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Loose housing of small goat groups: Influence of visual cover and elevated levels on feeding, resting and agonistic behaviour

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ABSTRACT

Frequent social conflicts among goats due to their strict rank relationships can pose problems in loose housing of goats by negatively influencing feeding and resting times of low-ranking group members. In this study, we tested whether enrichment of loose-housing pens with structural elements providing visual cover (partitions, lying niches) and elevated levels (platforms) is effective in reducing agonistic interactions and interruptions in feeding and resting behaviour in small groups of goats.

The study involved 8 groups of goats consisting of 8–9 non-lactating females that differed in grouping age and the presence of horns in a two-by-two factorial design. We compared the feeding, resting and agonistic behaviour the goats showed in pens to which they were well habituated (original situation) with the behaviour they performed in these pens after enriching them with additional structural elements providing visual cover and elevated levels (enriched situation). Finally, the arrangement of the pens was restored to the original situation (restored situation). In each group, the behaviour of two low-ranking, two medium-ranking and two high-ranking goats was continuously recorded by video. Using linear mixed-effects models, variables of goat behaviour were analysed with situation, rank, grouping age and presence of horns as fixed explanatory variables.

With most of the outcome variables, the effects of the housing situation interacted with those of the rank and/or the presence of horns. From the original to the enriched situation, the feeding bouts were generally longer. Furthermore, from the original to the enriched situation, fewer feeding bouts of low- and medium-ranking goats were interrupted by displacements, and fewer of these bouts were interrupted by medium- and high-ranking goats to initiate agonistic interactions. In addition, fewer resting bouts were interrupted by displacements received, and in medium- and high-ranking goats, the risk of an interruption whilst resting due to initiating an agonistic interaction decreased from the original to the enriched situation. The outcome variables' values in the restored situation hardly ever returned to the values of the original situation which is likely to indicate a carry-over effect of the enriched to the restored situation. In conclusion, our results show that enriching pens for small groups of goats with structural elements providing visual cover and elevated levels positively affects feeding, resting and agonistic behaviour.

1. Introduction

Frequent social conflicts among goats due to their strict rank relationships can negatively affect feeding and resting behaviour of low-ranking individuals in loose-housing

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systems. In an experimental study with loose-housed dairy goats, Andersen and Bøe (2007) and Jørgensen et al. (2007) varied space allowance in the lying area and at the feeding place, respectively, and found that with restricted space allowances, low-ranking group members spent less time feeding and lying than higher ranking individuals. Similarly, Loretz et al. (2004) observed that high-ranking dairy goats often defended several feeding places at once whereas low-ranking goats had to share feeding places or could even access feed only at a later time. This might be one reason why milk and meat performance can be reduced in low-ranking goats (Barroso et al., 2000) and may also indicate an impairment in terms of animal welfare.

Studies with different animal species have shown that provision of structures for hiding may have a positive effect on aggression level (pigs: McGlone and Curtis, 1985; Waran and Broom, 1993; cattle: Chamove and Grimmer, 1993; red deer: Whittington and Chamove, 1995). With goats, we found in a previous study that provision of visual cover at the feeding place was effective in reducing aggression rate during feeding (Aschwanden et al., 2009). Also in that study, dyads of goats who had to share one hayrack spent more time feeding simultaneously and showed less agonistic interactions if one of the goats could stand on a platform. Similarly, Andersen and Bøe (2007) reported that dividing the lying space in two levels rather than one resulted in fewer displacements and an overall lower aggression level in goats kept in small groups.

In the present study, we therefore tested whether enriching pens for small groups of goats with structural elements providing visual cover (partitions, lying niches) and elevated levels (platforms) has positive effects on feeding, resting and agonistic behaviour. Before (original situation) and after (restored situation) the enriched situation, the eight study groups were kept in pens equipped with only few structural elements. In each situation, behavioural data of two low-ranking, two medium-ranking and two high-ranking focal goats of each group was collected. The groups differed in the presence of horns and grouping age, and this was also considered in the analyses. The original housing conditions cannot be termed intensive, as the housing system was structured to some extent, the animal/feeding-place ratio was 1:1, space allowance at the feeding place was at least 45 cm per goat, and hay was offered ad libitum. Nevertheless, we expected that from the original to the enriched situation, the goats would spend more time feeding and resting and show longer feeding and resting bouts. Furthermore, we hypothesised that in the enriched situation goats would perform fewer agonistic interactions both during feeding and resting, and spend less time feeding at night to compensate for the possibly limited access to feed during daytime. From the enriched to the restored situation, we expected that the values would return to the original levels and that the effects of enrichment would be most pronounced for low-ranking individuals and for groups with horned goats.

2. Methods

2.1. Animals and general housing conditions

We used six groups of nine and two groups of eight female non-lactating, non-pregnant goats that were kept in eight identically equipped pens. The goats had been bought at different Swiss farms and were grouped in May 2005. They were of various Swiss milking breeds (Saanen, Toggenburger, Appenzeller, Chamois Coloured, St Gallen booted, Grisons striped and Valais blackneck) and their crossbreeds. At grouping, the breeds were randomly distributed over the eight groups. Four of the eight groups had been grouped as juveniles at an age of about 3 months (almost 2 years before the start of the study), and the other four groups as adult goats (average age per group at grouping: 2–3 years). Two each of the juvenile and adult goat groups had horns, whilst the other two were hornless (unknown if genetically hornless or dehorned) in accordance with a 2×2 factorial design.

The total area of each pen was 15.3 m^2 (approximately 3 m $\times$ 5 m), consisting of a deep-bedded straw area of 11.7 m^2 (approximately 3 m $\times$ 4 m) and a 0.5-m elevated feeding place (3.6 m^2, Fig. 1a and b). Hay was fed ad libitum in a 2.6-m hayrack at the feeding place and in an additional 1-m hayrack in the straw area. Fresh hay was provided in the morning between 8.00 and 9.00am and in the afternoon between 4.30 and 5.30pm. The animal/feeding-place ratio in the pens was 1:1 with a calculated space of at least 45 cm per goat. Each pen had one water trough, one licking stone with minerals and vitamins, and a broom.

2.2. Experimental housing situations

We recorded the behaviour the goats showed in the housing situation to which they were habituated for 2 years (original situation) and compared it to the behaviour they performed in a situation where the pens were additionally furnished with partitions and lying niches providing visual cover and elevated levels (platforms) for resting and feeding (enriched situation). Afterwards, as a control, the arrangement was restored to its former condition (restored situation). In this approach, each goat served as her own control and we were able to directly detect effects of enrichment.

In the original situation (Fig. 1a and c), the elevated feeding place was divided by a wooden partition (length 120 cm and height 110 cm) into two compartments of equal size. Further structures in the straw area were a 55-cm-high wooden platform (250 cm $\times$ 65 cm) on which goats could stay or lie beneath in two lying niches and a freestanding partition (80 cm in height) in the centre of the pen on which goats could also stay.

In the enriched situation (Fig. 1b and d), we modified the feeding places in such a way that the goats could feed with more visual cover and feed from different levels. To do so, the second short hayrack in the straw area of the pen was divided with a wooden partition (length 50 cm and height 110 cm), in a similar manner to the long hayrack on the elevated feeding place. Furthermore, a 70-cm-high wooden platform (50 cm $\times$ 100 cm) was placed

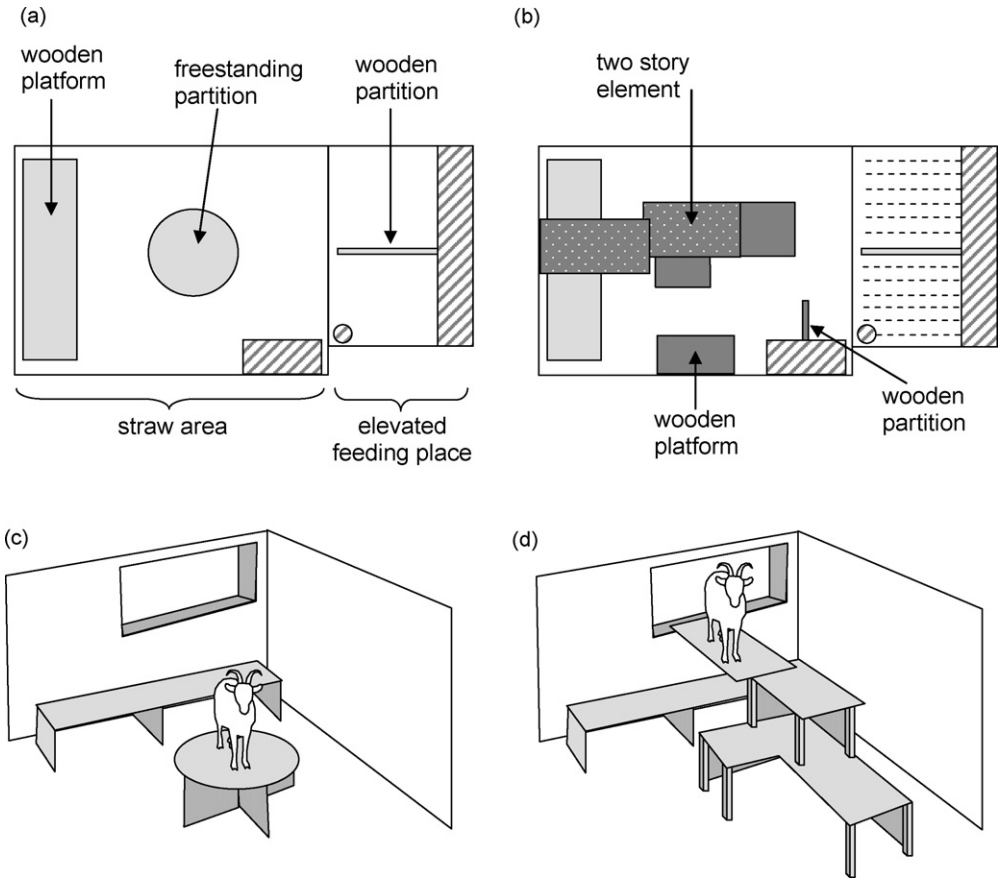

Fig. 1. Layout of the pens (true to scale) in the original (a) and in the enriched situation (b). Furthermore, a 3D-view on the freestanding partition in the original (c) and on the two storey modification in the enriched situation (d). In (a) and (b), hatched squares = long and short hayracks, hatched circles = water troughs, light grey = elements to which the goats were habituated in the original situation and that remained in the pen in the enriched situation, dark grey = newly installed elements, dark grey with white spots = second floor, dashed lines = wooden slats to prevent lying.

on one side of the short hayrack. Whilst standing on this platform, the goats could also feed from above. To reduce the number of high-ranking goats occupying the feeding place in front of the long hayrack by lying on the elevated area, the floor of this area was made uncomfortable for lying. This was done by fixing wooden slats (3 cm × 5 cm) to the floor of the elevated feeding place, parallel to the wooden partition with a space of 15 cm between each other. Without these slats, 13 (original situation) and 11 (restored situation) of the 16 high-ranking focal animals were observed lying on the elevated feeding place during the observation time. In contrast, only one of them lay in this area in the enriched situation with the slats. Also in the enriched situation, the freestanding partition in the centre of the pen (Fig. 1c) was removed and replaced by a two storey construction (Fig. 1d) to increase the allowance of elevated lying space and the number of lying niches. The first and second level of this construction had a height of 70 and 125 cm, respectively. Furthermore, the small wooden platform placed on one side of the short hayrack in the straw area could be used as an elevated resting place and lying niche. As a consequence, at least six goats could lie in niches simultaneously in the enriched situation.

2.3. Data collection

The experiment was conducted between September 2007 and March 2008. The eight goat groups were treated in two sets of four groups, respectively, that were investigated shifted in time by approximately 4 weeks. Each set consisted of two horned and two hornless groups, one of each either grouped as adults or as juveniles. In both sets, data were first collected in the original situation, then in the enriched situation and finally in the restored situation. After changes were made to a pen, groups had 6 weeks to habituate to the enriched and 4 (series 2) or 7 (series 1) weeks to do so to the restored situation. The variation between the two series was attributable to the restricted availability of assistance owing to a heavy workload on the farm. But the potential difference due to the aforementioned procedure was accounted for in the statistical analyses in the random effect of group (see below). In each housing situation, each group was observed and video-recorded on three different days (day 1–3), with three days in-between. In the original situation, the video observations were made over a period of 3 weeks before the pens were changed over to the enriched situation, whilst in both the enriched and

restored situations they were made over a 3-week period following the habituation period. From the videos, feeding, resting and agonistic behaviour of six focal goats of each group were continuously analysed: the feeding behaviour on each day for 120 min directly after the goats had received fresh hay in the morning, which was usually between the hours of 8:00 and 9:00am, and resting behaviour on 2 days (days 1 and 3) for 240 min between the hours of 1:00 and 5:00am. These time frames were chosen based on an analysis of the diurnal activity of the goats prior to this experiment, aiming at identifying periods when most animals were feeding or resting.

In order to select focal goats differing in rank within their groups, we determined the dominance relationships of the goats in each group before the start of the experiment by directly observing the agonistic behaviour of the goats in the pens during the morning and evening feeding times. Indicators for dominance/subordination were displacements effected by a dominant goat and avoidance behaviour by subordinate animals. Displacement behaviour was defined as one goat forcing another to leave her current position, either by a threat or a butt. Avoidance behaviour was defined as a goat leaving her current position after being approached by another goat which neither butted her nor constituted an obvious threat. In order for rank relationship within each dyad to be deemed clear-cut, at least three agonistic interactions with the same goat in the dominant role had to be observed. If at least one outcome of such interactions was contradictory, a dyad was observed until one goat was twice as often clearly dominant over the other. For each goat, a rank-index (between 0.0 = omega and 1.0 = alpha) was calculated by dividing the number of dominated group members by the number of possible rank relationships (i.e. eight for a group of nine). Based on this rank-index, individual goats were categorised as low-ranking (0.00–0.33), medium-ranking (0.34–0.66) or high-ranking (0.67–1.00). Two focal goats were randomly chosen from these three categories for each group.

During the behavioural observations it was continuously recorded when a goat was feeding or resting and for what reason a goat interrupted a feeding or resting bout. Feeding was defined as a goat being within a radius of 50 cm in front of a hayrack, directing her head towards the rack and taking hay from the hayrack with her mouth. Rarely, goats fed on hay that had fallen out of the hayracks to the floor. This type of feeding was defined as a goat repeatedly touched the floor surface with her mouth for a period of time longer than 1 min. A goat was recorded to interrupt a feeding bout when she turned her shoulders at least 90° away from the hayrack, taking more than one step or moved more than 50 cm away from the hayrack. A goat was recorded as resting when she was either lying or standing in a resting posture. To be classified as standing in a resting posture, a goat had to stand and remain motionless for more than 1 min with her head hanging downwards. An interruption of a resting bout occurred when a lying goat stood up on all four feet or when a goat standing in a resting posture lifted her head from the downward position and started moving around. The recorded reasons for interrupting a feeding or resting bout were classified as social or not social. For instance, social reasons were displacements of the focal goat, agonistic interactions initiated by the focal goat or disturbances owing to agonistic social interactions between other members of the group. Non-social reasons included, for instance, interruptions taking place without identifiable reason as well as interruptions due to defecation, or disturbances owing to external circumstances (e.g. noise emission from outside of the pen).

Based on these behavioural data, we calculated the following variables to be used as outcome variables in the statistical models:

1. Total feeding time ([min], max. 120 min).
2. Total resting time ([min], max. 240 min).
3. Length of feeding bouts interrupted due to a social reason [min].
4. Length of resting bouts interrupted due to a social reason [min].
5. Rate of displacements received whilst feeding [no./h] ((number of feeding bouts interrupted due to a displacement received/total feeding time) × 60 min).
6. Rate of displacements received whilst resting [no./h] ((number of resting bouts interrupted due to a displacement received/total resting time) × 60 min).
7. Rate of agonistic interactions initiated whilst feeding [no./h] ((number of feeding bouts interrupted due to an agonistic interaction initiated/total feeding time) - × 60 min).
8. Rate of agonistic interactions initiated whilst resting [no./h] ((number of resting bouts interrupted due to an agonistic interaction initiated/total resting time) - × 60 min).
9. Total duration of feeding at night (between 1.00 and 5.00am) ([min], max. 240 min).

Since feeding and resting times were expected to vary between animals and situations, we standardised the variables on agonistic behaviour (variables 5–8) by the duration of feeding and resting times so as to keep these values comparable.

2.4. Statistical analysis

For each outcome variable listed in the preceding section, a separate (generalised) linear mixed-effects model was calculated in R 2.6.1 (R Development Core Team, 2007). If errors were assumed to follow a normal distribution, residuals were checked graphically for that distribution, equality of variances and outliers. In the generalised case, it was graphically checked that errors averaged close to zero when plotted against fitted values such that there was no visible bias. The total feeding and resting time, the length of bouts interrupted due to social reasons at feeding and resting (log-transformed), the rate of displacements received whilst feeding (log-transformed), the rate of agonistic interactions initiated whilst feeding (log-transformed) and the duration of feeding at night (log-transformed) were evaluated using the "lme" method (Pineheiro and Bates, 2000). The rate of displacements received whilst resting and the rate of agonistic

interactions initiated whilst resting were only rarely observed and were thus evaluated using the method "glmmPQL" based on a Poisson distribution and on a binomial distribution (occurrence of agonistic interactions initiated yes/no), respectively.

In each model the fixed explanatory variables were the housing situation (ordered factor with levels original/enriched/restored), the rank (ordered factor with levels low-ranking/medium-ranking/high-ranking), the presence of horns (factor with levels no/yes) and the grouping age (factor with levels juvenile/adult). Furthermore, we included all combinations of two-way interactions and all possible combinations of three-way interactions including the factor housing situation. As a random effect, the individual was nested in a group to reflect the repeated measurement of all individuals and their nesting within the groups. To be able to simplify whenever possible the curvature modelled by the ordered factors situation and rank, we explicitly included the situation and rank coded as values 1–3 linearly and squared. If the observed values of the response variables were similar in situations 1 and 3, we would then find a highly significant effect of the squared term. The inverse was not necessarily true, i.e. if this squared term reached significance, we needed to investigate (e.g. based on the figures and/or estimated effects) whether the values in situations 1 and 3 were in fact similar, or whether situations 1 and 2 or 2 and 3 were similar, which would also induce a curvature in the change of the observed values across time and experimental situations.

The models were set up as full models, then reduced by a stepwise backward method (threshold $p < 0.1$). Interactions were excluded first, and main effects only if variables were no longer part of an interaction. In interactions where a squared term of a given variable was used, the interaction with the square was excluded before the interaction with the linear term of the same variable.

3. Results

Except for one, all outcome variables were significantly influenced by interactions of the housing situation with one or two other explanatory variables (mainly rank and presence of horns). Predominantly, the effects within an interaction were in the same direction from the original to the enriched and from the enriched to the restored situation in all categories of goats of an explanatory variable (e.g. same direction of effects for low-, medium- and high-ranking goats, but with values on different levels). However, in some variables, the values in the restored situation did not return to the same values as measured in the original situation.

3.1. Total feeding or resting time

The total feeding time was significantly influenced by the interactions of the housing situation with rank ($F_{1,92} = 5.42$, $p = 0.022$, Fig. 2a) and with the presence of horns ($F_{1,92} = 4.81$, $p = 0.031$, Table 1). The feeding time decreased from the original to the enriched and to the restored situation in all categories of rank as well as in hornless and horned goats. In all three situations, low-ranking goats had the shortest and high-ranking goats the longest feeding times whereas medium-ranking goats were in-between. Furthermore, in every situation hornless goats fed longer than horned goats.

Total resting time was significantly affected by the interaction of the situation with the grouping age ($F_{1,87} = 6.56$, $p = 0.0012$, Fig. 2e). In goats grouped as juveniles, the duration increased from the original to the enriched situation and decreased to the restored situation, whereas this effect was inversed in goats grouped as adults.

3.2. Length of feeding or resting bouts

In total, 11377 events were recorded where goats interrupted feeding and 963 events where goats inter-

Table 1
Estimated mean effects (back-transformed values) of the housing situation significantly interacting with other explanatory variables supplementing those shown in Fig. 2.

Outcome variables	Explanatory variables interacting with the housing situation	Levels		Housing situation		
				Original	Enriched	Restored
Total feeding time (min)	Presence of horns	Hornless		72.80	57.50	42.13
		Horned		44.30	34.00	23.80
Length of feeding bouts (min)	Presence of horns	Hornless		1.01	1.14	0.93
		Horned		0.21	0.29	0.28
Displacements received whilst resting (no./h)	Grouping age with rank	Juvenile	Low	0.18	0.07	0.18
			Medium	0.13	0.07	0.08
			High	0.18	0.13	0.14
		Adult	Low	0.28	0.19	0.14
			Medium	0.25	0.09	0.18
			High	0.13	0.07	0.09
Agonistic interactions initiated whilst resting (odds ratios)	Grouping age with rank	Juvenile	Low	1.01	0.34	0.91
			Medium	2.69	0.99	2.95
			High	7.19	2.92	9.59
		Adult	Low	1.61	2.75	37.79
			Medium	27.97	13.99	56.43
			High	100.00	71.31	84.27

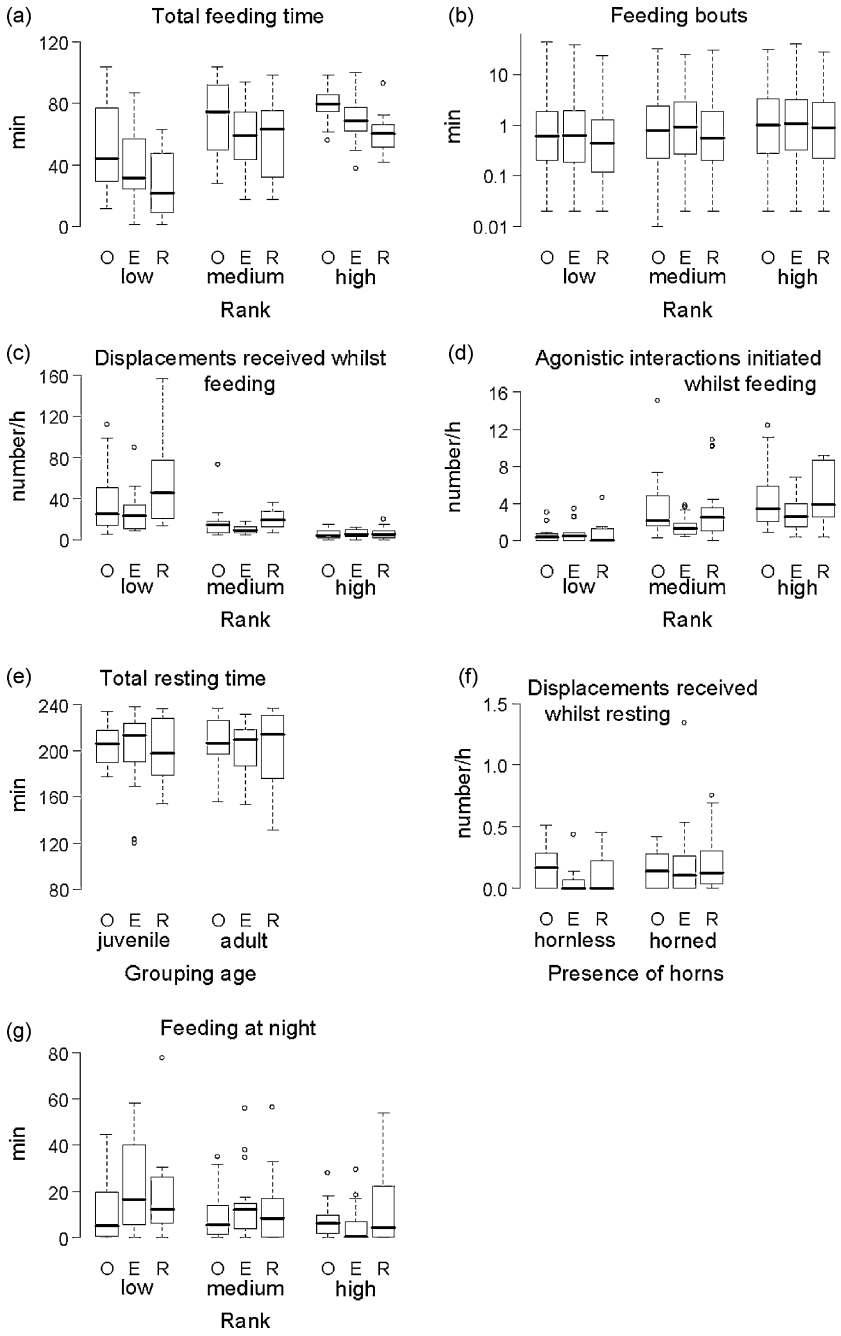

Fig. 2. Effects of the housing situation (O = original, E = enriched, R = restored) on variables stemming from the data sets of feeding (a–d) and resting (e–g). Included are the additional significant effects of rank, grouping age or presence of horns illustrating the according statistical interactions. Box plots show the median and the quartiles of the absolute values. Additional two- and three-way interactions are presented in Table 1.

rupted resting. At feeding 70.6% (i.e. 8038) and at resting 41.4% (i.e. 399) of the interruptions occurred due to a social reason. The main social reasons were displacements received (feeding: 69.7% of the interruptions and resting: 74.2%) and agonistic interactions initiated (feeding: 15.3% and resting: 16.5%).

The length of the feeding bouts was significantly dependent on the interactions of the housing situation with rank ($F_{1,92} = 4.72$, $p = 0.032$, Fig. 2b) and with the presence of horns ($F_{1,92} = 8.56$, $p = 0.004$, Table 1). All the values slightly increased from the original to the enriched situation and afterwards decreased again in the restored situation.

3.3. Displacements received whilst feeding or resting

The number of displacements received whilst feeding was significantly influenced by the housing situation

interacting with rank ($F_{1,89} = 4.32$, $p = 0.04$, Fig. 2c). There was a slight reduction of the number of displacements received from the original to the enriched situation and a stronger increase from the enriched situation to the restored situation in low and medium-ranking goats. In high-ranking goats a slight increase occurred from the original situation to the enriched situation and the values remained on a similar level in the restored situation. Furthermore, in all three situations the low-ranking goats were displaced more frequently than medium and high-ranking goats and medium-ranking more frequently than high-ranking goats.

For the number of displacements received whilst resting, there was a significant interaction of the situation with the presence of horns ($t_{80} = -2.50$, $p = 0.014$, Fig. 2f) and a three-way interaction of the situation with grouping age and rank ($t_{80} = -2.58$, $p = 0.012$, Table 1). The number of displacements received from the original to the enriched situation decreased slightly in horned and stronger in hornless goats. An increase occurred in both horned and hornless goats from the enriched to the restored situation. In all combinations of the factors grouping age and rank, there was a strong decrease from the original situation to the enriched situation. A strong increase was observed from the enriched to the restored situation in medium-ranking goats grouped as adults and in low-ranking as well as high-ranking goats grouped as juveniles.

3.4. Agonistic interactions initiated whilst feeding or resting

The rate of agonistic interactions initiated whilst feeding from the original to the enriched situation, strongly decreased in high-ranking and slightly decreased in medium-ranking goats, and from the enriched to the restored situation, the rate strongly increased in high-ranking and slightly increased in medium-ranking goats (interaction of the situation with rank: $F_{1,92} = 5.18$, $p = 0.025$, Fig. 2d). Generally, the frequency of agonistic interactions initiated at feeding was highest in high-ranking goats.

The probability that a goat interrupted a resting bout to initiate an agonistic interaction was influenced by the three-way interaction of the housing situation with grouping age and rank ($t_{90} = -1.99$, $p = 0.049$, Table 1). Except for low-ranking goats, grouped as adults, the odds ratios strongly decreased from the original situation to the enriched situation and increased from the enriched to the restored situation. In low-ranking goats grouped as adults, the levels increased over the course of time. In general, the odds ratios were considerably higher in goats grouped as adults than in goats grouped as juveniles. Within both goats grouped as juveniles and adults, high-ranking goats had the highest probabilities of interrupting a resting bout to initiate an agonistic interaction.

3.5. Feeding at night

The duration of feeding at night depended on the housing situation interacting with rank ($F_{1,88} = 4.74$, $p = 0.032$, Fig. 2g). From the original to the enriched to the restored situation, the duration first decreased and then increased in high-ranking and first increased and then decreased in low- and medium-ranking goats.

4. Discussion

In this experimental study, feeding, resting and agonistic behaviour of goats kept in small groups was compared between housing situations varying in the number of structural elements providing visual cover and elevated levels. Housing conditions of the original situation were first enriched by partitions, lying niches and platforms, and secondly restored to its former state. We split our discussion in line with these two steps in the experimental design first focusing on the differences in the behaviour of the goats between the original and the enriched situation, and later on those between the enriched and the restored situation.

4.1. Original situation versus enriched situation

Looking at the direction of all the effects that occurred between the original and the enriched situation, the structural elements added in the enriched situation positively affected feeding, resting and agonistic behaviour of the goats. There was an increase in the length of feeding bouts and fewer feeding bouts interrupted by displacements in low and medium-ranking goats. Furthermore, there were fewer resting bouts interrupted by displacements, fewer feeding bouts interrupted to initiate agonistic interactions in medium and high-ranking goats, and a lower risk for the latter occurring whilst resting.

The arrangement in the enriched situation enabled the animals to disperse more easily in horizontal and vertical space and to take advantage of increased visual cover. Possibly, this arrangement minimised the potential of social conflicts by reducing the occasions where the goats were directly confronted with each other face-to-face. When meeting face-to-face, the higher-ranking animal is usually motivated to exhibit agonistic behaviour or the lower-ranking animal shows avoidance as soon as the distance between the two individuals is smaller than a critical distance that is specific for a given dyad ("individual distance" according to Hediger, 1940; Aschwanden et al., 2008). In an experimental situation, Aschwanden et al. (2008) showed that the individual distance was >0.4 m and up to 4.0 m in most of the goat dyads when two goats fed side-by-side. The size of the individual distances demonstrate the potential for social conflicts in a pen of about 3 m × 5 m. Although there is no study about the size of individual distances at resting, the importance of observing an individual distance at rest is underlined by the fact that goats also interrupted resting to initiate agonistic interactions. A reduction in direct face-to-face confrontations may therefore have lowered the motivation for aggressive interactions. This reduction seems to have been very successful in the current experiment, given the small pens and thus the small absolute distances between pairs of goats.

Contrasting this proximate level of argument, the effect of the enrichment might be also interpreted on a more functional level in relation to the balanced ratio of cost and benefit of a behaviour (MacArthur and Pianka, 1966). It is reasonable to assume that compared to a situation without structural elements, a bigger effort is needed by a goat to chase away a lower-ranking animal when, e.g. jumping to

or from an elevated platform or walking around an element. This is supported by the study of Aschwanden et al. (2009) where two goats fed side-by-side at two feeding places either separated by a partition or not, or had to share one feeding place with the possibility for one goat to reach feed standing on an elevated level. In both situations, the duration of the first feeding bout during which both goats were feeding simultaneously was significantly longer with either a partition or a platform. This indicates that the effort of attacking a goat standing behind a partition or on an elevated level is greater than to do so without an obstacle.

Finally, it can be assumed that lower-ranking goats learn that they will not be attacked or that it takes longer until being attacked when they stay on a different height level than a higher-ranking animal or when the higher-ranking is behind a partition. It is known that goats avoid to approach a feeding place situated close to a higher-ranking goat without the higher-ranking goat exhibiting obvious agonistic behaviour (Aschwanden et al., 2008). Nevertheless, lower-ranking goats approached a feeding place separated by a partition or by an elevated level (see above) despite the close presence of the higher-ranking goat (Aschwanden et al., 2009). The same effects are likely to have occurred in the enriched housing situation with regards to feeding as well as resting behaviour.

With some of the outcome variables analysed in the present study the effects of the enrichment were not very pronounced when viewed on an absolute level. This can be attributed to the fact that the pen in the original situation was already furnished with some structural elements to avoid a continuous condition critical in terms of animal welfare. These were a partition in front of the long hayrack to avoid that one high-ranking goat was able to completely restrict access to feed, two lying niches and a freestanding partition to provide shelter for hiding and avoiding social conflicts. Nevertheless, we could detect an effect of the additional enrichment and it is plausible to assume that we would have observed even stronger effects when comparing the enriched situation to one without any structural elements. Our experimental design compared two different levels of enrichment, rather than a non-enrichment (i.e. barren) situation with an enriched situation. Consequently, in addition to the qualitative question concerning animal welfare, we also raise a quantitative one, viz., whether or not the positive effects would warrant the extra effort of additional enrichment. Whilst on the one hand we would argue that it is not particularly costly to build-in structural elements providing visual cover and elevated levels, on the other hand these elements are likely to require a greater time commitment for pen upkeep in the form of cleaning and clearing. Further investigations are thus necessary in order to reliably assess the economic aspects of such an enrichment.

In all models, the effect of the situation interacted with one or more of the other explanatory variables, i.e. rank, grouping age or presence of horns. In most of these instances, however, the pattern across the three experimental situations for goats differing in rank, grouping age or presence of horns was qualitatively the same but differed in the absolute level of the values. This was not the case in the outcome variables 'received displacements whilst feeding', 'initiated agonistic interactions whilst feeding' and 'feeding at night', though, for which goats of different rank reacted differently to the experimental situations. In the enriched compared to the original situation, high-ranking goats received more displacements whilst feeding (whereas medium- and low-ranking goats received slightly fewer) and low-ranking goats initiated more agonistic interactions whilst feeding (whereas medium- and high-ranking goats initiated fewer). Additionally, low-ranking goats fed longer at night in the enriched than in the original situation, in contrast to medium- and high-ranking goats. These results indicate that the enriched situation improved feeding conditions for low-ranking goats in that they defended their feeding place more frequently, and that they had more opportunities to feed at night. The latter was due to the fact that they could access the elevated feeding area at night in the enriched situation which was usually occupied by high-ranking goats lying in front of the hayrack in the original situation. However, this increase in time spent feeding at night observed in the low-ranking goats also indicates that even in the enriched situation, their access to feed during the day was considerably limited.

4.2. Restored versus original situation

After restoring the enriched situation back to the original situation, we also expected the behaviour of the goats to change back to as it was before. Values of only a few variables in the restored situation returned closely to the values of the original situation, though. These differences are likely to indicate that the behaviour in the restored situation was influenced by the way how the goats experienced the enriched situation (carry-over effect).

However, some patterns were not uniform in relation to the attributes of the goats (grouping age, presence of horns, rank). Thus it seems that the different categories of goats experienced the enriched situation differently and according to that their behaviour in the restored situation differed. For instance, in contrast to high-ranking goats low-ranking goats interrupted more feeding bouts to initiate an agonistic interaction in the enriched situation at feeding and this increased level was still kept in the restored situation. Possibly, this reflects some learning in the enriched situation of how to better prevail at feeding which low-ranking goats still applied in the restored situation. It might therefore be important to be aware of such effects when changing housing conditions on farms; however, we do not know whether the values of the outcome variables in the restored situation of our experiment would have reverted to the level of the original situation with time.

Interestingly, feeding time decreased dramatically across the three experimental situations. In the absence of an obvious reason for this, such as e.g. markedly reduced food consumption, or a change in either the daily feeding rhythm or in the physiological state of the goats (which were neither pregnant nor lactating), we can only speculate on the possible cause. Perhaps the quality of the hay changed over time, inducing the goats to feed

faster. Because variables on agonistic interactions collected during the goats' feeding bouts were standardised across feeding time, however, the reduction in total feeding time did not influence our results in terms of the rate of such interactions in the different situations.

4.3. Conclusion

The results of the present study show that equipping loose-housing pens of small groups of goats with partitions and lying niches to provide visual cover as well as with platforms providing elevated levels positively affects feeding, resting and agonistic behaviour. Generally, the feeding bouts were longer and fewer resting bouts were interrupted by displacements. Furthermore, fewer feeding bouts were interrupted by displacements in low- and medium-ranking goats, fewer of those bouts were interrupted by medium and high-ranking goats to initiate agonistic interactions, and a lower risk for the latter occurred whilst resting. Therefore, such structural elements can be recommended to minimise the number of agonistic interactions whilst feeding and resting in small groups of goats in loose-housing pens.

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