were reviewed for the entire light period over 6 days. The numbers of birds engaged in active dustbathing either in the dustbath or in the wood shavings at any time during a 90-s observation period were recorded as dustbathing incidents. Active dustbathing included the behaviour patterns of side-rubbing, head-rubbing, vertical wing shaking and side-lying with scratching (van Liere, 1991). Incidents of dustbathing were summed over the day, and daily sums were averaged over the 6-day period.

Paired t-tests were used to determine whether differences in the average daily sums of dustbathing incidents between environmental temperatures with a given substrate and between different substrates at a given temperature were different from zero (SAS Institute, 1982).

2.2. Results

Environmental temperature had a significant effect on the occurrence of dustbathing (Fig. 1). Hens dustbathed about 50% more often at 22°C than they did at 10°C. The mean differences in average number of dustbathing incidents differed significantly from zero ($P < 0.01$) regardless of whether peat or sand were available as dustbathing substrates.

The type of substrate made available to the birds in the dustbath did not influence the occurrence of dustbathing ($P > 0.10$). For a given temperature, the total numbers of dustbathing incidents were the same whether birds were provided with peat or sand (Fig. 1). Overall, the majority of dustbathing events were observed to occur in the shavings outside of the dustbath, where there was more space. However, when peat was available in the dustbath, hens tended to do more of their dustbathing in the bath than they did when sand was available.

3. Experiment 2: Effects of radiant heat and illumination on the occurrence of dustbathing

We decided to look at the effects of radiant heat and illumination since the evidence in published reports is rather confused. There are reports of domestic hens aggregating in patches of sunlight and coming into physical contact with each other (Gibson et al., 1985; Huber and Fölsch, 1985). They therefore seem to find sunlight attractive and it seems to diminish social spacing, but it is unclear whether it is the heat or the light or the combination of these factors that is important. Domestic fowl are also among species known to engage in ‘sun-bathing’ behaviour in which birds spread out their wings and ruffle their feathers (McFarland, 1981). Morris (1956) working with estrildine finches, reported that

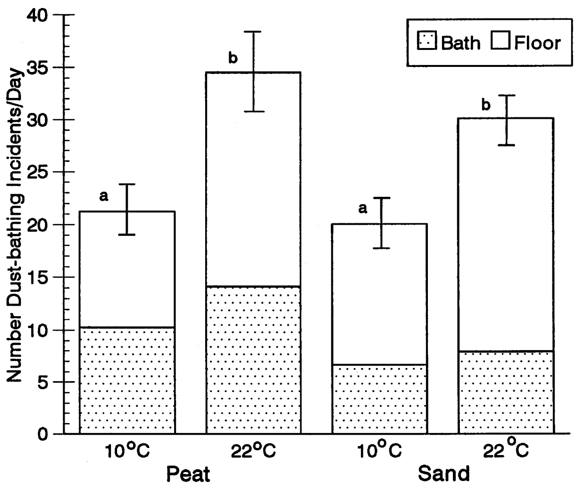

Fig. 1. Mean number (±S.E.M.) of dustbathing incidents per day when hens were kept at 10 or 22°C, and when peat or sand were available in the dustbath. Solid portion of bars represents dustbathing on litter floor; stipple represents dustbathing in substrate. Bars having different letters differ significantly ($P < 0.01$).

powerful lamps used to illuminate finches for photography 'produced such a high temperature that the birds began to ruffle and even sunbathe' (our quotes). Morris assumed that it was the high temperature rather than the illumination that was responsible for stimulating this behaviour. Similarly, McFarland and Baher (1968) working with Barbary doves (*Streptopelia risoria*) were able to stimulate sunbathing with high intensity illumination. They carried out their experiments in a temperature-controlled cage and concluded that it was the high illumination and not the temperature that stimulated sun-bathing. McFarland (1981) considers that the function of sun-bathing in birds is not primarily thermoregulatory, but may allow sunlight to reach the skin and encourage synthesis of vitamin D. The fact that Hogan and van Boxel (1993) were able to stimulate dustbathing behaviour using a flood light which produced both heat and light, suggests that sun-bathing and dustbathing share some common causal factors. However, in most of these reports there is confusion over air temperature and radiant heat. Thus even in the experiment of McFarland and Baher (1968), the birds may have been responding to perceived radiant heat in spite of the fact that air temperature was kept constant.

In this experiment, we attempted to separate out the effects of radiant heat and illumination. We based our experiment on the fact that it is impossible to get light (that would be in any way similar to sunlight) without heat, but it is possible to get radiant heat without light.

3.1. Materials and methods

3.1.1. Animals and housing

Six groups of three, mature, litter-reared, medium body-weight, laying hens (ISA Browns) were held in small floor pens (1.04 × 1.27 m) in a single room in each of two trials. Each pen had one tray feeder, two automatic-nipple drinkers, and a two-hole nestbox. The floors were covered with wood shavings. A black plastic curtain suspended 3 m high separated the pens so that hens could not see other hens or be affected by the heat/light treatment in adjacent pens. The room was illuminated with fluorescent lights maintained on a 15:9 h light/dark cycle (lights on 06:00–21:00 h). Average illumination in the pens was 20 Lux and the temperature in the room was always between 21–22°C throughout the experiment.

3.1.2. Experimental procedure

The experimental treatments consisted of exposure to either radiant heat alone or radiant heat + light. Dull-emitter radiant heaters (Wiegand 400 W Electric Radiant Heater) suspended over the pen were used to provide radiant heat, and photoflood lights (GE 120 v Photoflood) mounted in metal lamp shades suspended over the pen provided radiant heat + light. Dull-emitter radiant heaters produce mainly heat, but do emit a dull red glow indicating that they produce some light within the infra-red range of the human visible spectrum. This light cannot be detected by a standard light meter. The spectral sensitivities of chickens are somewhat similar to those of human beings within this range of the visible spectrum. Photoflood lights emit extremely bright light over a broad and continuous range of wavelengths that closely approximates bright sunlight. They also produce a great deal of energy in the form of heat.

The amount of radiant heat absorbed by hens from each of the sources was measured and balanced using a Vernon globe (Hertig, 1968). The globe consisted of a hollow copper sphere 20.3 cm in diameter painted a light brown which closely matched the colour of the hens. A thermometer was inserted into the sphere so that its bulb was suspended in the air space in the centre of the sphere. The sphere was placed at hen level in a pen and the heat/light source was suspended over the globe. The radiant heat absorbed by the globe caused the air inside the sphere to warm, and the temperature inside the globe was measured using the thermometer. The heights of the photoflood lights and the radiant heaters were adjusted over the globe so that air temperature inside the globe was between 32 and 33°C for each of the heat/light sources. The heat + light source gave 4300 Lux illumination at bird level directly under the source and 2000 Lux at the edge of the pen.

The experimental design was a series of incomplete Latin Squares. Every day from 14:00–15:00

Table 2
Schedules of stimulus exposures used in Experiment 2 (three groups of hens received each of the treatment schedules)

Time table	Stimulus schedule			
	1	2	3	4
Days 1–4	None	None	Radiant heat + light	Radiant heat
Days 5–8	Radiant heat + light	Radiant heat	None	None
Days 9–12	None	None	Radiant heat	Radiant heat + light
Days 13–16	Radiant heat	Radiant heat + light	None	None

h, each pen of hens was exposed to either radiant heat, radiant heat + light or no stimulus as a control. Each stimulus treatment was imposed over a 4 day period. A period of 4 days of no stimulus was interspersed between the periods of heat/light stimulus to prevent carry-over effects. Four treatment schedules were used (Table 2) so that three groups of hens received each treatment schedule. The treatment schedules were randomly allotted to pens over the two trials. Room temperatures were recorded before and after each stimulus hour to ensure that temperature within the room did not change.

3.1.3. Data collection and analysis

Behaviour sampling and data collection were similar to that described in Experiment 1. Videotapes were reviewed for the entire light period over the four days of each treatment. The numbers of birds engaged in either squatting/side lying, or active dustbathing at any time during a ninety second observation period were recorded. In 'squatting/side lying' the hen lowered her body to the ground and lay on her side with legs and sometimes wings held outward and away from the body. Active dustbathing was described in Experiment 1. Incidents of squatting/lying and dustbathing were summed for each hour of the light period so that the stimulus hour (14:00–15:00 h) could be compared across treatments and with other hours of the day. Hourly sums were averaged over the four day treatment period for the heat/light sources and over the eight days of no stimulus (control).

Analyses of variance using Latin square design were used to determine whether there were any differences in the incidents of squatting/lying and dustbathing during the stimulus hour due to exposure to radiant heat or radiant heat + light (SAS Institute, 1982). Square root transformations of data were used in the statistical analyses. Data appearing in the figures are untransformed. When F-tests were found to be significant, orthogonal contrasts were used to determine any difference between heat/light source versus control and between radiant heat versus radiant heat + light.

3.2. Results

The mean incidents of squatting/lying and dustbathing during the stimulus hour for each treatment are shown in Fig. 2. The birds performed significantly more squatting/lying when exposed

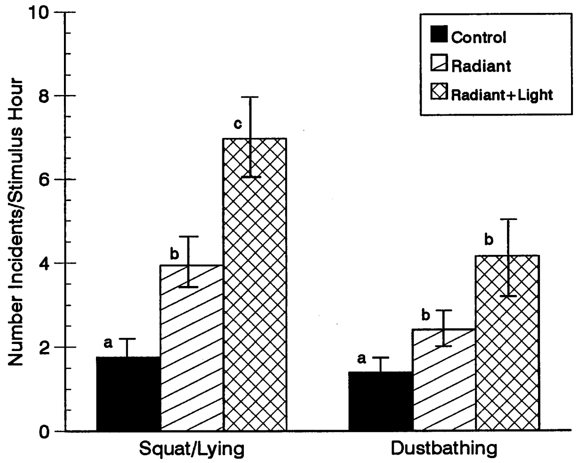

Fig. 2. Mean numbers (± S.E.M.) of incidents of squatting/lying and dustbathing occurring during the stimulus hour when radiant heat, radiant heat + light or no stimulus was present. Bars with different letters differ significantly ($P < 0.05$).

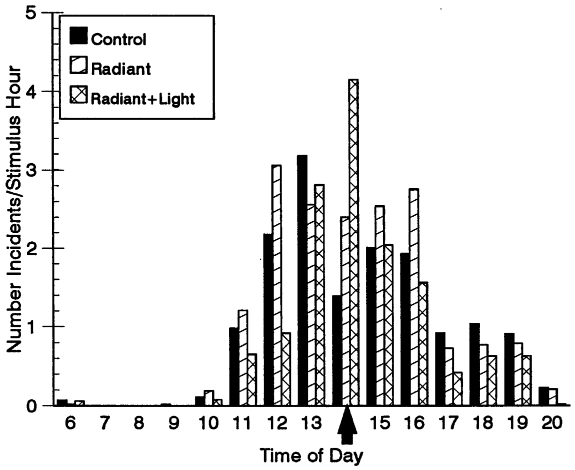

Fig. 3. Mean number of incidents of dustbathing per hour over the day when radiant heat, radiant heat + light, or no stimulus was present during the stimulus hour. Arrow indicates the stimulus hour.

to radiant heat and radiant heat + light compared to control ($P < 0.03$), with the highest incidents observed when exposed to radiant heat + light ($P < 0.01$). Dustbathing behaviour followed a similar pattern with significantly higher incidents of dustbathing when birds were exposed to a heat/light source compared to control ($P < 0.03$). Although the highest incidence of dustbathing was observed during stimulus hours of radiant heat + light, it was not statistically different from radiant heat ($P = 0.10$).

The hourly mean incidents of dustbathing for each treatment over the entire daylight period are shown in Fig. 3.

4. Experiment 3: Effects of visual exposure to a group of dustbathing hens on dustbathing behaviour of individually caged laying hens

Dustbathing is very much a social activity (Duncan, 1980; Vestergaard, 1982) and this experiment tested whether social stimulation might affect the occurrence of dustbathing. Earlier work has shown that chickens exhibit socially-facilitated feeding in the presence of other chickens that are feeding (Tolman and Wilson, 1965) and possibly even when exposed to the sounds or video images of feeding birds (Keeling and Hurnik, 1993). Comfort behaviour such as stretching and wing flapping have also been shown to be affected by the visibility and proximity of other birds (Black and Hughes, 1974; Nicol, 1989). Keeling and Duncan (1985) found that the activity of birds was related to the proximity of other birds; and a bird in close proximity to another could therefore experience alterations to its dustbathing motivation. In this study, we examined the effects of social stimulation on the incidence and timing of dustbathing bouts. Real hens, rather than a video stimulus, were used, since there is some doubt about the ability of hens to perceive a two dimensional image as a true representation of another hen (e.g. Dawkins, 1996; d'Eath and Dawkins, 1996; Patterson-Kane et al., 1997).

4.1. Materials and methods

4.1.1. Animals and housing

Twelve 18-week old litter-reared Amberlink hens housed in a group in a floor pen (furnished as described in Experiment 1) were used as the stimulus birds for eight additional hens placed in individual cages (test birds). The dustbath in the pen was filled with peat moss, a preferred substrate for dustbathing (Petherick and Duncan, 1989). The individual cages were portable and were constructed from wire mesh and measured $92 \times 61 \times 39$ cm ($l \times h \times w$), giving a total cage floor area of 5612 cm^2. The cages were positioned approximately 20 cm above the floor. Ad libitum access to water and to food in crumb form was provided. The room temperature was 18–25°C. The room was illuminated by incandescent lights maintained on a 15:9 h light/dark cycle (lights on 06:00–21:00 h) and giving an average illumination of 40 Lux.

4.1.2. Experimental procedure

The room was arranged so that birds in four of the individual cages had visual access to the group of hens in the floor pen (Fig. 4). The other four test birds in cages were allowed visual access to an identical floor pen that contained no birds. All of the test birds were visually isolated from one

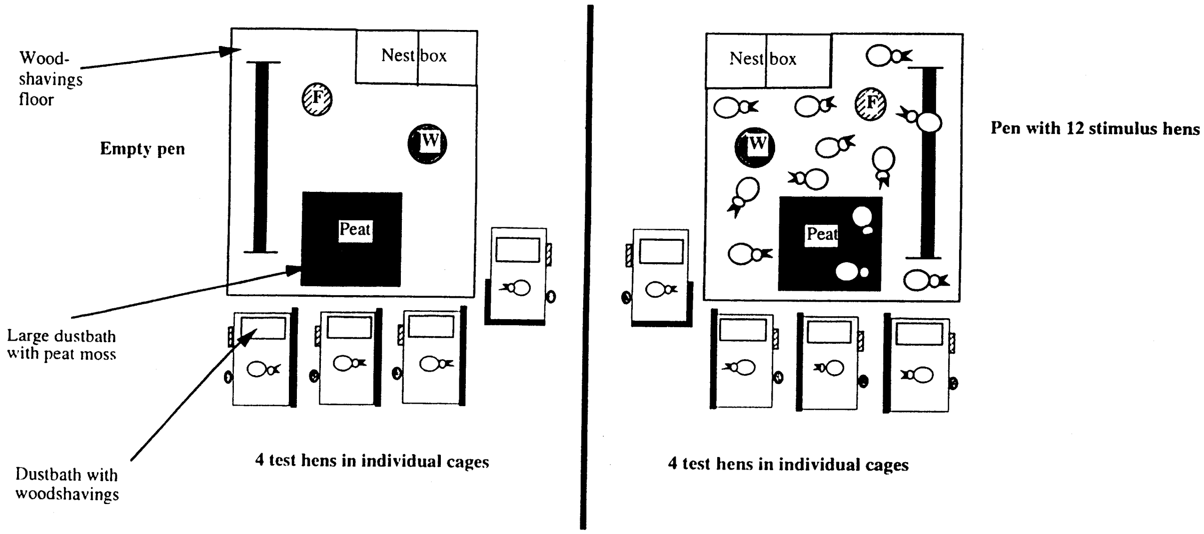

Fig. 4. Room plan for Experiment 3. F (hatched) indicates food and W (shaded oval) indicates water.

another by black plastic curtains attached to the sides of the cages. The treatments consisted of continuous visual exposure to one of two floor pens; one containing 12 stimulus birds or one containing no birds. At 10:30 h each day, a dustbath measuring 45 × 31 × 7 cm (l × w × h), giving an area of 1395 cm^2, was placed into each of the eight test cages. These dustbaths were filled with woodshavings and were attached to the floor of the cage. Woodshavings were used because they are of intermediate value to hens as a dustbathing substrate; peat moss is a very potent stimulus for dustbathing (Petherick and Duncan, 1989) and may have swamped any social effect in the current experiment. Immediately after placing the dustbaths in the cages, a small amount of fresh peat moss was added to each of the dustbaths in the floor pens. The addition of peat to the dustbaths in the pen containing hens always resulted in at least one of the birds beginning to dustbathe, thus exposing hens in four of the individual cages the visual (and auditory) stimulus of other birds dustbathing. Birds in the other four individual cages were only exposed to the visual stimulus of the dustbathing substrate.

Tests lasted from 10:30 h to about 15:30 h each day and the birds' behaviour during this time was video-recorded. At 15:30 h, recording was stopped and the dustbaths were removed from the cages unless a test bird was in its dustbath, in which case termination of the test was postponed until the bird left the dustbath.

After 6 days, the individual cages were moved so that each of the eight test birds was exposed to one of these two treatments for 6 consecutive days, followed by 6 days' exposure to the other treatment.

4.1.3. Data collection and analysis

Videotapes were reviewed for the entire test period over the 6 days of testing for each treatment. The frequencies and durations of all dustbathing bouts were recorded. A dustbathing bout was deemed to begin during the minute when the first vertical wing shake occurred and was deemed to end during the minute when the last vertical wing shake was observed. An interval of 10 min. was chosen to separate one bout from another. For analysis, separate bouts were added together to give a total number of minutes of dustbathing during that test. The durations of dustbathing for each day of testing were averaged for each hen over the 6 days of treatment. Paired *t*-tests were used to determine whether there was any difference between mean durations of dustbathing when hens had visual exposure to the group of hens versus visual exposure to the empty pen.

4.2. Results

Table 3 shows the mean total durations of dustbathing performed by each hen in each of the two treatments. There was a significant difference between treatments ($t = 3.1$, df $= 7$, $P = 0.018$). All hens except one performed more dustbathing when visually exposed to the group of hens. Slightly more dustbathing bouts were performed when test hens were visually exposed to the group of hens (mean 0.7 ± 0.2 bouts hen^{-1} day^{-1}) than when no hens were visible (mean 0.3 ± 0.1 bouts hen^{-1} day^{-1}), although this difference was not significant ($P > 0.10$).

5. General discussion

Environmental temperature, radiant heat, illumination and social stimulation all had an effect on the occurrence of dustbathing in laying hens. It has been shown previously that the sight of a dry dusty substrate can also stimulate dustbathing (Petherick et al., 1990, 1995). The importance of external stimulation in triggering dustbathing, therefore, appears to be much greater than is acknowledged in several previous studies (e.g. Vestergaard, 1980, 1982; van Liere et al., 1991). Even when external stimuli have been shown to exert an effect, the emphasis has been on internal control mechanisms. For example, Hogan (1997) suggested a causal model of dustbathing that involves internal factors building up in a negative exponential manner as a function of time in a Lorenzian process, and decreasing during dustbathing. In this model, there is also an upper and lower threshold which vary according to time of day. Dustbathing can occur when the internal factor reaches the upper threshold and is inhibited when the level drops to the lower threshold. Hogan and van Boxel (1993) showed that a light/heat stimulus could influence the timing of dustbathing.

Table 3
Mean dustbathing durations (min ± S.E.M.) from Experiment 3 for the 6 test days when hens were exposed to the group of hens and when hens were exposed to the empty pen

Hen number	Treatment 1: Exposed to group of hens	Treatment 2: Exposed to empty pen
1	9.7 ± 8.4	14.5 ± 5.5
2	15.3 ± 10.3	7.5 ± 5.0
3	18.2 ± 11.1	8.3 ± 5.9
4	21.7 ± 15.1	19.6 ± 12.0
5	14.7 ± 9.3	0 ± 0
6	37.2 ± 13.6	7.5 ± 7.5
7	26.5 ± 8.1	1.7 ± 1.5
8	26.5 ± 11.6	12.2 ± 12.2
All[a]	21.2 ± 3.1	8.9 ± 2.3

[a] Paired t-test indicates mean difference differs from zero ($P < 0.05$).

With regard to environmental temperature, it seems likely that temperatures within the thermal comfort zone allow a 'normal' occurrence of dustbathing, whereas cool temperatures, such as the 10°C in the present study, probably inhibit it. Some form of inhibitory mechanism at cool temperatures would be adaptive for energy conservation. During dustbathing the bird's body is in close contact with the ground and so heat could be lost by conduction. In addition, the fluffing of the feathers combined with the vigorous movements of dustbathing would accelerate convective losses. It seems unlikely that warm to high environmental temperatures have a further stimulatory effect on dustbathing; studies which have observed a variety of birds at high environmental temperatures, describe feather sleeking rather than feather raising and do not report sunbathing or dustbathing (Morris, 1956; McFarland and Baher, 1968; Whittow, 1986).

The fact that both radiant heat and light stimulate dustbathing, suggests that sun-bathing and dustbathing share some common causal factors. Sun-bathing and dustbathing have some postures in common, such as side-lying and raising of the feathers, which raises the possibility that what starts as sun-bathing may easily trip over into dustbathing. We make the tentative suggestion that radiant heat and light may often trigger sun-bathing. Then, if the factors responsible for dustbathing are present, (if the threshold for dustbathing is low, according to the model of Hogan and van Boxel (1993)) the behaviour may quickly switch to dustbathing. We suggest that this might be a case of 'postural facilitation'.

The sight and sounds of other hens, which were dustbathing in an adjacent pen for at least part of the time, stimulated the test hens to dustbathe more that the sight of an empty pen. We can conclude that social contact has a stimulatory effect on the occurrence of dustbathing. We cannot say definitively that it is the sight and sound of other hens dustbathing that triggers the behaviour, but it seems likely that it is. Designing an experiment to test this is problematical, without the help of a standard stimulus such as a video-recording of dustbathing hens.

In conclusion, there are various external factors, including environmental temperature, radiant heat and light, and social factors, which influence the occurrence of dustbathing in hens. These have not always been properly controlled in previous experiments, which might explain some of the discrepant results. We are now working to incorporate these factors with previously-known external factors, such as the sight of a dusty substrate, and with internal factors well-described by Hogan (1997) into a more comprehensive causal model of dustbathing.

Acknowledgements

This work was supported by an Operating Grant from the Natural Sciences and Engineering Research Council of Canada to Ian Duncan and by the Ontario Ministry of Agriculture, Food and Rural Affairs.

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