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Light intensity and social communication between hens

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Abstract 1. The effect of light intensity on social communication in laying hens was investigated experimentally by comparing the transmission and detection of social signals between familiar and unfamiliar hens of similar or unequal rank in a competition for food.
2. The experimental method consisted of mutual inspection by a pair of hens at short range (approximately 24 cm), followed by a competition at a feed trough from which only one hen could eat a favoured food. The relative rank of a hen was inferred from success in this competition.
3. The relative rank of individual hens within 5 groups, each of 6 adult laying hens, was determined to identify those of high and low rank within their home group.
4 Social communication between pairs of either unfamiliar or familiar hens of either similar or unequal rank (highest and lowest ranking within their home groups) was then assessed under light intensities of 1, 5, 20 and 100 lux with all other cues present. Only the dimmest light of 1 lux perturbed some aspects of the competition for food.
5. The findings provide scientific justification, in part, for the current legal requirement in England for 'all hens to see other hens' by specifying a minimum light intensity of at least 5 lux for hens kept in close proximity to each other.

INTRODUCTION

Hens kept in small flocks readily establish a stable peck order and discriminate individuals using visual cues (Dawkins, 1995; D'Eath & Stone, 1999). However, in large flocks, Pagel and Dawkins' model of aggression predicts that hens do not need to recognise individuals and will not attempt to establish a peck order, using instead social signals of status to resolve contests over resources (Pagel & Dawkins, 1997). Visual discrimination of individuals and detection of status signals implies that the light environment will affect social behaviour in both small and large flocks. The term 'status signals' is used in its widest sense to mean those anatomical features and behaviours, including posture, that can communicate the relative ability of a hen to secure or hold on to a resource, i.e. its resource-holding potential.

It is clear that visual cues are involved in discrimination by hens; the visual mechanisms are subtle with birds using frontal and lateral vision for different purposes (Dawkins, 1995). Discrimination between familiar and unfamiliar individuals occurs at distances of less than 30 cm (Dawkins, 1996). However, there is very limited information on the effect of the light environment on visual discrimination in domestic fowl. In one study, laying hens were only able to discriminate between a familiar and an unfamiliar conspecific in white light at 77 lux when compared with white, red or blue light at a similar or dimmer illuminance (5·5, 11·0 and 16·4 lux, respectively; D'Eath & Stone, 1999).

These few studies illustrate the need for more information on how light affects social

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discrimination in hens. Furthermore, while it may be important for a hen in a small flock to discriminate conspecifics or to recognise the identity of specific individuals to maintain a beneficial affiliative relationship, it may be equally or more advantageous for a hen in a large flock to detect the social signals of status or intent projected by other hens. Effective communication of social signals is important amongst both familiar as well as unfamiliar individuals and may reduce aggressive encounters, for example. The detection of social signals is likely mediated through the same visual channels as those needed for discrimination and will require a minimum intensity of light of suitable wavelengths. For example, if the light environment in a poultry house does not provide ultra-violet radiation (UV_A, $320 < \lambda < 400$ nm), then UV_A-reflective features of a hen's appearance could not be perceived (Prescott & Wathes, 1999*a*). Similarly, if the intensity was too dim for photopic vision then only monochromatic information would be available; spatial vision could also be compromised, thereby affecting the bird's ability to identify behavioural signals of intent. At present, the light intensity needed for the effective communication of social signals amongst hens is unknown.

In England, current legislation states, 'all buildings must have light levels sufficient to allow hens to see other hens and be seen clearly, to investigate their surroundings visually and to show normal levels of activity' (The Welfare of Farmed Animals (England) Regulations, 2007, No. 2078). A presumed purpose of this requirement is to allow effective communication of social signals amongst conspecifics that allows information to be conveyed about status or intent. Guidance about the optimum light environment to satisfy this requirement is given in the Code of Recommendations for the Welfare of Laying Hens (Defra, 2002), which states, 'in normal conditions, in cage and multilevel systems, light intensity should be at least 5 lux, and preferably not less than 10 lux, measured at any feed trough level; in other systems, light intensity in the perching, walking and feeding areas should be at least 10 lux measured at bird eye height. However, a temporary reduction in lighting level may assist in addressing behavioural problems such as feather pecking or cannibalism' (Defra, 2002). A similar Code is not available for pullets.

The overall aim of our experiments was to determine the minimum light intensity required for effective communication of social signals between pairs of either familiar and/or strange hens. A method to test the effectiveness of social communication was developed, that was based upon competition for a palatable food. This was then used to determine the effects of light intensity on communication of social signals at short range amongst familiar and/or strange hens of similar or unequal rank. Testing both familiar and unfamiliar hens allowed us to draw conclusions about both small and large flocks, on the assumption that most birds in the large commercial flocks will be strangers.

MATERIALS AND METHODS

Experimental design

Four experiments were undertaken (Table 1). In the first, the relative ranking within 5 groups, each of 6 hens that were kept together, was determined in a round robin test, this allowed the highest (H) and lowest (L) ranked hen within each group to be identified. The relative rank of each hen was inferred from its success in a competition for food between a pair of hens. Pairs of hens of different rank and/or familiarity were then tested in three other experiments; only the highest (H) and lowest (L) ranked hens within each group were used. The treatments were: experiment 2 – unfamiliar hens of different rank, that is, H vs. L from different groups, with 5 pairs at each of 4 light intensities; experiment 3 – unfamiliar hens of the same rank, i.e. either H or L from different groups, with 5 pairs at each of 4 light intensities; and experiment 4 – familiar hens, that is, H and L from the same group, with 5 pairs, each tested at 4 light intensities. Pairs of hens in experiments 2 and 3 were tested once only to ensure complete unfamiliarity. Prior to the experiments, the hens were familiarised with the wedge and finding the mealworms during habituation trials with familiar pairs of hens (randomly selected but all hens familiarised equally).

Table 1. *Overview of the design of the experiments*

Experiment	Intensity (lux)	Number of trials
1: Identification of the highest (H) and lowest (L) ranked hens in each group of six birds	100	75 trials (15 pairs × 5 pens)
2: Unfamiliar pairs of the highest and lowest ranked hens (H vs. L) from different groups	1, 5, 20, 100	20 trials (20 pairs × 1 intensity each)
3: Unfamiliar pairs of same rank (H vs. H; and L vs. L) from different groups	1, 5, 20, 100	20 trials (20 pairs × 1 intensity each)
4: Familiar pairs of the highest and lowest ranked hens (H vs. L) from the same group	1, 5, 20, 100	20 trials (5 pairs × 4 intensities)

The light intensity in the first experiment was 100 lux, while the effects of 4 intensities (1, 5, 20 and 100 lux) were measured in the other experiments. In the second and third experiments, each pair was tested at only one light intensity using a Latin square design (to select the groups) and to ensure unfamiliarity; in the fourth experiment, each pair was tested at each intensity since these pairs were already familiar. The intensities were chosen to represent a dimly-lit poultry house, one lit at the minimum recommended by Defra (2002), a brighter intensity advocated by some authorities and the brightest intensity that could conceivably used commercially.

Animals and husbandry

Thirty adult hens (Lohman Tradition strain) were housed in 5 home pens, each holding 6 hens, from one-day-old. The pens were placed in the same room but there was no visual contact between hens in different pens. The home pens were lit by a mixture of overhead fluorescent tubes in the room and incandescent bulbs over each pen to give an intensity of approximately 50 lux and a day-length of 12 h. Each pen was 150×170 cm in size and contained wood shavings for litter, three nest boxes and two perches (each 170 cm long at 40 cm height). The hens had *ad libitum* access to a commercial layer diet, barley grain and oyster shell grit, as well as water. They were marked with coloured leg bands for identification; colours were allocated randomly.

Test procedure

The test pen (Figure) comprised two start-boxes (A and B), separated by wire mesh, and an arena. The two start-boxes gave access to a triangular social arena via a mesh door, which could be lifted from outside the test-room by the experimenter.

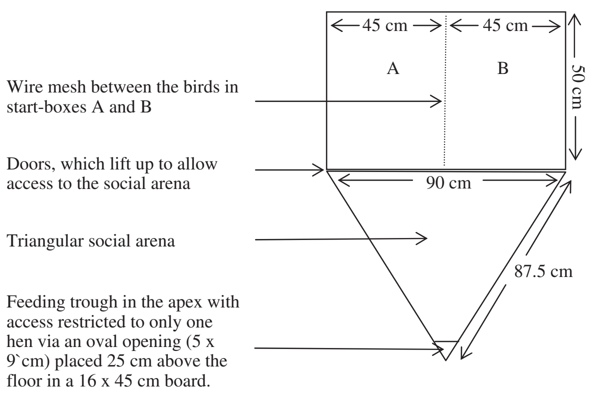

Figure. *The design of the experimental apparatus used in the competitive food wedge test.*

A feeder was placed in the apex of the social arena and contained mealworms mixed with wood shavings. Mealworms are a food much favoured by hens so it was not necessary to give them prior experience. Access to the wedge feeder was restricted to one hen only by an opening in a wooden board in front of the feed trough. The hens could use auditory, olfactory as well as visual cues in the test.

Prior to each test, a pair of hens was collected from their home-pens, a piece of black tape was taped over the coloured leg rings to mask any artificial identification cues, and the hens were placed in individual cages for approximately 15 min in a light-proof acclimatisation room, which was lit by a similar fluorescent tube (Osram 830) and at the same intensity (either 1, 5, 20 or 100 lux) as used in the test conditions. This acclimatisation period allowed the hens to adjust to the intensity at which they were tested. The acclimatisation cages had solid floors covered with wood-shavings and were visually isolated from each other, so that the hens could not perceive or transmit visual cues during acclimatisation. The birds were not able to view other birds during the transfer between the home pen, the acclimatisation boxes and the experimental arena.

Following acclimatisation, each hen was transferred to a start-box in the test pen. The light source and light intensity in the start-boxes were identical to that in the test arena and the acclimatisation room. The hens were allowed a period of 2 min for inspection in the start-boxes before being released into the social arena. Next, the mesh door separating the start-boxes from the social arena was raised and the hens were allowed to compete for access to the wedge feeder for 3 min in the social arena. The behaviour of the hens in the social arena was observed closely by the experimenter via a video-monitor placed behind a lightproof curtain immediately outside the test area. Aggression was defined as threats and pecks. The trial was terminated immediately by the experimenter when one hen was aggressive towards the other, even if the subordinate hen showed submissive behaviour or when aggressive behaviour was shown by both hens. However, threats or single pecks were allowed, providing they ceased as soon as submissive behaviour was shown.

After the test, the hens were returned to their home pens. The social arena and start-boxes were cleaned between all trials with an odour-neutralising disinfectant (benzalkonium chloride 50 g/l, diluted with water to 5 g/l) in order to avoid any carry-over effects of odour cues between trials.

Behavioural observations

Social and other behaviours, both within the start-boxes, in the social arena, and in proximity to the wedge feed trough were recorded for each individual using a slightly different protocol according to the experimental need. In experiment 1, the behaviour of the hens in the social arena was assessed *in situ* via a remote video-screen. The hen that first entered the social arena and put her head into the feed trough was identified. The time each hen spent with her head in the feed trough and the number of successful and unsuccessful displacement attempts was recorded as well as any aggressive and submissive behaviour while the hens were in the social arena. The winner was designated as the bird in the pair with the highest number of successful displacement attempts, but when these were equal, the winner was determined from the number of aggressive and submissive behaviours shown. (Aggressive behaviour and successful displacements were strongly correlated.) The relative rank of each hen within its group was then inferred from its overall success.

In experiments 2, 3 and 4, the behaviour of the hens in the start-box as well as in the social arena was assessed via video-recordings. In the start-boxes, the distance between the mesh and each hen, as well as the tail and head height of each hen was measured visually every minute. The duration and number of times each hen faced the other hen were recorded throughout the inspection period. Recording the time spent facing the other hen allowed us to infer but not conclude that frontal, binocular vision was used. In the social arena, the first bird to leave the start-box and start feeding, the number of successful and unsuccessful displacement attempts, the duration and number of times of feeding, facing the corner of the social arena, and the number of other submissive behaviours were either identified, counted or measured. The total number of threats and aggressive pecks were combined since the number of aggressive pecks was very low.

Statistical analysis

Experiment 1 comprised a round robin of pair-wise trials between individual hens within each group. Over 5 d, there were 15 trials per day such that all 30 birds were tested once daily, but with different partners on each day. Hens were identifiable within each group, giving a nested form for the treatment structure. The measure of success (winner or not) was analysed as a Generalised Linear Model with binomial errors and a logit link. The proportion of successes for hens within each group measured their rank.

In experiment 2, each light intensity was repeated 5 times amongst the 20 trials, while the hen pairs were chosen from the appropriate group so that rank and its interaction with light intensity were assessed within trials in a split-plot design. In experiment 3, pairs of hens of similar rank were tested together and hence the effect of rank was tested between trials as was the effect of light intensity and its interaction with rank. (This accounts for the residual degrees of freedom in this experiment being much lower than in the other experiments.) Finally, experiment 4 was the complement to experiment 2 except that hens were chosen from the same group and so are termed familiar. The analysis is as a split-plot design with effects of light intensity being tested between trials while the effects of rank and its interaction with light intensity were evaluated within trials. In the second, third and fourth experiments the data were analysed using ANOVA after logarithmic transformation where necessary to ensure a uniform variance and normality, except where noted.

RESULTS

Experiment 1: rank determination

The food wedge method was successful in allowing a ranking order to be established amongst familiar birds from each group. Hens inspected each other within the start-box and readily competed for access to the wedge feeder for mealworms when released into the social arena. The highest and lowest ranked hen (i.e. the most frequent winner and loser) within each group could be clearly identified and these hens were used subsequently in the remaining experiments. There were unambiguous linear hierarchies in two groups and triangular relationships in three others; in the latter, the highest and lowest ranked hen could be identified in two groups – the triangular relationship occurring in the middle order – while in the third, two hens each won 4/5 contests and the winner when these two hens were tested was assigned the highest ranked hen in that group. On average (±SE) and across all contests, a H hen made $1{\cdot}9 \pm 0{\cdot}33$ successful attempts to displace a L hen and spent $108 \pm 17{\cdot}5$ s (out of 180 s) feeding. L hens made only $0{\cdot}45 \pm 0{\cdot}16$ successful displacements and fed for far less time, on average for only $51 \pm 7{\cdot}4$ s per trial. Aggressive behaviour, defined as the number of counts of pecks and threats towards another hen, was observed $1{\cdot}6 \pm 0{\cdot}43$ times per trial on average in H hens but was rarely seen in L hens. Similarly, submissive behaviour, defined as crouching, ducking or escape behaviour, was observed $2{\cdot}1 \pm 0{\cdot}44$ times per trial in L hens and never in

H hens. These social behaviours were consistent with the birds' ranking in the social hierarchy.

Experiment 2: highest vs. lowest ranked, unfamiliar hens

Inspection behaviour in the start-boxes between unfamiliar hens of pre-determined rank was recorded in the second experiment. Unfamiliar hens maintained an average distance of approximately 12 cm from the dividing mesh in the start-boxes and appeared to inspect each other intently, spending about 47 s (out of 120 s) facing each other, regardless of rank or light intensity ($P > 0{\cdot}05$). The number of times one hen faced another was greater for H vs. L hens (H: 3·25; L: 2·48; SED = 0·284; $P = 0{\cdot}031$) and was least at 1 lux (mean count over 2 min. 1·90, 3·10, 3·10 and 3·15 at 1, 5, 20 and 100 lux, respectively; SED = 0·282; $P < 0{\cdot}001$). Neither rank nor light intensity affected the stance of the birds, as measured by the height of the head and tail ($P > 0{\cdot}05$).

Once released into the arena, and compared with L hens, H hens made more successful displacements during the first minute, fed for longer, spent less time facing the corners opposite the wedge's apex, and were more aggressive and less submissive, even though both hens made similar number of displacement attempts (Table 2). This summary is supported by the trend ($P = 0{\cdot}065$) for a difference between the hens in the number of aggressive pecks in the first minute. There were no interactions between light intensity and rank for any of the measures recorded in the arena, i.e. the H hen was able to assert its dominance regardless of the light intensity. Light intensity affected only one measure; the duration of feeding behaviour during the first 2 min was shorter at 1 lux than 5, 20 and 100 lux (mean 0–1 min; 15, 28, 26 and 27 s; SED = 2·6; $P < 0{\cdot}001$; mean 1–2 min: 8, 26, 23, 28 s; SED = 5·1; $P = 0.005$ at 1, 5, 20 and 100 lux, respectively). The effect was independent of rank, that is, the dimmest light discouraged hens from feeding. Overall, the highest ranked hen that was ranked as dominant in its home pen was also dominant when competing with one assessed as a low rank (in its respective home pen). Light intensity had minimal effects on this competition.

Experiment 3: equal ranking, unfamiliar hens

Some behaviours amongst equal ranking strangers in the start-box were rarely or never observed, for example, sitting, standing 'idle', while other behaviours were too infrequent to be analysed statistically, that is, preening and pecking the mesh towards the other bird. Analysis was valid for the frequency and duration of the following behaviours: facing the other hen, facing the front of the start-box towards the arena and walking. These measures were unaffected ($P > 0{\cdot}05$) by either the hens' rank or light intensity, or their interaction. Typically, a hen spent 35 s facing the other hen, 44 s facing the front of the start-box and walked for 5 s during the 2-min period of inspection.

Dim light delayed the time that hens left the start-box (mean latency 8·7, 3·7, 4·4 and 4·0 at 1, 5, 20 and 100 lux, respectively; SED = 1·55; $P = 0{\cdot}023$). On average, hens first started to feed 19·7 s after the start of the arena session and latency was unaffected by either light intensity or rank. In terms of those behaviours thereafter that were unaffected by either light intensity or rank or their interaction, the typical hen made 0·8 unsuccessful attempts to displace the other hen

Table 2. *Significant measures of pair-wise trials for food between pairs of unfamiliar hens of unequal rank (H vs. L) in the second experiment*

Measure	H hens	L hens	SED	*P*
Number of successful displacement attempts during the first minute	0·65	0·10	0·36	<0·001
Duration (s) of feeding during the first minute	36	12	1·5	0·005
Duration (s) of feeding during the second minute	38	5	1·4	<0·001
Duration (s) of feeding during the third minute	36	5	0·6	<0·001
Duration (s) facing the corners during the first minute	1	26	4·8	<0·001
Duration (s) facing the corners during the first minute	4	38	5·3	<0·001
Duration (s) facing the corners during the third minute	7	37	6·2	<0·001
Number of aggressive pecks in the first minute	0·35	0	0·18	0·065[1]
Number of aggressive pecks in the second minute	0·55	0	0·20	0·013
Number of aggressive pecks in the third minute	1·2	0	0·32	0·003
Number of submissive behaviours in the first minute	0	0·4	0·14	0·044
Number of submissive behaviours in the second minute	0	0·55	0·23	0·029
Number of submissive behaviours in the third minute	0	0·95	0·25	0·001

All other measures were non-significant ($P > 0{\cdot}05$).
[1]Not significant but indicates a trend.

from the feeding trough, fed for 12 s in 1·8 bouts, and made 0·3 threats to which the other hen responded. Some behaviours were affected significantly by the rank of the birds, that is, whether the contest was between two highest ranked hens (H vs. H) or two lowest ranked hens (L vs. L). H hens faced the arena corners for less time (H: 2·6; L: 6·3 s, $P = 0{\cdot}017$), made more successful displacement attempts (H: 0·52; L: 0, $P = 0{\cdot}011$), and made more pecks at the other hen (H: 0·6; L: 0·04 pecks, $P = 0{\cdot}013$); back-transformed means shown for all these measures. There was no effect of light intensity or its interaction with rank on these latter behaviours. Overall, light intensity did not affect the ability of two strangers of similar rank to resolve a competition for food.

Experiment 4: unequal ranking, familiar hens

As in experiment 3, some behaviours were observed infrequently during the inspection phase, e.g. preening and pecking the mesh towards the other bird. Neither the time spent facing the other hen nor the time spent facing the front of the start-box towards the arena were affected by light intensity, rank or their interaction, with a total duration of 46 and 63 s in 4·3 and 5·0 bouts, respectively. On the logarithmic scale, L hens spent significantly less time walking at the dimmest light intensity than H hens (back-transformed mean total time (s): H: 20, 17, 21, 10; L: 4, 11, 12, 29 s; $P = 0{\cdot}014$ at 1, 5, 20 and 100 lux, respectively). Compared with hens in experiment 3, the hens in this experiment typically spent more time facing each other and facing the front of the start-box.

On average, hens left the start-box after 4 s and fed 6 s later. Once in the arena, H hens were clearly more successful in the feeding competition than L hens (with whom they were familiar in their home pen). The mean number of bouts of feeding was 5·8 and 1·5 ($SED = 0{\cdot}701$; $P < 0{\cdot}001$) for H and L birds, respectively, though the average number of unsuccessful displacement attempts was 4·1 and was not affected by rank or light intensity; there were too few successful attempts to be analysed statistically, indicating the robustness of the original rank determination in the first experiment. The time spent feeding was affected by an interaction between rank and intensity (total duration: H: 57, 159, 149 and 140 s; L: 14, 12, 19 and 44 s for light intensities of 1, 5, 20 and 100 lux, respectively; SED 25·0 s; $P = 0{\cdot}003$); thus at the dimmest intensity there was no difference in time spent feeding between familiar hens of different rank.

DISCUSSION

A competitive food wedge test to establish rank order amongst hens

Although laborious, the competitive food wedge test was a successful method by which the relative rank of two hens could be determined. The method assumes that birds are equally familiar with the procedure, and hungry for the novel food; there was no evidence to doubt these assumptions since all birds participated readily in numerous tests. Furthermore, the sheer number of displacement attempts, although unsuccessful, of the L birds in experiment 1 demonstrates their motivation for the mealworms. A further assumption is that the outcome of two trials is independent. Use of the number of successful displacement attempts, supplemented by information on aggressive and submissive behaviours, as the measure of success allowed clear separation of the birds' rank and appeared to be associated with the time spent feeding. On average, H hens spent over twice as long feeding than L hens in the first experiment and 5 times longer in the second. The reliability of the ranking was high: similar results were obtained in the fourth experiment when the hens were retested as those in the first, except at the dimmest light where L hens spent a similar amount of time feeding as H hens. The behaviour of two familiar hens was consistent with their rank: H hens made more successful displacement attempts and showed more aggressive behaviour than L hens, which showed submissive behaviour in the form of crouching, ducking or escape behaviour. When two unfamiliar hens competed for food, the results were consistent with common sense predictions of success: H hens were more successful than L hens while the outcome was unpredictable for strange hens of similar relative rank (in their home pen). Whether success in a competitive food wedge test corresponds with that in other measures of social dominance or resource-holding potential is unknown but was not the purpose of this research. The wedge test appears to be an effective means of establishing a peck order; other methods rely on direct observation of pair-wise aggressive interactions in the home pen (Forkman & Haskell, 2004) and are even more laborious.

When placed side-by-side and separated by a mesh, both familiar and unfamiliar hens were curious about their competitor, spending between 35 and 47 s out of 120 s directly facing the other hen in the three experiments in which this was measured. The inference is that the bird was viewing its competitor with frontal, binocular vision. Of course, we cannot tell whether they may also have been inspecting each other using lateral vision when side-by-side. Moreover, the viewing distance of two facing hens was approximately 24 cm, which is similar to that estimated by Dawkins (1995) as being necessary for social discrimination. Given the importance of vision in social discrimination, we can infer that perception of visual signals is the explanation for the viewing distance observed, although the involvement of auditory and olfactory cues cannot be discounted. Our results also show that hens inspect each other, regardless of whether they are flock-mates or strangers. However, what use is made of any information gathered during inspection is unknown.

Communication of social signals

Hens that were either flock-mates or strangers spent up to 47 s facing each other before release into the social arena for access to the wedge feeder, a process with which they were familiar. It is reasonable to assume that inspection took place during this period in which hens faced each other in the start boxes but inspection and assessment could also have taken place in the arena too: it may be that only the contest is only settled once the birds are in physical contact. Dawkins observed that, during the first minute of an encounter between two familiar hens, only a relatively short period of a few seconds is spent in either 'one-way or mutual looking' (Dawkins, 1995); it is therefore reasonable to assume that the wedge test allowed sufficient time for inspection to take place. Our results do not provide information about which signals were used to determine the status of a conspecific. Social signals emanate from the head and neck but their exact nature is unknown (Dawkins, 1995). Various badges of social status have been postulated and rejected, including mass, tarsus length, comb height and length (jungle fowl; Kim & Zuk, 2000), though Forkman and Haskell (2004) found a good correlation between comb size and social rank in small flocks of domestic hens. Alternatively, hens may estimate status from behavioural signals during inspection.

The domestic hen has a powerful visual sense. Its basic abilities in terms of spectral sensitivity, flicker sensitivity, accommodation and acuity have been determined (see review by Prescott *et al.,* 2003), and all of these are pertinent to the perception of visual signals. Hens are tetrachromatic and have excellent colour vision (Prescott & Wathes, 1999*b*): although they can perceive UV radiation, signals in these wavelengths would be minimal in this experiment because of the light sources used. A recent model of spatial contrast sensitivity shows that their ability to resolve spatial detail is poor (Jarvis & Wathes, 2007), implying that only coarse features or details of another bird's appearance would be apparent. Dawkins (1995) found that one bird can only discriminate other birds when they are within 30 cm and the separation distance (approximately 24 cm) observed during inspection in this experiment is consistent with this. However, it is possible that increasing the viewing distance beyond that used in this experiment, would exaggerate any effect of light intensity on spatial vision, as shown in broiler chickens (Kristensen, 2004).

The second, third and fourth experiments showed that light intensities of 5 lux and brighter have no effect on the interaction between two familiar or unfamiliar hens of similar or unequal rank when they compete for a palatable food. The inference is that hens were able to assess effectively the social signals of conspecifics at these light intensities, either while the hens were adjacent to one other in the start boxes or during the competition in the social arena, with the conclusion that there was no effect of intensity (of 5 lux or brighter) on social communication between hens, regardless of their familiarity or rank.

Only the dimmest light intensity of 1 lux affected the outcome of the competition for food. At this dim intensity, strange hens of unequal rank faced one another less frequently during the inspection period and feeding duration was shorter (experiment 2); hens delayed leaving the starting boxes (experiment 3); and L hens spent less time walking and a similar amount of time feeding compared with H hens (experiment 4). Although these responses were not observed consistently in all the experiments, they do raise some questions about the consequences of such dim light for social behaviour. The responses could be due to the differences between the light intensity of the home pen and that tested experimentally but the birds were allowed to acclimate to the light intensity of the test to overcome a known visual effect; to test whether there were chronic effects would require a much larger experiment than that reported here. The responses could be due to a greater anxiety, reduction in activity and/or poorer visual acuity (Jarvis & Wathes, 2007) but our findings suggest that such a dim light perturbed the competition for food and perhaps some aspects of social communication.

Application to the husbandry of laying hens

In terms of those aspects of social behaviour studied here, our findings provide scientific justification for current English law that requires light levels to be sufficient to allow all hens to see other hens (The Welfare of Farmed Animals (England) Regulations, 2007, No. 2078). A light intensity of the minimum recommended in the welfare code (5 and preferably 10 lux; Defra, 2002) enabled hens to see sufficiently well to compete for food. The minor effects of a light intensity of 1 lux are relevant to the aetiology of injurious pecking in hens. Dim light of a few lux is used regularly to control injurious pecking: our findings suggest that this may be explained, in part, by its effects on social communication. Regular use of dim light is contrary to guidance provided by Defra (2002) and would also affect other aspects of behaviour. For example, light intensity significantly affects spatial vision in broiler chickens at a longer viewing distance than that employed here (Kristensen, 2004): there is little reason to believe that spatial vision differs substantially between broiler chickens and laying hens. It is therefore possible that social communication over longer distances would require a higher light intensity than that used in the current experiment.

In conclusion, light intensities of 5 lux and brighter are sufficient to allow strange and/or familiar hens to compete effectively for food when in close proximity of each other. In this sense, there is scientific justification for the current legal requirement in England for 'all hens to see other hens'. If intensities brighter than 5 lux are used, then there will be no adverse effects on social communication over short distances, as defined here.

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