

Feather pecking in growers: a study with individually marked birds

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- Abstract**
1. The aim of the present study was to investigate whether individual birds specialise in feather pecking. Growers were individually marked and reared in groups of 30 or 31 in pens with a slatted floor. At an age of 4 to 6 weeks feather pecking was frequent in all pens.
 2. On average 83% of all group members (10 groups, experiment 1) were recorded at least once as initiator of a feather pecking interaction. In each group 2 to 6 individuals feather pecked more than twice as often as the average for the group, and were defined as 'high rate peckers'. They initiated 39% of all recorded feather pecking interactions.
 3. Every interaction was classified (with increasing intensity) as pecking, pinching, pulling or plucking. Compared to the others, 'high rate peckers' had more of their feather pecking classified as plucking and less classified as pecking.
 4. There was no evidence that particular individuals specialised in pecking at other specific birds, at specific areas of the body or at birds engaged in specific activities.
 5. Growers (3 groups, experiment 2) that had just feather pecked engaged in more feather pecking during a subsequent 2-min focal observation than control birds that had not pecked before the start of the observation.
 6. It was concluded that feather pecking interactions are clustered in time and that the behaviour is not performed by just a few members of a group. However, some individuals are characterised by relatively high rates and more severe forms of feather pecking.

INTRODUCTION

Feather pecking can occur during both the rearing and laying periods of domestic fowl (Hughes and Duncan, 1972; Allen and Perry, 1975). The behaviour causes serious economic and animal welfare problems, as it may lead to feather damage, injuries and even mortality. Knowledge of individual variation in feather pecking is important in understanding the development and spread of the behaviour within a group. It has been hypothesised that some individuals specialise in feather pecking and that other group members copy the behaviour of these birds (Appleby *et al.*, 1992).

There are few studies on feather pecking that have focused on the behaviour of individual birds (Blokhuys and Arkes, 1984; Martin, 1986; Vestergaard *et al.*, 1993; Keeling and Jensen, 1995). In many studies feather pecking has only been measured indirectly by a score of feather damage without systematic behavioural observations (Allen and Perry, 1975; Simonsen *et al.*, 1980; Hughes and Michie, 1982; Nørgaard-Nielsen *et al.*, 1993). When records of the behaviour itself have been made the results are usually presented in the form of average feather pecking rates of experimental groups (Blokhuys, 1986; Blokhuys and van der Haar, 1989; Braastad, 1990).

In this paper we present results from a detailed analysis of feather pecking interactions in groups of individually marked growers. The birds were observed when they were 4 to 6 weeks old. Both Hughes and Duncan (1972) and Martin (1986) have described a strong increase in feather pecking in growers at this age. In our study we addressed the following 3 questions: Is feather pecking only performed by a few members of a group? Do some individuals specialise in feather pecking in terms of the rate of pecking, the quality of the pecks, the identity of the receiver of the pecks, the area of the body that is pecked at or the activity of the receivers? Do feather pecking individuals tend to peck at several receivers in succession?

MATERIALS AND METHODS

Experiment 1

Ten groups of white growers (Lohman Selected Leghorn hybrids) were reared at a density of 12.6 birds/m² in 10 pens of identical size (265 × 90 cm, height 235 cm) arranged along one side of a corridor. During data collection (weeks 4 and 5) there were 5 groups each of 30 and 31 growers

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Table 1. Group size, average rate of feather pecking interactions per bird (per h) in each group (means \pm SD), number of growers recorded at least once as actor of a feather pecking interaction, number of growers defined as high rate peckers, average rate of feather pecking interactions per high rate pecker (per h) and percentage of all feather pecking interactions of a group that were initiated by high rate peckers

| Group | Group size | Feather pecking of all group members | Number of feather pecking actors | Number of high rate peckers | Feather pecking of high rate peckers | % interactions initiated by high rate peckers |
|-------|------------|--------------------------------------|----------------------------------|-----------------------------|--------------------------------------|---|
| 1 | 31 | 2.0 \pm 2.0 | 25 | 4 | 5.9 \pm 2.2 | 38.5 |
| 2 | 30 | 3.7 \pm 3.2 | 30 | 4 | 10.0 \pm 2.9 | 36.4 |
| 3 | 31 | 0.5 \pm 0.8 | 18 | 3 | 2.3 \pm 1.4 | 41.2 |
| 4 | 31 | 3.1 \pm 2.7 | 29 | 4 | 8.5 \pm 1.2 | 35.1 |
| 5 | 31 | 2.0 \pm 2.9 | 22 | 6 | 7.3 \pm 2.0 | 72.1 |
| 6 | 30 | 1.6 \pm 1.9 | 24 | 5 | 5.0 \pm 1.9 | 52.1 |
| 7 | 30 | 1.8 \pm 2.6 | 26 | 2 | 10.3 \pm 3.9 | 38.7 |
| 8 | 30 | 4.2 \pm 2.8 | 30 | 3 | 9.8 \pm 0.8 | 23.7 |
| 9 | 31 | 1.3 \pm 1.8 | 24 | 2 | 6.8 \pm 3.2 | 34.2 |
| 10 | 30 | 2.0 \pm 2.9 | 25 | 3 | 8.8 \pm 5.9 | 45.3 |

(Table 1). All individuals were females and not beak-trimmed. Growers in adjacent pens had no visual contact, because the pens were separated by plywood walls, which were 190 cm high and allowed auditory contact between groups. Fresh air was introduced above the plywood walls, and spent air removed from each pen by a separate pipe. Ventilation was controlled by temperature. The average daily house temperature was 22 °C. Each pen was illuminated by an incandescent light bulb (75 W). In addition, there was one fluorescent tube (36 W) per 2 pens. Light intensity at the height of the animals was about 60 lx. The photo-period was constant at 13 h/d with a 15 min twilight phase at the start and end of the period. Lights came on at 05.00 h.

In each pen an area of 200 \times 90 cm next to the corridor (75.5% of the total floor) was made of slats (width 1 cm, 2.5 cm apart, 20 cm above the ground). The floor in the rear of the pen was varied. In 5 pens there was a 65 \times 90 cm board covered with a 5 cm layer of grey river sand (particles less than 2 mm in diameter). In the other 5 pens this floor area was also made of slats. The 2 housing conditions were chosen to measure the influence of access to sand on the development of feather pecking (Huber-Eicher and Wechsler, 1997). In the slatted floor area of each pen there were 2 cup drinkers and a suspended food trough (diameter 30 cm), which was automatically refilled: The animals had *ad libitum* access to a commercial starter food. From each pen a glass door (72 \times 142 cm) opened on to the corridor through which behavioural observations were made.

The chicks, from a commercial breeder, were assigned at random to the pens on the day after hatching. An area of 150 \times 90 cm of the slatted floor next to the corridor was covered with a perforated plastic mat (polyester gauze coated with PVC) to prevent the chicks from falling between the slats. The chicks were only allowed access to an

area of 120 \times 90 cm on this mat to ensure that they stayed close to the food and the water. The rest of the pen was partitioned off by a wooden barrier (height 30 cm) which was removed when the chicks were 10 d old. For 17 d heat was provided by a red lamp (250 W) next to the feeder, which was replaced by a ceramic lamp (250 W) which provided heat but no light and was removed when the growers were 6 weeks old. During the third week of life the growers were subjected to the following procedures: application of wing tags (2.5 \times 2 cm) on each wing for individual recognition (day 15), food was changed from mash to pellets (day 15), removal of the plastic mat on the slatted floor (day 17). The wing tags were fixed around the upper wings by means of a crêpe rubber tape (width 1.2 cm).

Each group was observed for 4 periods of 30 min (between 11.00 h and 17.30 h) when the growers were between 24 and 32 d old and all occurrences of non-aggressive feather pecking were recorded. Pecks successively directed at the same receiver were recorded as one single interaction, but interactions were classified as 1 to 4, 5 to 9 or \geq 10 single feather pecks. An interaction was terminated when the pecking chick moved away from the receiver or started to peck at another chick. Only pecks at feathered parts of conspecifics were classified as feather pecking. Pecks at legs, beaks, combs or wattles were ignored, because such pecks may be under the control of another behaviour system. Every feather pecking interaction was attributed to one of the following 4 types of behaviour: 'pecking' at a feather without pinching; 'pinching' a feather and pulling slightly; 'pulling' at a feather with a vigorous backward movement of the head; or 'plucking' a feather. Interactions that were composed of repeated pecks were classified according to the most intense type of behaviour observed. For each interaction the identity of the actor and the receiver, the area of the body (head,

neck, breast, wing, back, rump, tail, vent) that was pecked and the activity (resting, standing, exploring, eating/drinking, preening, dustbathing) of the receiver during the interaction were recorded.

There was no difference in the rate of feather pecking interactions in weeks 4 and 5 between groups reared with and without access to a sand area in the rear of the pens (Huber-Eicher and Wechsler, 1997). The 2 housing conditions also did not differ in the percentages of feather pecking interactions that were assigned to the 4 types of behaviour and to the 3 categories of numbers of pecks observed during the interaction (Mann–Whitney *U* tests; $n_1 = n_2 = 5$, all *P* values > 0.05). By the end of week 5, bloody injuries caused by feather pecking had been recorded in all 5 pens without and in 4 pens with a sand area. In order to avoid unnecessary pain, all injuries to the rump as well as serious injuries to other parts of the growers' body were covered with tar. This effectively prevented other growers from pecking at the wounds. The rate of feather pecking interactions (per h) was calculated for each grower. Individuals with a feather pecking rate that was higher than twice the average rate for their member group were defined as high rate peckers. There were no significant differences in the number of high rate peckers per group and in the proportion of all feather pecking interactions recorded in a group that were initiated by high rate peckers between groups reared with and without access to a sand area (Mann–Whitney *U* tests; $n_1 = n_2 = 5$, both *P*-values > 0.05). Data from both housing conditions were therefore combined in the analysis.

Experiment 2

One group of 30 and two groups of 31 white growers (Lohman Selected Leghorn hybrids) were reared in 3 pens of identical size (265 × 90 cm, height 235 cm) in the same house used for experiment 1. In the rear of each pen there was a sand area (65 × 90 cm, as in 5 pens of experiment 1). All individuals were females and not beak-trimmed. Ventilation, lighting, duration and start of the light period, drinkers, feeders and procedures during rearing were the same as in experiment 1.

The growers were observed on 11 d (between 08.00 h and 14.00 h) distributed over weeks 4, 5 and 6 after hatching. Focal animal observations of feather peckers and control birds were made. Growers that had just directed a non-aggressive peck at a feathered part of a conspecific were chosen as focal animals for 'feather pecker' observations, which started 10 s after this peck and lasted for 2 min. All occurrences of non-aggressive feather pecking interactions initiated by the focal animal were recorded. As before, only pecks at feathered areas were classified as feather pecking. A given individual was observed only once per week. Immediately after the end of an observation

another grower that was active (not lying or sitting) but had not pecked at any conspecific for 10 s was chosen as a control, and was similarly observed for 2 min. A total of 29, 38 and 39 paired feather pecker and control birds were observed in weeks 4, 5 and 6, respectively.

Statistical analyses

The analyses were performed using Systat (Wilkinson, 1992) or Microsoft Excel. All statistical tests were 2-tailed with an alpha level of 0.05. Tables published in Rohlf and Sokal (1981) were used to assess statistical significance.

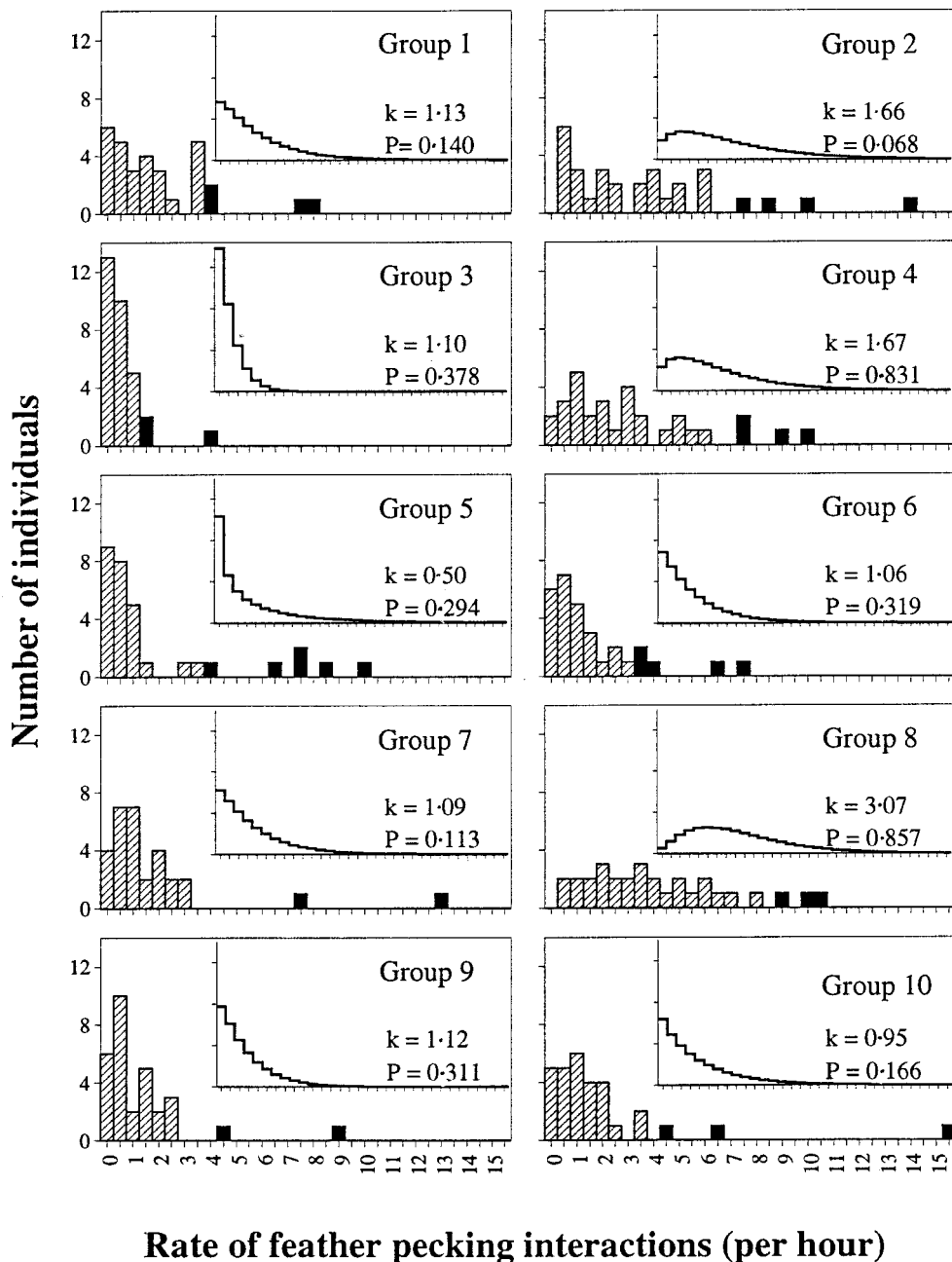
Whether high rate peckers focussed on particular individuals was assessed by comparing the observed results with those from a computer simulation. The simulation assumed that every grower in the pen had an equal chance of being pecked, and that interactions were independent. For each number of interactions the simulation was run 100,000 times to yield an expected distribution of numbers of receivers. Median and 2-tailed confidence limits could then be derived from these distributions. The number of receivers for each of the 36 high rate peckers was tested against the expected distribution. Because this involved 36 separate tests, the Bonferroni correction was used, with a significance level of $P = 0.0014$. Any data points beyond the 99.86% confidence limits were thus regarded as significantly different from our random expectation.

RESULTS

Experiment 1

The average rate of feather pecking interactions per bird (per h) over the different groups varied between 0.5 and 4.2 (Table 1). The average (\pm SD) rate over all groups was 2.2 ± 1.1 ($n = 10$) feather pecking interactions/bird/h. Feather pecking was observed in most growers of each group. On average 83.1% (range 58.1% to 100%) of all group members were recorded at least once as actor in a feather pecking interaction.

Figure 1 gives the distributions of the rates of feather pecking interactions of all individuals in each group. The distributions were not bimodal with 2 distinct groups of birds characterised by low or high rates of feather pecking interactions. If the probability of performing a feather pecking interaction were the same for all birds, then the distribution shown in Figure 1 would be expected to follow a Poisson distribution. However, the distribution of interactions in all groups, except group 3, differed significantly from that predicted by the Poisson distribution (group 3: $P = 0.313$, all other groups: $P < 0.03$). The interactions are significantly clumped (while many birds show no or few interac-



Rate of feather pecking interactions (per hour)

Figure 1. Distribution of rates of feather pecking interactions in 10 groups of 30 or 31 growers. Individuals with more than twice the average rate for the group (high rate peckers) are represented by black bars. Inset into each graph is the expected frequency given by a negative binomial distribution of the same mean, together with the estimated value of the dispersion parameter k for this distribution and the P-value for the null hypothesis that the data are negatively binomially distributed.

tions, a few show many interactions) and do not differ significantly from those predicted from a negative binomial distribution with dispersion parameter k close to one (Figure 1; Negative binomial distributions calculated using the methods presented in Krebs, 1989). We therefore chose an arbitrary criterion to define individuals with high pecking rates for each group (see methods; birds represented by black bars in Figure 1).

In each group there were between 2 and 6 (average 3.6 ± 1.3) growers defined as high rate peckers (Table 1). These individuals made up 12.0% of all growers observed in this experiment but initiated 39.4% of the recorded feather pecking interactions ($n = 1339$).

Pecking, pinching, pulling, and plucking made

up 54.4%, 19.8%, 23.4% and 2.4%, respectively, of all feather pecking interactions. The different types of behaviour were on average ($n = 10$ groups) shown by 70.9% (pecking: range 35.5% to 100%), 42.8% (pinching: range 29% to 63.3%), 38.1% (pulling: range 13.3% to 70%) and 6.9% (plucking: range 0% to 13.3%) of all members of a group. In 55.2%, 23.9% and 20.9% of all feather pecking interactions there were 1 to 4, 5 to 9 or ≥ 10 single feather pecks, respectively, during the interaction. Individuals defined as high rate peckers differed significantly from the other members of their group in that a lower percentage of their feather pecking interactions were classified as pecking and a higher percentage as plucking (Table 2). No such differences were found with regard to the proportion of

Table 2. Comparison of high rate peckers and other group members (means \pm SD, $n = 10$ groups) shown as percentage of feather pecking interactions assigned to different types of behaviour and to different categories of numbers of pecks observed during the interaction. Average percentages calculated for high rate peckers and other group members within each group were compared using the Wilcoxon signed ranks test

| | High rate peckers | Other group members | <i>P</i> |
|-------------------|-------------------|---------------------|----------|
| Type of behaviour | | | |
| Pecking | 47.6 \pm 9.6 | 58.9 \pm 15.6 | < 0.02 |
| Pinching | 25.1 \pm 13.6 | 20.3 \pm 6.1 | NS |
| Pulling | 23.2 \pm 11.2 | 20.4 \pm 14.4 | NS |
| Plucking | 4.2 \pm 3.9 | 0.4 \pm 0.6 | < 0.02 |
| Number of pecks | | | |
| 1 to 4 | 61.9 \pm 14.5 | 57.0 \pm 15.9 | NS |
| 5 to 9 | 24.2 \pm 13.3 | 21.5 \pm 5.2 | NS |
| ≥ 10 | 13.9 \pm 12.4 | 21.5 \pm 16.0 | NS |

interactions that were classified as consisting of 1 to 4, 5 to 9 and ≥ 10 pecks.

Individual high rate peckers did not direct their feather pecking interactions at few selected members of their group. Only one bird pecked at significantly fewer receivers than predicted based on a computer simulation in which it was assumed that feather pecks are randomly directed at other group members (Figure 2). If high rate peckers specialised in pecking at particular individuals, then it would be expected that the number of observed receivers would be lower than the median number of expected receivers. Only 7 birds pecked at fewer than the expected median number of receivers, while 18 birds pecked at more than the expected median number.

The distribution of feather pecking over the defined areas of the body was as follows: head 0.5%, neck 2.7%, breast 4.3%, wings 46.6%, back 3.6%, rump 17.6%, tail 20.2% and vent 4.6%.

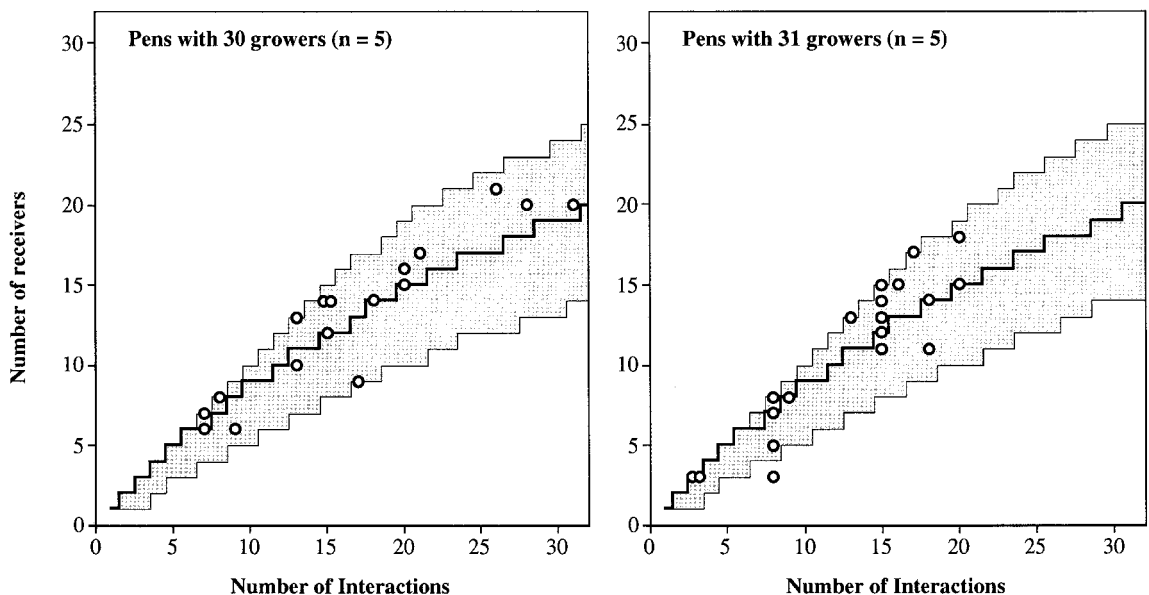


Figure 2. Relationship between the number of feather pecking interactions initiated by high rate peckers ($n = 36$) and the number of receivers of feather pecks. The shaded areas represent 99-86% confidence bands of the expected relationship based on a computer simulation of random interaction. The solid line in the centre of this area represents the median number of expected receivers. Combined data from 5 pens with 30 growers and 5 pens with 31 growers observed over 2 h.

Most of the feather pecking occurred whilst the receiver was resting (48.7%), followed by standing (37.3%), exploring (5.8%), preening (4.6%), eating/drinking (2.0%) and dustbathing (1.7%). The feather pecking records of all high rate peckers ($n = 36$) were examined in detail. There was no evidence that these birds specialised in pecking at specific areas of the body or at group members engaged in specific activities. They directed their feather pecks at an average of 3.6 different body areas (range 2 to 6 out of 8 defined areas), and the receivers of these pecks were on average engaged in 2.9 different activities (range 2 to 4 out of 6 defined activities).

Experiment 2

The number of feather pecking interactions during a focal animal observation was significantly increased if the focal animal had pecked at the feathers of a conspecific in the preceding 10 s (Table 3). A maximum of 9 interactions was recorded in one feather pecker protocol.

DISCUSSION

The results of experiment 1 show that most birds of a group were recorded at least once as actor in a feather pecking interaction. The behaviour itself was thus not restricted to a few individuals. There was, however, specialisation with respect to the intensity of the behaviour. Compared to other group members, individuals defined as high rate peckers had less of their feather pecking classified as pecking (gentle pecks) and more as plucking (severe pecks), so that they were more likely to

Table 3. Number of feather pecking interactions during 2-min focal animal observations of growers of different ages (means \pm SD). It is differentiated whether the focal individual had pecked at the feathers of a conspecific during the last 10 s preceding the start of the observation (feather pecker) or not (control bird)

| Age | Feather pecker | Control bird | <i>n</i> | <i>P</i> |
|---------|----------------|---------------|----------|----------|
| 4 weeks | 3.0 \pm 2.2 | 0.7 \pm 0.8 | 29 | <0.0001 |
| 5 weeks | 3.7 \pm 2.2 | 0.6 \pm 0.9 | 38 | <0.0001 |
| 6 weeks | 2.3 \pm 1.7 | 0.5 \pm 0.9 | 39 | <0.0001 |

P values are derived from analysis by the Wilcoxon signed ranks test.

cause feather damage. A similar shift was found when feather pecking interactions were compared before and after the occurrence of bloody injuries in groups of growers (Huber-Eicher and Wechsler, 1997). After the occurrence of bloody injuries the rate of pulling at feathers had increased whereas the overall rate of feather pecking had not changed.

Hoffmeyer (1969) used the term 'feather pecking specialists' for pheasants that showed a certain constancy in feather pecking. She observed that "these birds repeatedly pecked at the feathers of pen mates, or even sometimes at the same body region of several birds in succession" (p. 8). In the present study we confirmed that individual birds usually peck at several receivers within a short period (experiment 2) but there was no evidence that high rate peckers specialised in pecking at specific areas of the body (experiment 1). Allen and Perry (1975) reared growers in cages and reported that in some cages injuries caused by feather pecking were located at the same body area in most birds. Their observations suggest that the tendency to peck at the same body area in different group members may indeed be increased. The authors did not, however, present data from behavioural observations in support of this hypothesis. Our results show that growers in a larger group which frequently initiate feather pecking interactions do not direct their pecks at a few selected group members. The number of receivers of feather pecks observed in high rate peckers fitted well with a model assuming that feather pecks are randomly distributed at group members.

In experiment 2, growers that had just pecked at a conspecific's feathers (feather peckers) initiated on average between 2.3 (week 6) and 3.7 (week 5) feather pecking interactions during the subsequent 2-min focal animal protocol. Control birds on average initiated only 0.5 (week 6) to 0.7 (week 4) interactions. The difference suggests that feather pecking tends to occur in bouts characterised by an increased probability of pecking at several individuals in succession. Alternatively, this difference could be due to a bias in the selection of focal animals, in that the individuals chosen generally had an increased rate of feather pecking (calculated per h), not only during the focal animal protocol. The second explanation is, however, unlikely to be correct because the average rate of feather pecking

interactions during the 2-min observations of feather peckers was very high. In fact, these birds only had to peck for 6.3 and 3.9 min/h in weeks 6 and 5, respectively, to reach the rate of feather pecking interactions (per h) that was on average calculated for high rate peckers in experiment 1 (7.3 interactions/h).

Because each feather pecker observation was immediately followed by a control (matched pairs), the difference suggests that a bird's tendency to initiate feather pecking does not depend only on the presence of stimuli in the receivers that release the behaviour. Otherwise one would have to assume that the birds of the 2 samples met group members presenting different stimuli when moving around the pen. Consequently, the peckers themselves seem to be in a motivational state that results in a series of interactions. In order to understand the development and spread of feather pecking in a group it is important to know whether this motivation is limited to a few members that could be labelled as 'feather pecking specialists'. Keeling and Jensen (1995) addressed this question by subjecting feather peckers and controls to a series of tests measuring pecking frequency, exploration, fearfulness and sociality. However, no clear differences in personality could be identified in their study.

In both experiments we were surprised by the very sudden appearance (typically within a few hours) of high rates of feather pecking in week 4. Although we immediately started to collect data on the behaviour of the individually marked birds, we were not able to document a spread of feather pecking within the groups. We can therefore not decide if the sudden appearance of feather pecking in most members of a group was attributable to an identical reaction of most individuals to specific environmental conditions or if there was a spread of the behaviour as a consequence of social learning (stimulus enhancement, imitation; Nicol, 1995). Experimental studies with naive birds that can observe a feather pecker or a control bird could reveal whether social learning is of any importance for the development of feather pecking.

In conclusion, we found that feather pecking interactions of individual growers are clustered in time and that the behaviour is not only performed by a few specialised members of a group. However, in comparison to other group members some individuals were characterised by relatively high rates and more severe forms of this behaviour. Such birds are more likely to cause feather damage and welfare problems.

APPENDIX

This appendix provides some additional analysis to address points raised in the review process of this manuscript.

Criterion for choice of high rate peckers

The choice of where to make the division between high rate peckers and the remaining birds in each pen is inevitably arbitrary, because the number of pecking interactions is a continuously-distributed trait with no evidence of bimodality (Figure 1). There were, however, large differences between pens in the average and maximum number of interactions recorded (Figure 1), which may well reflect different stages in the development of the phenomenon of feather pecking. It is for this reason that we decided to use a relative measure of pecking rate (more than twice the mean rate) to define high rate peckers. Other criteria for the choice of high rate peckers are also possible, for example all those birds showing more than a certain absolute number of pecking interactions per hour. To our minds the important question is not how to define high and low rate peckers, but whether there is a qualitative difference in the interactions of birds with few and many interactions.

To examine this point we carried out further data analysis to look for any correlation between numbers of interactions and the quality of interactions. This makes the definition of high rate peckers unnecessary, as it treats the number of feather pecking interactions as a continuous variable.

Because each interaction was classified as one of 4 mutually-exclusive categories, correlation using a multcategory dependent variable was necessary. The most appropriate form of analysis is the use of a generalised linear model with a multinomial error distribution (McCullagh and Nelder, 1989). This allowed the examination of the effect of independent variables on the proportion of interactions classified in each category, while taking into account differences in the total number of interactions performed by each bird (Figure 1). For the analysis the independent variables fitted were Group, Rate of feather pecking interactions per hour, and their Interaction. Analysis was carried out in Microsoft Excel 5.0, using the solver add-in to iteratively maximise the log-likelihood function of the multinomial distribution, with the significance of each term in the model being assessed by the change in scaled deviance caused by the removal of that term from the complete model (McCullagh and Nelder, 1989). The change in scaled deviance (Δ deviance below) is asymptotically distributed as χ^2 with degrees of freedom equal to the change in degrees of freedom (Δ DF below) resulting from removal of the term from the model. *P* values for the analysis are those corresponding to this χ^2 value.

Results of this analysis showed that after correcting for slight overdispersion (Estimated scale = 1.163, McCullagh and Nelder, 1989), the minimum adequate model contained both Group and Rate of interactions per hour, but not the Interaction between these terms, although this was

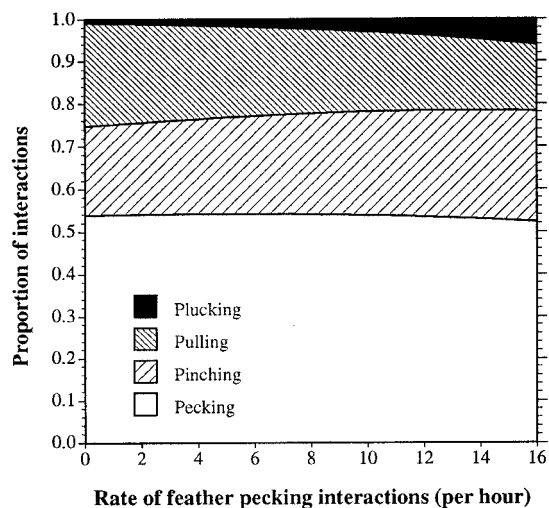


Figure 3. Fitted multinomial model showing the relationship between the proportion of feather pecking interactions classified as pecking, pinching, pulling and plucking and the rate of feather pecking interactions per hour. The proportions given are the mean values for all groups combined.

close to significance (Group: Δ deviance = 112.01, Δ DF = 27, $P < 0.001$; Interactions per hour: Δ deviance = 8.79, Δ DF = 3, $P = 0.032$; Group \times Interactions per hour: Δ deviance = 39.04, Δ DF = 27, $P = 0.063$). This shows that there is significant variation between groups in the proportions of interactions classified as pecking, pulling, pinching and plucking, and that there is a significant change in the quality of interactions as the number increases, which is the same for each group. As the rate of interactions increased, the proportion classified as pinching and plucking increased, the proportion of pulling decreased, and the proportion of pecking decreased slightly (Figure 3). Thus our finding that high rate peckers pluck more frequently and peck less frequently than lower rate peckers is supported from this analysis of feather pecking interaction rate as a continuous variable.

Categorisation of feather pecking as number of interactions

We chose to use number of interactions as our measure of pecking rate rather than the absolute number of pecks for practical reasons, because by doing so we could record all interactions between growers. This would not have been possible if each peck was scored individually. If, however, there were motivation for a grower to produce a certain number of pecks, regardless of the number of interactions that this involves, then our results may be biased by considering numbers of interactions rather than numbers of pecks. In other words, our birds defined as high rate peckers may not have given more pecks, but simply had more interactions.

Because the number of pecks within each interaction were quantified into three classes (1 to

4 pecks, 5 to 9 pecks and ≥ 10 pecks), we do have some information on the number of pecks involved in each interaction. To examine this question further, we therefore performed another analysis using a generalised linear model with multinomial error structure to determine whether there was any correlation between the feather pecking interaction rate and the proportion of interactions that were classified in each class. After correction for slight overdispersion in the data (Estimated scale = 1.282), the minimum adequate model was found to involve all 3 terms (Group: Δ deviance = 66.96, Δ DF = 18, $P < 0.001$; Interactions per hour: Δ deviance = 26.51, Δ DF = 2, $P < 0.001$; Group \times Interactions per hour: Δ deviance = 36.07, Δ DF = 18, $P = 0.007$). Hence each group differed in the proportion of interactions classified within each class, and in how this proportion changed with the number of interactions. In 7 of the 10 groups, the number of pecks per interaction decreased with increasing number of interactions, whereas in groups 3, 6 and 9 there was an increase in the number of pecks per interaction with increasing interaction number. In conclusion, this analysis shows that the feather pecking interaction rate may give a different measure of feather pecking than the total number of pecks given by a bird. The choice of whether to measure feather pecking interactions or total number of pecks given in a study depends on the type and scale of that study. We chose to measure rates of feather pecking interactions for practical reasons. In other studies we have shown that the rate of feather pecking interactions is sensitive to housing conditions (Huber-Eicher and Wechsler, 1997) and associated with injuries caused by feather pecking (Huber-Eicher and Wechsler, in press), so we believe that it gives a good practical measure of feather pecking in growers.

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