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Social distances of goats at the feeding rack: Influence of the quality of social bonds, rank differences, grouping age and presence of horns

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Abstract

To minimise social conflicts between goats and improve pen design, knowledge of factors affecting social distances at the feeding rack is needed. In our study, we investigated the influence of the quality of social bonds, rank differences, grouping age and presence of horns on two types of social distances: (1) the distance goats choose freely at feeding when they have the option of keeping a large distance between each other; (2) the minimum distance possible without agonistic interactions if the goats are forced to feed in close proximity.

We used eight groups consisting of nine goats of different Swiss milking breeds and their crossbreeds that were kept in eight identical pens. Goats in four groups each either had horns or were hornless, and had been grouped either as juveniles or adults (2 × 2 factorial design). Information on social parameters (rank difference, quality of social bonds using the categories ‘‘amicable’’, ‘‘neutral’’ and ‘‘antagonistic’’) was collected for each dyad in the groups’ home pens. For each dyad within a group, we recorded the ‘‘freely chosen distance’’ at a 6-m-long hayrack (experiment 1) and the ‘‘individual distance’’ (=minimum distance possible in which no agonistic interactions occur) when two small mobile hayracks (one for each goat) were moved towards each other (experiment 2). The two types of social distances measured in the experimental situations were analysed using linear mixed-effects models.

The social distances in both experiments were significantly influenced by the quality of social bonds and age at grouping. Dyads with an amicable bond showed smaller distances than neutral or antagonistic dyads (experiment 1: $p = 0.05$, experiment 2: $p = 0.001$), and goats grouped as juveniles kept smaller distances apart than goats grouped as adults ($p = 0.01$ in both experiments). Rank differences and the presence of horns had no significant influence on the sizes of social distances. In conclusion, our results stress the

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importance of a sensible grouping management in goats aiming at grouping the animals early in ontogeny and keeping group composition stable.

Keywords: Goat; Loose housing; Horns; Individual distance; Social bond

1. Introduction

Spacing behaviour among gregariously living animals provides information about the social structure within a group (Kummer, 1970; McBride, 1971). Kummer (1970) stated that social distances between gregarious animals emerge on one hand from forces which repulse conspecifics from each other (e.g. aggression), and on the other hand from forces which attract them to each other (e.g. sexual reproduction). In other words, the social distances observed in a group-living animal will vary between the closest an animal can get to a conspecific and the furthest distance it moves away from its group. Moreover, several studies have discussed and shown that social distances are influenced by factors such as species, sex, behavioural context (e.g. foraging, lying) and the motivational status of the animals (e.g. King, 1965; Kummer, 1970; McBride, 1971; Keeling, 1994; Calhim et al., 2006).

Social distances are strongly linked to the dominance relationships within a group: normally, subordinate animals provoke aggressive reactions from the dominant animal if they reduce the distance to that conspecific below a certain minimum (Leyhausen, 1971; McBride, 1971). This critical distance at which further proximity of the two animals would trigger active displacement behaviour by the higher-ranking animal or passive avoidance behaviour by the lower-ranking one was first described by Hediger (1940), who termed it the ‘‘individual distance’’.

In a spatially unrestricted area such as a pasture, it is reasonable to assume that animals of a group will avoid constantly reaching the individual distance of others. Thus, the size of the distance they choose freely is likely to be greater than the individual distance. In intensive animal-housing systems, the individual distance as defined by Hediger (1940) could be highly significant for the animals because it is linked to the occurrence of agonistic behaviour. On pasture or in other areas with sufficient space, subordinate animals are able to avoid dominant group members and keep the individual distance (Bouissou, 1981; Lindberg, 2001). In a spatially limited area, however, for example in indoor housing, it may not always be possible for animals to respect individual distances, which may result in increased rates of aggressive interactions, as was found for a group of 10 cows (Bouissou, 1981), a group of six Scottish Blackface ewes (Lynch et al., 1985) and a herd of 20 Girgentana goats (Di Grigoli et al., 2003).

Thus, in order to optimise housing conditions in intensive systems, knowledge of the size of social distances – especially the individual distance typical for a given species – as well as of the factors influencing such distances, is necessary. Although available, at least to a limited extent, for different farm-animal species (e.g. poultry: McBride et al., 1963; Keeling, 1994; cattle: Sambraus, 1973; Manson and Appleby, 1990; pigs: McCort and Graves, 1982; sheep: Sibbald et al., 2005), such information is nearly completely lacking for domestic goats.

The aim of the present study was, therefore, to analyse social distances in goats. Of special interest to us were factors found to have an influence on social distances in other farm animals, such as rank relationships (cattle: Syme et al., 1975; Manson and Appleby, 1990; pigs: McCort and Graves, 1982; goats: Loretz et al., 2004), the quality of social bonds between conspecifics of a group (sheep, cattle, donkeys and horses: Wasilewski, 2003), familiarity of group members (cattle: Bouissou and Andrieu, 1977; sheep: Boissy and Dumont, 2002), and the presence of horns (cattle: Graf, 1974; Kimstedt, 1974; Oester, 1977; goats: Loretz et al., 2004). In our study, we experimentally investigated social distances of goat dyads in the context of feeding. We differentiated between the ''freely chosen distance'' (=distance to one another chosen by goats where there was the option of keeping a big distance between each other, experiment 1) and the ''individual distance'' (=where goats were forced to feed in close proximity, the minimum possible distance at which no agonistic or avoidance behaviour occurred, experiment 2). In eight groups differing in terms of grouping age and presence of horns, the quality of the social bonds as well as the rank difference were specified for each dyad. In the statistical analysis, we investigated the effects of the quality of the social bonds, the rank difference, the grouping age, and the presence of horns on both the freely chosen distance and the individual distance.

2. Methods

2.1. Animals and housing conditions

We used eight groups of nine female non-lactating goats that were kept in eight identically equipped pens. The goats had been bought on different Swiss farms and were grouped in May 2005. Four of the eight groups were grouped as juveniles at an age of about 3 months (nearly 1 year before the start of the study), and the other four groups as adult goats (average age per group at grouping: between 2 and 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) according to a 2×2 factorial design. In groups of goats grouped in adulthood, no more than two animals came from the same farm. In groups of goats grouped as juveniles, no more than four animals per group originated from the same farm. The goats were of various Swiss milking breeds (Saanen, Toggenburger, Appenzeller, Chamois Coloured, St Gallen Booted, Grisons Striped and Valais Blackneck) and their crossbreeds. Since the presence of horns is either strongly desired (e.g. Grison striped) or completely undesired (e.g. Appenzeller) by the breeders for certain breeds, it was not possible to include horned and hornless animals of every breed; however, the distribution of the breeds was balanced over the groups as much as possible, also in combination with grouping age.

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) divided by a wooden wall into two compartments of equal size (1.2 m $\times$ 1.5 m). Hay was fed ad libitum in a 3 m hayrack at the feeding place and in an additional 1 m hayrack in the straw area. The animal/feeding-place ratio in the pens was 1:1 with a calculated space of 45 cm per goat. Each pen had one watering place, one licking stone with minerals and vitamins, and a broom. Further structures in the straw area were a 55-cm-high wooden platform (2.5 m $\times$ 65 cm) which goats could stand on or lay beneath, and a freestanding partition in the centre of the pen.

2.2. Quality of social bonds and rank differences

Spatial distribution of the goats in their home pens during lying was used to characterise the quality of social bonds between goats. Each group was observed and videorecorded for 24 h on two different days. Between the two observation days, there were at least 3 days with no video observation. The videotapes were analysed by dividing each pen with a virtual grid into 0.8 m^2 (more or less the space occupied by the body of a lying goat). The position (i.e. square number) of the heads of all simultaneously lying goats was noted in intervals of 10 min. Data were then analysed to determine which dyads were lying in spatial proximity. Provided that two goats were on the same height level without any physical walls between them, the criteria for a dyad to be specified as ''lying in spatial proximity'' were one lying with bodily contact or two lying close with heads in the same or directly adjacent squares but never with bodily contact. All other dyads of simultaneously lying animals were deemed to be lying without spatial proximity. Because there was no high correlation ($r < 0.3$ in seven groups and $r = 0.54$ in one group) between the two parameters ‘‘lying with bodily contact’’ and ‘‘lying close but never with bodily contact’’, they seemed to reflect different qualities of lying relationships. Accordingly, three qualities of social relationships were selected: (a) antagonistic: dyads which never lay in spatial proximity; (b) neutral: dyads which lay close to each other but never with bodily contact; and (c) amicable: dyads which lay with bodily contact. As the data of the 2 days were strongly correlated (r = between 0.5 and 1.00), the recording of 2 × 24 h was judged to be adequate.

The dominance relationships of the goats in each group were evaluated by direct observation during the morning and evening feeding times in the barn. Indicators for dominance/subdominance were displacements effected by a dominant goat and avoidance behaviour by subordinate animals. In a displacement, a goat forced another goat 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 it nor constituted an obvious threat. For each dyad, at least three agonistic interactions with the same goat as the dominant one (=unidirectional relationship) had to be observed to clearly assess the rank relationship. If at least one outcome of such interactions was contradictory (=bidirectional relationship), a dyad was observed until one goat was twice as often clearly dominant over the other. The following rank index was calculated for each goat: number of dominated group members/number of possible rank relationships (eight for a group of nine). In this way, a rank index (between 0 = omega and 1 = alpha) was calculated for each animal and a rank-index difference for the two animals of each dyad. The greater the rank-index difference, the further apart the goats were in the hierarchy of their group. Data for calculating these parameters were collected either shortly before the start of the experiments or during the actual experiments. Furthermore, hierarchies of the groups were checked for linearity using the number of circular triads according to Kendall (1962).

2.3. Experimental room and period

Both experiments were carried out in a separate room away from the home-pen building during the period of December 2005 to May 2006. To avoid separation of individuals from their group, the entire goat group was always taken to this room. The experimental room consisted of a waiting area (2.7 m × 8 m) where all the goats were tethered to avoid agonistic interactions in the group, and a test area (4 m × 8 m). The waiting and test areas were separated by wooden panels and metal barriers. Goats involved in the experiments always had visual and acoustic contact with their group. To enhance feeding motivation for the experiments, goats were given straw only instead of hay the evening and morning before a test. Before starting the experiments, all goats were habituated to the experimental room and the experimental procedure by regularly being taken as a whole group into the experimental room and being allowed to explore the experimental equipment (three to four times for half a day spread over a period of several weeks).

2.4. Experiment 1: freely chosen distance

This experiment lasted 1 day per group. In order to measure the distance freely chosen by two goats when ample feeding space was available, a 6-m-long hayrack was fixed along one side wall in the test area of the experimental room. Each goat dyad of a given group (36 × 8) was allowed to feed 5 min at the hayrack. Every 30 s the distance between the two goats’ heads (measured from central points between the roots of the horns) was estimated (by eye) by means of a scale in 25-cm steps painted on the edge of the hayrack, and was recorded with the ETHO software (non-commercial). Each dyad was tested once, and from the 10 distance values recorded for each dyad an average freely chosen distance was calculated. Because it was teamed up with every other goat of its group for this experiment, each goat was tested several times, but the dyads were chosen in such a sequence that no given goat was ever used twice in a row. Since goats of all dyads were seen to feed simultaneously at a distance of less than 6 m from each other, the rack was judged to be long enough for the goats to choose their distances freely.

The freely chosen distance was successfully determined for 268 dyads of 288. No data could be collected for the remaining 20 dyads: one goat completely refused to participate in the experiment (=8 excluded dyads), and of the other dyads, at least one goat showed too little feeding motivation, and was more interested in the equipment in the experimental room (=12 excluded dyads).

2.5. Experiment 2: individual distance

In the second experiment, we assessed the individual distance, defined as the minimum distance at which two goats fed simultaneously side by side without showing agonistic (=*threats* and *attacks*) or avoidance behaviour. A *threat* was defined as an aggressive interaction without physical contact where one goat levelled her horns/head together with pricked ears towards the other goat, sometimes combined with moving a maximum of one step towards the other goat. An *attack* involved physical contact, with one goat butting and/or chasing the other goat with head/horns. *Avoidance* described the behaviour where one of the two goats refused to feed as long as the other goat was feeding. Two small mobile wooden hayracks with just one 5-cm gap through which to take the hay were put on the wall. The animals of each dyad of a group were allowed to feed at the two hayracks in the test area, in the same chosen sequence as in experiment 1. This experiment lasted for 4 days (=test session) for each group. The individual distance for each dyad of a group was tested out roughly on the first day of a test session, with only the results obtained on days 2–4 being used for purposes of analysis. This approach was chosen with the intention of minimising the number of trials (one trial = one feeding event at a given distance) on test days 2–4 in order to keep the goats' feeding motivation at a similar level throughout the trials.

In order to do this, on day 1 we started with the average distance freely chosen by a goat dyad in experiment 1, and continued to push the two hayracks together in steps of 25 cm (=one distance step). With each step, a goat dyad was given 1 min time to feed (=one trial). After each distance step, both goats were removed from the hayracks, and one hayrack – usually the same one – was pushed closer to the other. Afterwards, first the higher-ranking goat and then the lower-ranking goat were allowed to approach again. The high-ranking goats did not show a preference for one particular hayrack. Thus, their choice did not depend on the hayrack—whether it was moved or not. The distance between the racks was reduced until agonistic behaviour occurred, or until at least one of the goats refused to feed. The minimum distance at which simultaneous feeding was obviously possible without agonistic interactions was noted as the individual distance of day 1. The individual distance was re-measured for each dyad of a group once daily on three consecutive test days (test days 2–4) with slight modifications of the method. On test days 2–4, the starting point for pushing the hayracks together was the individual distance measured on the previous test day. In addition, the goats of a dyad were allowed to feed for 2 min (instead of 1 min) at a given distance, and the behaviour of both goats (threats, attacks, feeding, not feeding due to any reason, not feeding due to avoidance) was continuously recorded in ETHO. Goats standing with their heads within a 30-cm radius of the hayrack and simultaneously chewing hay taken out of the hayrack were recorded as feeding. As the individual distance of a dyad varied slightly from day to day, agonistic interactions or avoidance could occur as early as in the starting trial of a given day (i.e. with the individual distance of the previous test day). In such cases, the hayracks were put two steps (=2 cm $\times$ 25 cm) further apart, and the pushing-together procedure restarted from this point. If the agonistic interactions in the starting trial involved physical contact, the restart of the next trial was usually carried out after a break of at least 30 min, after which all the animals started to feed again. For most of the dyads (95%), no more than three trials were needed to determine the individual distance. If the lower-ranking goat of a dyad showed avoidance behaviour right from the start until the end of a given trial, it was unclear whether the distance between the hayracks was shorter than the individual distance of the given dyad, or the feeding motivation of the lower-ranking goat was too low. To differentiate between these two possibilities, the higher-ranking goat was taken away from the hayrack. If the lower-ranking goat then immediately approached the hayrack and started feeding, her avoidance behaviour was attributed to the inability to respect the individual distance. Sometimes the higher-ranking goat of a dyad changed feeding place. The experiment would then be interrupted briefly and continued after both goats had started to feed again. For the analysis, the average individual distance was calculated for each dyad over the three test days 2–4. For 20 dyads, however, the average individual distance could be only calculated from 2 days' worth of values. This was because outside circumstances (mostly sudden noises) had interrupted the experiment, resulting in missing values.

We managed to assess the average individual distance for 279 dyads out of 288. The same goat that would not cooperate in experiment 1 again refused to participate in this second experiment (resulting in eight excluded dyads), and in one dyad the feeding motivation of one of the goats was generally too low. For the statistical analysis of the individual distance, we only used the data of dyads for which a value was also available for experiment 1 ($n = 267$).

2.6. Statistical analysis

Because of the repeated occurrence of each individual in dyads with all the other animals in a group, the analysis of social interaction matrices posed a special problem (Hemelrijk, 1990). Hemelrijk (1990) proposed an approach for calculating correlations between two social matrices from the same group, correcting for the dependence in the data of the same individual. Here, we needed an extension allowing us to include data from several groups and explanatory variables. Such a data structure may be viewed as a special case of a linear mixed-effects model with crossed random effects (Gill and Swartz, 2001; Li and Loken, 2002).

For each of the two experiments, a separate linear mixed-effects model was calculated using the ''lmer'' method (Bates and Sarkar, 2006) in R 2.3.1 (R Development Core Team, 2006). Residuals were checked graphically for normal distribution, homoscedasticity and outliers. Outcome variables for experiments 1 and 2 were the freely chosen distance (log-transformed) and the individual distance (log-transformed), respectively. The explanatory variables were the fixed-effects quality of social bonds (factor with antagonistic/neutral/amicable levels), grouping age (factor with adult/juvenile levels), the presence of horns (factor with yes/no levels), and the difference in rank index (continuous). We also included the farm of origin (factor with same/different levels) and the interaction of grouping age and presence of horns. The model for experiment 2 also included the freely chosen distance (the outcome variable of experiment 1, log-transformed) as a further continuous explanatory variable. The crossed random effects of the row individual of a dyad and the column individual within the same dyad nested within group were included in both models. The crossed random effects reflected the variability attributed to the general sociability of the row individual and the general effect of the column individual on its dyadic partner.

The models were set up as full models as described above, then reduced by a stepwise backwards method (threshold, $p < 0.05$). The calculation of the p-values of such a model are non-trivial (Bates, 2006), and we followed the recommendations of Bates (2006) and Bates et al. (2006) and used a Markov Chain Monte Carlo method to resample the posterior distribution of the parameter estimates (a method borrowed from Bayesian statistics, e.g. Gelman et al., 2004) to provide confidence intervals for the model parameters. By calculating the percentile X at which the confidence interval borders on the value zero (e.g. the 99% confidence interval), we attributed a p-value to the parameter as $p = 1 - (X/100)$ (e.g. $1 - (99/100) = 0.01$).

Based on binomial distribution, for each initial behavioural reaction in experiment 2 when the distance between the hayracks was shorter than the individual distance of the two goats, a separate linear mixed-effects model with crossed random effects was calculated. In all three full models, the explanatory variables were the presence of horns, grouping age, and the interaction of the presence of horns with the grouping age. As crossed random effects, the row individual of a dyad and the column individual within the same dyad were again nested within the group. Additionally, the dyad was included as random effect because three values of each dyad were used for analysis.

3. Results

3.1. Quality of social bonds, rank index and dominance structures

Out of all 288 dyads (8 groups $\times$ 36 dyads), 23% ($n = 66$) were categorised as amicable, 47% ($n = 136$) as neutral and 30% ($n = 86$) as antagonistic. Percentages for the three categories did

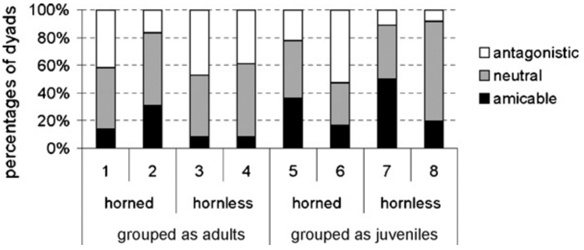

Fig. 1. Percentages of dyads in each goat group (1–8) whose quality of social bond was categorised as amicable, neutral or antagonistic. For each group, 36 dyads represent 100%.

indeed vary from group to group, as shown in Fig. 1. As regards the presence of horns and the age at grouping, there is no obvious pattern. In 42 dyads out of a total of 66, the ‘‘lying time with bodily contact’’ of amicable dyads was less than 10% of the total time where both goats were lying simultaneously. Moreover, eight dyads lay together with bodily contact for less than 20% of the total simultaneous lying time. For the remaining 16 dyads, the percentages of ‘‘lying with bodily contact’’ were between 30 and 85% of their total simultaneous lying time. All three categories of social-bond qualities could be found in dyads coming from the same farm of origin (antagonistic: $n = 10$, neutral: $n = 23$, amicable: $n = 23$) as well as in animals that had not met before purchase (antagonistic: $n = 76$, neutral: $n = 123$, amicable: $n = 43$).

Dominance relationships were clarified for all dyads of each group. Two groups, both horned and grouped adult, showed a complete linear hierarchy (Kendall index = 1), whilst all other herds exhibited a near-linear hierarchy (Kendall index ≥ 0.7). Diversity of hierarchies and Kendall Indices per group are shown in Fig. 2. Neither for the presence of horns nor for the grouping age is there a noticeable uniform pattern in dominance structures. Although it was not possible to check statistically for breed differences, there was no obvious effect of breed on rank status. Of much more apparent importance for the status in hierarchy was the live weight of the goats (correlation of rank index with weight: in goats grouped as adults, $r = 0.7$; in goats grouped as juveniles, $r = 0.5$), which, except for the fairly light Appenzeller breed, was not strongly associated with breed. The breeds and crossbreeds with the highest as well as the lowest rank indices varied in different groups (highest: St Gallen Booted, Chamois Coloured, Toggenburger, Saanen, Saanen crossbreed, Grisons Striped, Peacock crossbreed; lowest: Toggenburger, Appenzeller, Grisons Striped, Saanen and Peacock crossbreed). In 250 of 288 dyads, rank-specific interactions were unidirectional. Twenty-six of the 38 dyads in which bidirectional interactions had been observed were from the hornless groups, and 12 from horned groups. Moreover, 32 of the bidirectional dyads had a rank-index difference of less than 0.4, meaning that the goats of such dyads were relatively close in the hierarchy. In general, all three categories of social-bond qualities could be found in almost every class of rank-index differences (Fig. 3). Clearly, therefore, the quality of a social bond between two goats was not strongly associated with their rank-index difference.

3.2. Experiment 1: freely chosen distance

The range of the average freely chosen distance for the dyads (out of 10 values per dyad) was between 0.44 and 4.75 m (Table 1). Around 50% of the dyads chose an average distance of between 1.00 and 1.99 m, around 27% between 2.00 and 2.99 m, and 14% of over 3.00 m. In 70% of the dyads, the standard deviation of the 10 values from which averages were calculated was between 0.50 and 1.00 m, whilst in 6% of the dyads it was under 0.50 m. A standard deviation of

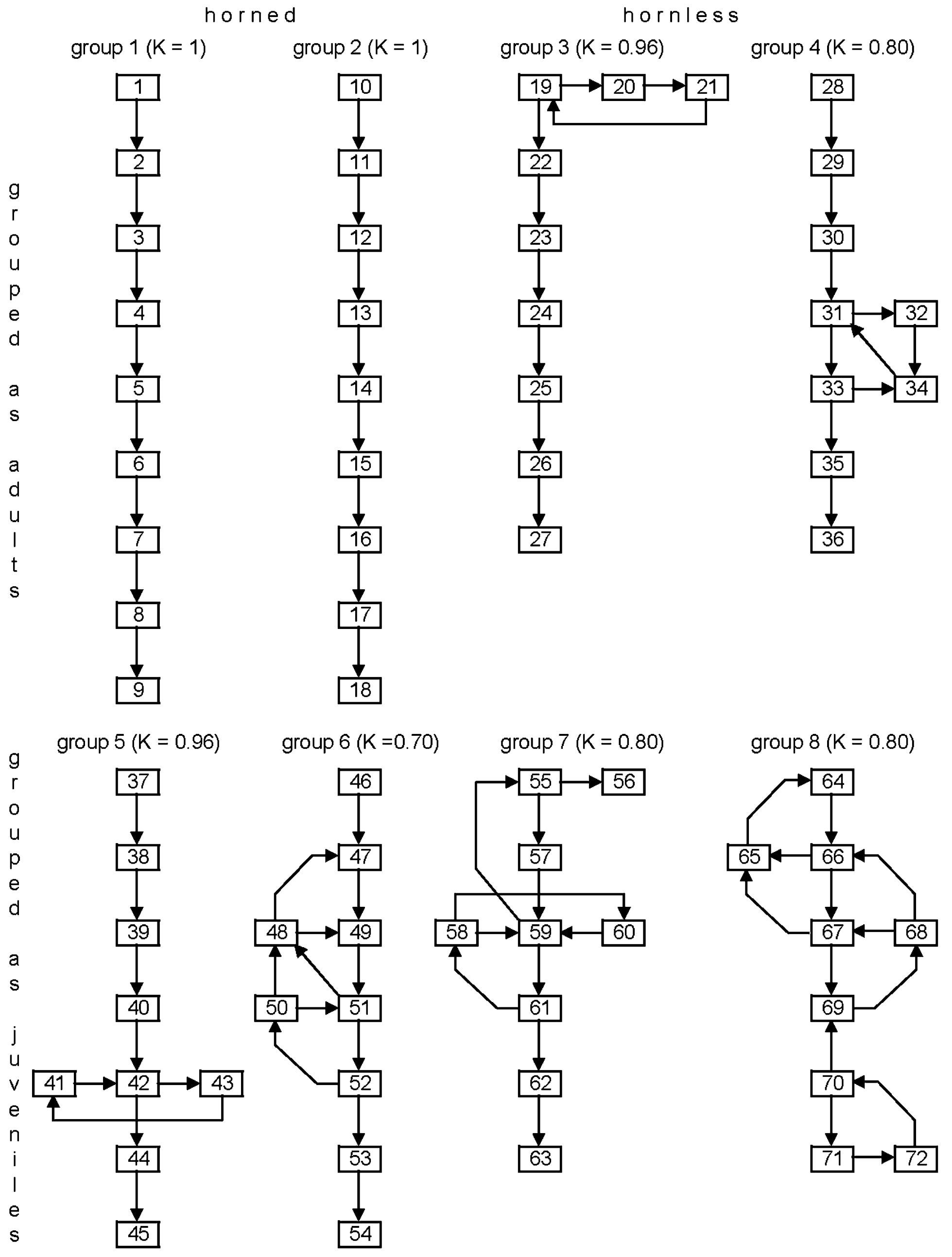

Fig. 2. Dominance structures of the eight goat groups during the experimental phase. Each number stands for an individual goat. From top to bottom, goats of a group are ordered by descending rank indices. Dominance is shown in two ways: firstly by the level of a goat within the structure (e.g. goat 37 of group 5 is dominant over goats 38–45) and secondly by arrows, if the dominance relationships are more complex (e.g. goat 64 of group 8 is dominant over 66 but subordinate to 65), or when two or more goats are on the same level (because they dominate equal numbers of group members but not the same individuals). K = Kendall index (values between 0 and 1, 0 = complete absence of linearity, 1 = linear hierarchy).

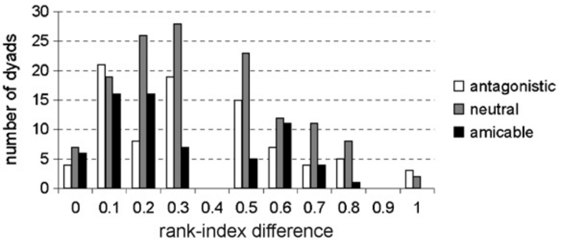

Fig. 3. Distribution of the frequency of dyads attributed to different categories of social bonds (antagonistic, neutral or amicable) in relation to the rank-index difference calculated for a given dyad.

Table 1
Frequencies and percentages of dyads characterised by different sizes of freely chosen and individual distances

Distance classes (m)	Experiment 1: freely chosen distance		Experiment 2: individual distance	
	Number of dyads	%	Number of dyads	%
<0.49	1	0.4	40	14.3
0.50–0.99	18	6.7	97	34.8
1.00–1.49	68	25.4	84	30.1
1.50–1.99	67	25.0	38	13.6
2.00–2.49	40	14.9	10	3.6
2.50–2.99	36	13.4	7	2.5
3.00–3.49	17	6.3	2	0.7
3.50–3.99	13	4.9	0	0.0
4.00–4.49	4	1.5	1	0.4
4.50–4.99	4	1.5	0	0.0
>5.00	0	0.0	0	0.0
Total	268	100.0	279	100.0

more than 1.00 m was found in 24% of the dyads. For the groups, the freely chosen median distance was between 1.20 and 2.50 m (Fig. 4a). This distance was significantly influenced by grouping age and the quality of social bonds: goats grouped as juveniles freely chose smaller distances than those grouped as adults ($p = 0.01$, Fig. 4b), and the freely chosen distance shortened from antagonistic to neutral and from neutral to amicable social bonds ($p = 0.001$, Fig. 4c). No significant effects could be found for rank difference, the presence of horns, the interaction of grouping age $\times$ presence of horns, and farm of origin.

3.3. Experiment 2: individual distance

During the three consecutive test days (days 2–4), the individual distances of 88% of the dyads did not vary more than ±25 cm ($n = 245$). Moreover, 10% of the dyads ($n = 28$) had a range of less than ±50 cm, 1.4% of less than ±90 cm ($n = 4$), and finally 0.6% ($n = 2$) a range of ±130 cm. The sizes of individual distances (=averages of the three consecutive test days) for the dyads were between 0.1 and 4.0 m (Table 1). The individual-distance size range was between 0.5 and 0.99 m for about 34% of the dyads, and between 1.0 and 1.99 m for about 43% of dyads. In 219 dyads (=82%), the individual distance was over 25 cm less than the freely chosen distance in experiment 1. In 41 dyads (=15.5%), the individual distance was nearly the same size

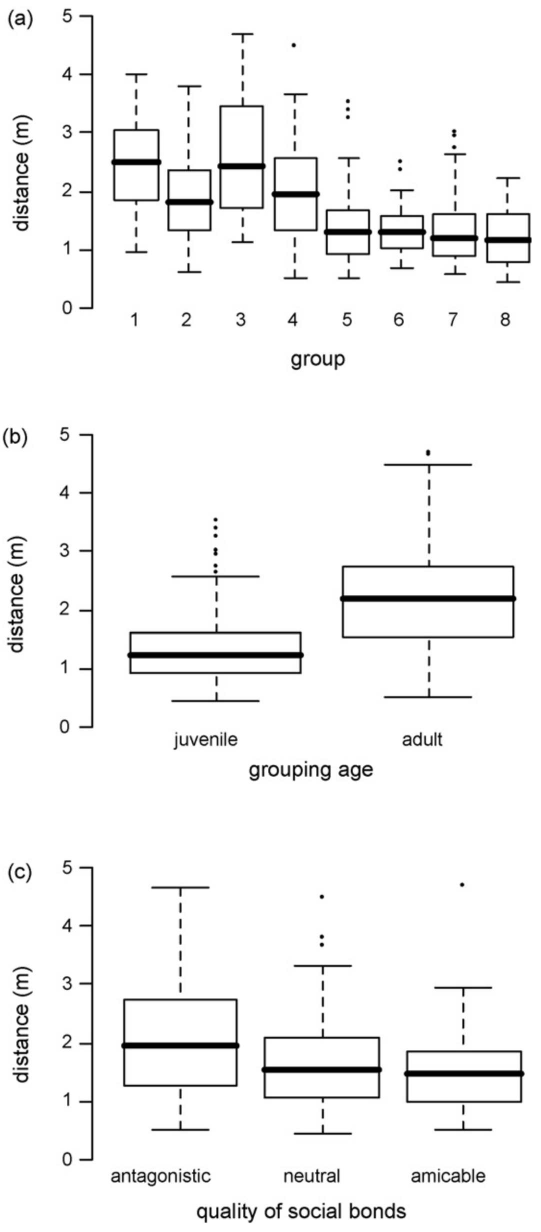

Fig. 4. Experiment 1: freely chosen distance per group (a) in relation to grouping age (b) and quality of social bonds (c).

(±25 cm). Only in a few dyads ($n = 7$) was the individual distance over 25 cm greater than the freely chosen distance.

Median individual distances of the groups were between 0.4 and 1.4 m (Fig. 5a). Dyads of goats grouped as juveniles showed a shorter individual distance than dyads of those grouped as adults ($p = 0.01$) (Fig. 5b). The quality of social bonds had the same effect on the size of individual distance as in experiment 1: distances shortened from antagonistic to neutral to

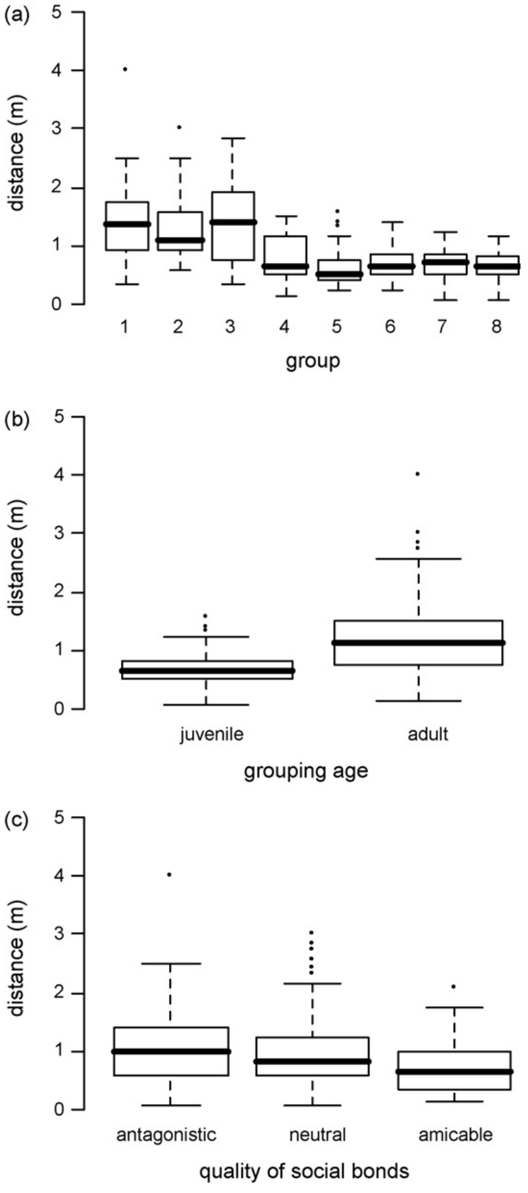

Fig. 5. Experiment 2: individual distance per group (a) in relation to grouping age (b) and quality of social bonds (c).

amicable social bonds ($p = 0.001$) (Fig. 5c). Additionally, the farm of origin was found to have a significant influence on individual distance, as goat dyads originating from the same farm had smaller individual distances than those bought on different farms ($p = 0.001$). Finally, the greater the freely chosen distance of experiment 1, the greater the individual distance in experiment 2 ($p = 0.001$). No significant effects could be found for rank differences, the presence of horns, and the interaction of grouping age × presence of horns.

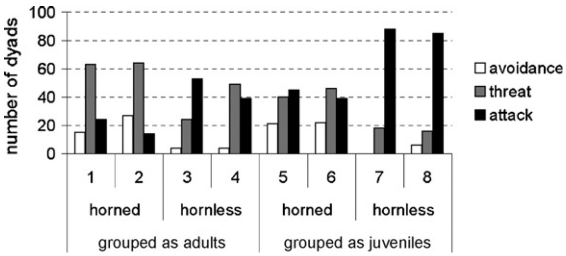

Fig. 6. Distribution of the number of dyads ($n = 817$) within each group (1–8) with regard to the initial behavioural reaction on a given test day (avoidance, threat or attack) when the distance between the two mobile hayracks in experiment 2 was shorter than the individual distance of the dyads.

Fig. 6 shows the distribution of the frequencies of initial behavioural reactions (avoidance, threats and attacks) when the distance between the hayracks was shorter than the individual distance of the dyads. The three initial behavioural reactions were mutually exclusive. With some exceptions (mentioned in Section 2), each dyad is represented by three values. The initial behavioural reaction within a dyad was not necessarily the same on each of the three test days. In general, the behavioural patterns of the two groups belonging to one of the four categories defined by the experimental design (‘‘horned and grouped adult’’, ‘‘hornless and grouped adult’’, ‘‘horned and grouped juvenile’’, ‘‘hornless and grouped juvenile’’) seemed to be consistent. All three initial behavioural reactions were significantly dependent on the presence of horns, and two of them were additionally dependent on the grouping age: avoidance behaviour as well as threats, both reactions involving no physical contact, were most frequent in horned groups (avoidance: $z = 2.71$, $p < 0.05$; threat: $z = 4.39$, $p < 0.0001$). By contrast, attacks (=reactions with physical contact) were significantly more frequent in hornless groups ($z = -5.96$, $p < 0.0001$). Furthermore, in goats grouped as adults, threats were significantly more frequent ($z = 4.80$, $p < 0.0001$) and attacks significantly less frequent ($z = -4.31$, $p < 0.0001$) than in goats grouped as juveniles.

4. Discussion

In this study, we investigated social distances in goats during feeding on a dyadic level. Two types of distances were differentiated: the freely chosen distance when the goats had the option of keeping a large feeding distance between each other, and the individual distance when the goats were forced to feed close to each other. Both types of distances were influenced by the quality of social bonds and the age at grouping, but were not significantly influenced by the rank difference or the presence of horns.

The freely chosen median distance between goats was between 1.2 and 2.5 m, with maximum values between 4 and 5 m in eight dyads. These distances are in a similar range to the distances found in feral goats feeding on pasture (Calhim et al., 2006: 4 m between mothers with kids and females without kids, Shi and Dunbar, 2006: 3.4 m (±1.5 m) for mixed groups of different ages and sexes).

To our knowledge, to date there has been no study measuring sizes of ‘‘individual distances’’ in goats. The median individual distance in our groups was between 0.4 and 1.4 m. Considering the feeding space usual in farming practice (around 30–45 cm per goat: Cull, 1988; Mottram, 1991; Gall, 2001), the potential for social conflicts between goats unable to keep to a sufficient individual distance is obvious, and should explain how low-ranking goats often only have limited access to food owing to high-ranking goats dominating several feeding places at once (Loretz et al., 2004). When drawing final conclusions from the results of our study for the recommendation of feeding-space allowance for goats, however, it must be borne in mind that we measured individual distance in dyads separated from their group. We do not know to what extent the individual distance of a dyad is influenced by the presence of further group members. Moreover, testing whole groups would be very difficult to control. To optimise pen design, we would also need to know how individual distance changes according to social context (e.g. drinking, moving and lying), and which structures in a pen (e.g. separations and different levels) could minimise this distance.

Goats grouped as juveniles freely chose smaller distances than goats grouped as adults (experiment 1). Moreover, dyads from herds grouped as juveniles tolerated a smaller individual distance than dyads of goats grouped as adults (experiment 2). Regarding the effect of grouping age, however, it must be borne in mind that in our experiments, goats grouped as juveniles differed in two more respects from goats grouped as adults which could also have affected social distances: they were younger, and all of a similar age ($\pm$1 month). Possibly, social distances are generally smaller in younger goats and in groups whose members are all of a similar age. Schake and Riggs (1970) e.g. easily placed a group of cows in a dominance order but were not able to do this for a group of calves. From this, the authors inferred that social rank was not yet apparent in young cattle. In our study, however, all of the goats grouped as juveniles were sexually mature at the start of the experiment, as European milking breeds normally reach maturity at the age of 7 months (Gall, 2001). Furthermore, rank relationships were clearly detectable, which would not have been the case if no meaningful ranking order existed. Bearing this in mind, we assume that the differences in distance between goats grouped as juveniles and those grouped as adults can mainly be ascribed to age at grouping, rather than age differences or immaturity.

The results of our study also show that the quality of a social bond plays a decisive role in the size of social distances between goats. Dyads with an amicable bond showed smaller freely chosen distances and individual distances than dyads with either a neutral or antagonistic relationship. Amicable bonds developed in all groups, and – interestingly to us – also in dyads coming from different farms, in goats grouped as adults, and in dyads with large rank differences. Amicable bonds would therefore seem to reflect a particular attraction between two individuals.

All groups had been grouped at the same time, and had therefore spent the same amount of time in their new groups. Growing up together seems to play a significant role in the development of social distances, however, with goats grouped as juveniles in general observing shorter distances to each other than goats grouped as adults. This was also found in cattle, where heifers that were reared together kept closer distances than those that were reared apart (Bouissou and Andrieu, 1977). We also found that goats originating from the same farm accepted smaller individual distances (though not smaller freely chosen distances) than goats from different farms. Possibly they were more familiar to each other from having already spent time together before purchase for our study. Sheep on pasture also grazed closer to familiar companions than to unfamiliar sheep (Boissy and Dumont, 2002). We do not know, however, how close the contact among goats coming from the same farms was before purchase.

Because almost no circular triads appeared, we can consider the dominance structures of our groups as being linear (Kendall, 1962; Appleby, 1983). The differences in rank which we calculated in order to analyse their effect on social distances are therefore likely to correlate strongly with the animals' relative position in the dominance hierarchy. No influence of rank-index difference could be found on either the size of freely chosen or individual distance between goats, however. Results of other studies on spacing behaviour and rank relationships are contradictory: Hinch et al. (1982) did not find a relationship between dominance values and inter-pair distances in groups of heifers, steers and bulls grazing on pasture. Manson and Appleby (1990) investigated distances between dairy cows at a food trough and found cows of similar rank feeding closer to each other than cows of dissimilar rank. Loretz et al. (2004) observed for goats at the feeding rack that on average, higher-ranking animals claimed larger distances between each other (in average numbers of empty feeding places between two goats) than lower-ranking goats did. Sambraus (1973) reported increasing avoidance distances between cattle on pasture with increasing rank differences. None of these studies, however, considered social bonds, and it is unknown how such additional data would have affected their results. In a multivariate approach such as in our study, the effect of social bonds on the size of distances might possibly have been a more important explanatory variable than rank order. Manson and Appleby (1990) even discuss the possibility that affiliate relationships, relatedness and rearing experience might have affected nearest-neighbour distances and choices of neighbours in their study.

Neither freely chosen distances nor individual distances varied as a function of the presence of horns. In fact, in the study of Loretz et al. (2004), hornless goats at a feeding rack claimed larger distances (in average numbers of empty feeding places between two animals) than horned goats. Nevertheless, our data shows that the presence of horns did influence the initial behavioural reactions occurring when the distance between the two mobile hayracks in experiment 2 was shorter than the individual distance of two goats. The behavioural reactions without physical contact (avoidance and threat) were more frequent in horned than in hornless goats, and avoidance behaviour by lower-ranking goats was rarely seen in hornless groups. This pattern is possibly related to the experienced consequences of previous aggressive interactions: a head-butt with horns might be more painful or entail a higher risk of injury than a head-butt without horns. In cattle, Oester (1977) found that threats of horned cows were effective in displacing lower-ranking cows at a greater distance than were those of the same higher-ranking cows after dehorning. Moreover, Graf (1974) found significantly more displacements involving physical contact in dehorned than in horned cows. Menke et al. (1999) observed higher levels of agonistic interactions in hornless than in horned cows. All these results might be evidence that the individual distance is less strictly respected in hornless animals, leading to more agonistic interactions over time as well as more conflicts involving physical contact. This challenges the value of dehorning cattle and goats, as it can be assumed that frequent head butts might also cause injuries (e.g. bruises). Further investigations on the potential health consequences of head butts from hornless and horned animals are necessary.

In conclusion, goats which grew up together and goats with amicable social bonds display smaller freely chosen and individual distances, whereas the presence of horns and rank difference have no significant effects on these distances. In intensive loose housing systems, it is likely to be favourable for the animals if they are able to keep small individual distances. Consequently, sensible grouping management aimed at grouping the animals early in ontogeny and keeping group composition stable would seem to be important for goats.

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