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Effect of density and relative aggressiveness on agonistic and affiliative interactions in a newly formed group of horses

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ABSTRACT

Group housing provides horses with social contact, a lack of which is associated with health and behavior problems. Despite the benefits of group housing for horses, horse owners are concerned about aggression and resulting injuries. This study focused on agonistic and affiliative interactions in a focal group of (originally) 12 horses with short-term and longer term changes in composition, variation in available area, and presence of periparturient mares. Age and density had no significant effect on agonistic or affiliative behavior. However, when agonistic behavior was considered within 3 subcategories, density did have a significant positive effect on contact and threat aggression but not on passive aggression (avoid and displace). When analyzing only the days without the most aggressive horse, age and density had a positive effect on agonistic interactions, and density had a negative effect on affiliative interactions. Days with and without the most aggressive horse showed no significant overall differences in either category of social interactions. Agonistic and affiliative interactions were not significantly correlated, but agonistic interactions had a significant linear and quadratic effect on affiliative interactions. Relative level of aggressiveness was used instead of a formal measure of dominance rank as aggression level is the main issue for horse owners. Comparing interactions with more and less aggressive horses, there was no overall effect for affiliative interactions. However, overall, horses in the focal group were on average 3.7 times more aggressive toward less aggressive horses, compared to more aggressive horses. Relationships between agonistic and affiliative interactions, density, age, and the role of relative aggressiveness are complicated, and more research is needed to clarify the most relevant factors under particular sets of circumstances and their contribution to intraspecific aggression in various contexts.

Introduction

When they are free to choose, horses live in social groups, as observed in feral populations (Feist and McCullough, 1976; Berger, 1977; Salter and Hudson, 1982; McCort, 1984; Linklater, 2000) and semifree populations (Tyler, 1972; Wells and von Goldschmidt-Rothschild, 1979). Stabled horses will make an effort to gain access to a conspecific (Lee et al., 2011; Søndergaard et al., 2011). Lack of social contact has been associated with a higher prevalence of stereotypies (McGreevy et al., 1995; Heleski et al., 2002; Waters et al., 2002; Bachmann et al., 2003; Wickens and Heleski, 2010; Normando et al., 2011), and with undesirable changes in stress-related physiology and behavior (Visser et al., 2008; Yarnell et al., 2015), trainability (Rivera et al., 2002), and reactivity (Lesimple et al., 2011). Löckener et al. (2016) reported that, after 6 months of individual stabling, horses demonstrated a positive cognitive bias when they regained access to social contact and pasturing.

Despite the evident benefits of social contact, group housing of horses is not generally popular in the equestrian industry globally (Hartmann et al., 2012). That said, a large survey in Denmark, Finland, Norway, and Sweden (Hartmann et al., 2015) collected data on group housing and found that only 8% of reported horses were never housed together with conspecifics, 45% were together with other horses part of the day, and 47% were permanently group housed. It is important to note that the high prevalence of group housing in this Scandinavian survey is not reflected in the rest of Europe. Bachmann and Stauffacher (2002) reported on their survey concerning housing of horses in Switzerland that 83.5% of horses

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were housed alone, and 16.5% were reported to live in group housing. A cross-sectional assessment on 150 horse farms in the Netherlands (Visser et al., 2014) showed fewer than 14% of horses were housed with at least one other horse.

These low percentages of reported group housing in non-Scandinavian European countries sit poorly with survey findings from Great Britain (Horseman et al., 2016) and the Netherlands (Visser and Van Wijk-Jansen, 2012), which show that a large proportion of horse owners consider social isolation and continuous housing in individual stables to be main issues for horse welfare. The reasons for rejection of group housing solutions vary. Hartmann et al. (2015) reported that over 40% of respondent horse owners expressed concern over injuries in group housing, difficulties with introducing new horses in an existing group, and group feeding. Yet, studies show no higher prevalence of injuries in group-housed horses (Knubben et al., 2008; Christensen et al., 2011; Keeling et al., 2016; König Von Borstel et al., 2016), despite a higher frequency of agonistic interactions in unstable groups, compared to stable groups (Christensen et al., 2011). Flauger and Krueger (2013) studied 11 groups of domestic horses and found an effect of space allowance on agonistic behavior, especially at higher densities, but frequency and severity of injuries were not measured. Risks during introduction of new horses into an existing group can be minimized by a gradual approach (Hartmann et al., 2011).

Studies on social behavior of animals often look for a measure of rank or dominance hierarchy. However, dominance is a very complex concept, and there is no agreement on how to measure or interpret it (Rowell, 1974; Syme, 1974). Drews (1993) shows the wide variety of definitions that have been used and the very different interpretations of agonistic behavior in relation to dominance across studies, including variation in aggressiveness, absence of aggression, and different ways to calculate consistent asymmetry in wins and losses between individuals. Shizuka and Mcdonald (2015) mention the potential influence of key individuals on the social relationships within the entire group and the importance of sufficient data on all potential dyads.

The present study investigated agonistic and affiliative behavior in a focal case of group-housed horses. To evaluate the concerns of many horse owners faced with the practical challenges of group housing, it studied a group with regular changes in composition, variable space allowance, and the presence of periparturient mares. The relationships between varying stocking density, age, and social interactions were investigated, as well as the associations between affiliative and agonistic interactions. The effect of individual horse's rank of relative aggressiveness on both agonistic and affiliative interactions with higher or lower ranking group members was evaluated. By design, this study did not calculate dominance hierarchy because horse owners are primarily concerned about aggression and resulting injury levels rather than a given social rank.

Material and methods

Observation protocol

Data on the horses were collected on 17 days between February 21 and April 25, 2008 by a single observer. Total observation time was 54 hours and 25 minutes. Horses were fed concentrates from buckets in the morning; amounts and composition varied among the individuals within the group and, for the pregnant mares, their stage of gestation. Hay was available all the time, and water was only unavailable on the 2 last days while horses were at pasture. Observations began at least 15 minutes after the morning feeds had been consumed and the routine cleaning stopped. All horses were fed concentrates again in late afternoon, and all daily observations ended before this feed. Concentrates were distributed individually with horses either being tied by their lead ropes to the wall of the barn or put into a stable during feeding. This made it impossible to observe free social contacts at feeding times. Observations were distributed over the day without a fixed schedule but adapting to ongoing activities. Observation periods generally lasted between 90 and 120 minutes and, on most days, 2-4 observation periods were included. To keep track of all animals, the position of each horse was noted on a map every 15 minutes during observations.

All occurrence sampling (Altmann, 1974) was used to collect data on all behaviors in the ethogram (see Ethogram) on all of the horses simultaneously. Observations were dictated into a tape recorder (for later transcription and data entry) to allow the observer to keep looking at the horses continuously. The observer stood between the arena and the pasture (see Figure 1) and could see all the horses continuously, except on rare occasions when a horse might enter the barn.

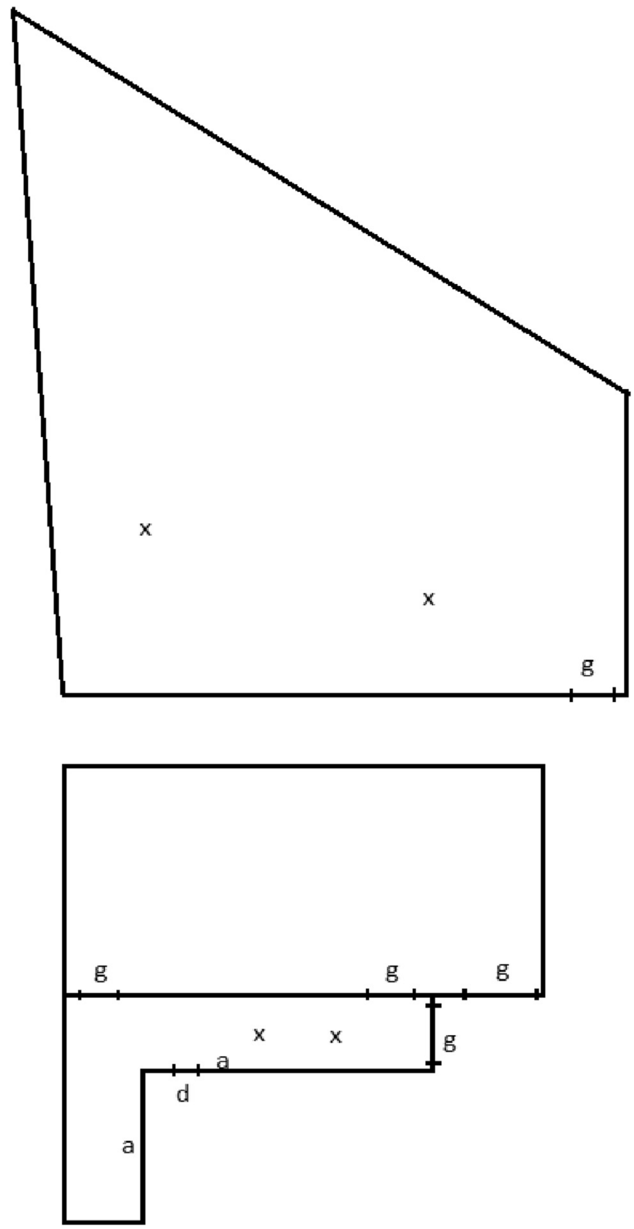

Figure 1. Schematic plan of the site, comprising the L-shaped covered yard, the adjacent uncovered arena and the separate pasture. Indications show hay feeding sites (x), automatic water points (a), gates (g), and the door (d) to an indoor area.

Location

This study was performed at a new facility in Belgium, which was undergoing continued development. It was a multifunctional facility, combining breeding with equestrian education and equine-assisted activities. Besides the observed group of horses, there were 2 breeding stallions singly housed close to the group but never mixed with the group during the study period. Outside horses, brought to the facility for lessons or training, were regularly housed directly adjacent to the group for a few days or weeks.

The housing for the studied horses varied with circumstances (see Figure 1). Except for the last week of the study, they remained mostly in an L-shaped covered yard that had an area of about 160 m^2, consisting of 90 m^2 hard surface and 70 m^2 of sand-covered surface on the short side of the L-shape. The long side of the yard was adjacent to a sand arena of 30 by 15 m. Two separate gates between the covered yard and the arena were opened on occasions, creating a total available surface of 610 m^2. The covered yard and the arena each had an additional separate gate as a main access point. The covered yard was connected by a door to the adjacent barn but preliminary observations showed that the horses seldom went into the barn during the daylight hours. Separated from the arena by a corridor of 5 m, there was a pasture of about 1200 m^2 in area. Because of ongoing fencing and inclement weather during the study period, the horses did not have access to the pasture until April and even then the grass sward was still low and they received supplementary hay in 2 large piles. In the covered paddock, there were 2 wooden hay crates of 1.2 by 1.2 m and 0.75 m high and 2 automatic waterers on the wall of the barn. The yard and the arena had a combination of wooden and electric fencing, whereas the pasture only had electric fencing.

Horses

The studied group initially consisted of 12 horses with a mean age of 9.9 years; details are shown in Table 1. The group was brought together only 2 months before the start of observations, with horses coming from different backgrounds, although some had lived together before. Three of the Irish cobs were pregnant with 2 foals being born during the observation period and the third a few weeks after observations finished. Two of the Irish cobs were sold and left the group on 19th and 20th March, the latter on an observation day. On 3rd April, the Arabian gelding and the Warmblood mare were moved to another location after they had shown aggressive behavior toward the remaining pregnant mare. All pregnant mares were regularly put in an individual box for the night or for several days when parturition was expected and after foaling. On 3rd April, both dams with their foals were returned to the group during the daytime. On 7th April, the mare that had yet to foal was removed from the group because she showed aggression toward the foals who were in the group 24/7 by that time. From that day on, she spent nights in an individual box and daytime in a paddock adjacent to the group. Horses were regularly taken out of the group for lessons or to go to shows. Their periods of absence and distance from the group varied considerably, from 30 minutes right next to the paddock to several days at a show.

Table 1
Details of the original group of horses

Name	Code	Age	Breed	Gender	Remark
Havanna	Ha	29	Warmblood	Mare	
Juan	Ju	15	Arabian	Gelding	
Eniec	En	6	Arabian	Mare	
Impala	Im	14	Arabian	Mare	
Appleby	Ap	10	Irish cob	Mare	Foaled on 19 March
Shana	Sa	9	Irish cob	Mare	Foaled on 14 March, mother of Sissy
Shakira	Sk	4	Irish cob	Mare	Foaled after study
Kyra	Ki	10	Irish cob	Mare	
Magic	Ma	5	Irish cob	Mare	Mother of Shiva
Shiva	Sv	1	Irish cob	Mare	Daughter of Magic
Sissy	Si	5	Irish cob	Mare	Daughter of Shana
Gipsy	Gi	11	Irish cob	Mare	

Ethogram

After preliminary observations, 12 social interactions were selected, based on relevance and ease of detection. Table 2 lists those behaviors and their definitions. Definitions were based on McDonnell (2003), but alterations were made to accommodate practical limitations and optimize scoring efficiency. Social interactions were scored as only events (Altmann, 1974), regardless of their duration. For allogrooming, a bout was considered to have terminated if the horses showed an incompatible behavior, such as moving away or an agonistic interaction, or when they paused for 5 seconds or more.

Statistics

Social interactions were analyzed with SAS 9.2 (www.sas.com), applying Generalized Estimating Equations (GEEs) (Liang and Zeger, 1986; Hanley et al., 2003), correcting for the correlation arising from taking repeated measurements on each horse, using a log link of counts, using Wald-tests for model building, and dropping insignificant covariates. The relative level of aggression was compared using Empirical Bayes' estimates, based on Poisson regression with random effects. The relationships between 3 subcategories of agonistic interactions were investigated, using a multivariate generalized linear mixed model and the subcategories as the response, with unstructured covariance for random effects. Empirical Bayes' estimates were used to evaluate the relative level for each subcategory of agonistic interactions separately, based on linear mixed models with covariates age, density, time, and surface.

Table 2
Ethogram with definitions of agonistic and affiliative interactions scored

Behavior	Definition	Category
Bite	Extension of the neck toward another horse, opening mouth and closing it in contact with other horse	Agonistic
Kick	Rapid extension of one or both hind limbs, hitting another horse	Agonistic
Strike	Rapid extension of one or both front limbs, hitting another horse	Agonistic
Chase	Running after another horse for at least 3 strides, often trying to bite or strike the other horse, while the latter is running away	Agonistic
Threat bite	Extension of the neck toward another horse, opening and closing mouth but no contact with other horse	Agonistic
Threat kick	Rapid extension of one or both hind limbs toward another horse but without contact	Agonistic
Threat strike	Rapid extension of one or both front limbs toward another horse but without contact	Agonistic
Head threat	Rapid extension of the head toward another horse, with ears pinned and mouth closed	Agonistic
Avoid	Horse moving and increasing distance with other horse that is moving closer without actually taking the same place	Agonistic
Displace	Horse moving toward another horse and taking the exact same place after the other horse moved away	Agonistic
Allogroom	Two horses standing next to each other, nibbling or rubbing the other's hair	Affiliative
Approach	One horse moving toward another horse, stopping within touching distance and standing there for at least 5 s, without any agonistic interaction	Affiliative

Reported effects only represent a statistical relationship and not necessarily a causal one.

Any rankings were limited to relative aggressiveness. Evaluations of winners and losers of every interaction and some sort of calculation of a formal dominance rank were not included for 2 reasons. First, rates of agonistic interactions and resulting injuries are the main issues for owners. Second, preliminary observations showed that, in many cases, it would be very difficult to establish winners and losers. Despite engaging in agonistic interactions, both horses would often simply continue with their previous activity, for example, eating hay in the same location, making it difficult to determine a winner. In addition, horses would regularly exchange consecutive agonistic interactions in a relatively brief period, requiring an arbitrary decision on when to group multiple interactions with one overall winner and loser and when to consider them separately.

The weighted average number of horses in the group was calculated by taking the number of group members during each observation session, multiplying it by the time of that session, adding them all up and dividing the sum by the total time. Weighted mean density was derived by a similar calculation. Weighted rates of behaviors per horse per hour were obtained by dividing the total number of occurrences by the total time and the weighted average number of horses.

Agonistic interactions were evaluated overall and as 3 subcategories. Contact aggression included all agonistic interactions with physical contact and chasing because it was considered a high-intensity activity and chasing horses almost always tried to bite their target. Threat aggression was the sum of all threat behaviors. Passive aggression was defined as agonistic interactions without overt physical contact or explicit threat, in particular being avoided or displacing another horse. For every interaction, both actor and receiver were identified. For the behavior "avoid," the avoided horse was scored as the actor and the avoiding horse or horses as the receiver, so the direction of the activity aligned with "displace" and other behaviors. Allogrooming was counted as an interaction for both horses involved if it was reciprocal (which was always the case in this study). Due to their very young age, the 2 foals were not included when analyzing interactions.

Table 3
Dates of observations, number of horses present, durations of observations, available surface, identity of absent horses, and stocking density of horses (foals included)

Date	Horses	Time (min)	Surface (m^2)	Horses absent	Density (horses/100 m^2)
21/02	12	241	160		7.5
22/02	12	154	160		7.5
	11	26	160	Sv	6.86
	12	50	610		1.97
23/02	12	15	610		1.97
	12	210	160		7.5
28/02	12	90	160		7.5
29/02	11	50	160	Ki	6.88
	12	112	160		7.5
	11	35	160	Sv	6.88
	9	48	160	Sv, Ju, En	5.63
	11	30	160	Gi	6.88
6/03	9	150	160	Ap, Sk, Sa	5.63
7/03	12	156	160		7.5
	10	14	160	Si, En	6.25
8/03	11	8	610	Sk	1.8
	12	142	610		1.97
13/03	12	161	160		7.5
	10	19	160	Ju, En	6.25
14/03	11	60	160	Sa + foal	6.88
	10	69	160	Si, Sa + foal	6.25
	10	25	160	Ma, Sa + foal	6.25
	9	57	160	Ju, En, Sa + foal	5.63
15/03	11	120	610	Sa + foal	1.8
20/03	9	30	160	Sa + foal, Ap + foal; Sv sold	5.63
	8	90	160	Sa + foal, Ap + foal; Sv and Si sold	5
28/03	7	40	160	Sk, Ap + foal, Sa + foal, Sv, Si	4.38
	7	79	610	Sk, Ap + foal, Sa + foal, Sv, Si	1.15
29/03	7	104	160	Sk, Ap + foal, Sa + foal, Si, Sv	4.38
	6	48	160	Gi, Sk, Ap + foal, Sa + foal, Si, Sv	3.75
	6	78	160	Ma, Sk, Ap + foal, Sa + foal, Si, Sv	3.75
04/04	10	22	160	Ju + Ha relocated, Sv, Si	6.25
	8	49	160	Sa + foal, Ju, Ha, Sv, Si	5
	10	199	610	Ju, Ha, Sv, Si	1.64
24/04	8	52	1200	Ma, Sk, Ju, Ha, Sv, Si	0.67
	9	128	1200	Sk, Ju, Ha, Sv, Si	0.75
	6	60	1200	Ki, Gi, En, Sk, Ju, Ha, Sv, Si	0.5
25/04	9	245	1200	Sk, Ju, Ha, Sv, Si	0.75

Results

Agonistic interactions

Because available area and number of horses varied regularly, stocking density ranged from 0.5-7.5 horses/100 m^2, with a weighted mean density of 4.75 horses/100 m^2 and a weighted average of 10.16 horses in the group. Table 3 gives an overview of the horses absent during observations, the available surface, and the resulting density. In total, 3047 social interactions were scored during the observation period, with 79.9% of these being agonistic interactions. The weighted rate of agonistic interactions was 4.41 interactions per hour per horse. Table 4 shows the numbers for each behavior of both categories, including the 3 subcategories of agonistic interactions. Figure 2 plots the rate of agonistic interactions as actor for each horse on each observation day. No injuries were observed for any horse, except once when a horse sustained minor abrasions when it slipped while being chased.

When applying GEEs on agonistic interactions as an actor, there was no significant effect of density ($Z = 1.86$, $P = 0.063$), affiliative interactions received ($Z = 1.76$, $P = 0.079$), age ($Z = 1.41$, $P = 0.16$), or agonistic interactions received ($Z = -0.53$, $P = 0.6$). The interaction effect of agonistic and affiliative interactions received was not significant ($Z = -1.8$, $P = 0.073$).

The relationships between the 3 subcategories of agonistic interactions showed high, positive correlations between all subcategories (contact × threat 0.92; contact × passive 0.89; threat × passive 0.89). Age had no significant effect on these subcategories, while density had a significant effect on contact ($t = 2.15$, $P = 0.031$) and threat aggression ($t = 9.62$, $P < 0.0001$) but not on passive aggression ($t = 0.2$, $P = 0.84$).

Affiliative interactions

Applying GEEs on affiliative interactions as actor, there was no significant interaction effect of agonistic and affiliative interactions received and so this was dropped from the model. The final model showed no significant effect of age ($Z = 1.32$, $P = 0.19$) and density ($Z = 0.26$, $P = 0.79$), a significant positive effect of affiliative interactions received ($Z = 8.87$, $P < 0.0001$) and a nonsignificant effect of agonistic behavior received ($Z = -1.84$, $P = 0.066$). Figure 3 plots the rate of affiliative interactions as actor for each horse on each observation day.

Relation between agonistic and affiliative interactions

The overall correlation between agonistic and affiliative interactions as actor was not significant ($r = -0.025$, $P = 0.72$). Using a GEE model with agonistic interactions as the response and affiliative interactions as the covariate, corrected for age and density, there was no significant effect of affiliative interactions on agonistic behavior (Z = −0.03, $P = 0.98$). However, when using the affiliative interactions as the response and the agonistic as the covariate, there was a significant effect (Z = −2.62, $P = 0.0088$) of agonistic interactions on affiliative behavior and even a significant quadratic effect (Z = 2.80, $P = 0.0051$).

Aggressive order and impact on interactions

The relative level of aggression was calculated, using the agonistic interactions as actor, as shown in Figure 4. For comparison, this was repeated with the difference between agonistic interactions as actor minus those received, and these results are shown in Figure 5.

Once this relative order of aggression as actor was calculated, agonistic and affiliative interactions toward more or less aggressive horses were compared. Overall, there was a significant effect of aggression rank on agonistic interactions (Z = 2025, $P = 0.024$). Indeed, on average, a horse was 3.7 times more aggressive to less aggressive horses than to more aggressive horses. For 9 horses, individual results for the effect of aggression rank on agonistic interactions could be calculated, and they were significant for 6 horses, with 4 horses being more aggressive to less aggressive horses (Kyra: Wald chi-square = 104.91, $P < 0.0001$; Juan: Wald chi-square = 74.42, $P < 0.0001$; Havanna: Wald chi-square = 4.96, $P = 0.026$; Shakira: Wald chi-square = 20.87, $P < 0.001$) and 2 being less aggressive to less aggressive horses (Magic: Wald chi-square = 17.63, $P < 0.0001$; Shiva: Wald chi-square = 6.91, $P = 0.0086$).

Analyzing affiliative interactions overall revealed no significant difference between affiliative interactions toward either more or less aggressive horses (Z = −0.26, $P = 0.79$). Individual analyses showed no significant effect for 5 horses, one being significantly more affiliative to less aggressive horses (Shakira: Wald chi-square = 26.1, $P < 0.0001$) and 2 being significantly less affiliative to less aggressive horses (Gipsy: Wald chi-square = 13.73, $P = 0.0002$; Sissy: Wald chi-square = 11.33, $P = 0.0008$).

Effect of absence of most aggressive horse

An analysis was performed on the social interactions of the 4 days when the most aggressive horse was not present in the group. For the agonistic interactions as actor, this revealed a significant positive effect of age (Z = 3.48, $P = 0.0005$) and density (Z = 2.37, $P = 0.018$) but no effect for agonistic or affiliative interactions received and no interaction effect between these 2. For affiliative behavior, there was a significant negative effect of density (Z = −2.14, $P = 0.032$) and a positive effect of affiliative interactions received (Z = 4.41, $P < 0.0001$) but no effect of age or agonistic interactions received. Agonistic and affiliative interactions did not have an effect on each other, regardless of which category was the response or the covariate. When the days with and without the most aggressive horse were compared, there was no significant difference for either agonistic or affiliative interactions as actor.

Table 4
Number of agonistic and affiliative interactions observed for the whole group over the entire time, including the foals

Category	Behaviors	Number	Subcategory	Total	%	Rate/h
Agonistic	Bite	117	Contact aggression	163	6.7%	3
	Kick	3				
	Strike	0				
	Chase	43				
	Head threat	808	Threat aggression	1127	46.3%	20.7
	Threat bite	221				
	Threat kick	92				
	Threat strike	6				
	Displace	43	Passive aggression	1145	47%	21
	Being avoided	1102				
			Total agonistic	2435	100%	44.8
Affiliative	Allogroom	486	Total affiliative	612		11.2
	Approach	126				

Agonistic interactions were divided into 3 subcategories and the numbers, percentage of agonistic interactions, and rate per hour of each subcategory is shown.

Discussion

This project set out to evaluate social interactions between group-housed horses with regular changes in composition and available area, using a real-life situation. The weighted mean density of 475 horses/ha was higher than densities in feral populations. For example, Linklater (2000) reviewed 21 studies of feral and free-ranging horses and reported densities ranging from 0.1 to 35 horses/ha. Two studies on domestic horses had densities in the same range as our group (Weeks et al., 2000; Benhajali et al., 2009), but others had lower densities, within the range of feral populations (Van Dierendonck et al., 1995; Sigurjonsdottir et al., 2003; Van Dierendonck et al., 2004; Heitor et al., 2006a; Heitor et al., 2006b; Jørgensen et al., 2009; Heitor and Vicente, 2010).

Aggressiveness has been positively correlated to dominance rank (Tyler, 1972; Clutton-Brock et al., 1976; Houpt et al., 1978; Houpt and Wolski, 1980; Weeks et al., 2000; Heitor et al., 2006a). However, because of the many reported ways to calculate dominance rank and the lack of a standard, our study calculated only the ranks of relative aggressiveness and compared those results to the extant literature on dominance hierarchies, based on this correlation between aggressiveness and dominance rank. When comparing ranks based only on agonistic interactions as actor with ranking based on the difference between agonistic behavior acted minus received, the present study has revealed changes in the lower ranks, demonstrating how alterations in calculating the social order can lead to differences in ranks.

The weighted rate of agonistic interactions of 4.41 interactions per hour per horse was very close to the median rate of 4.78 in Flauger and Krueger (2013). Benhajali et al. (2009) reported a higher rate of 8.51 for the group with forage. The rate in the present study falls into the category of low aggressiveness that Flauger and Krueger (2013) calculated as between 2 and 7 aggressive interactions per horse per hour. Several studies reported lower mean rates than ours (Clutton-Brock et al., 1976; Keiper and Sambraus, 1986; Rutberg and Greenberg, 1990; Sigurjonsdottir et al., 2003; Rho et al., 2004; Heitor et al., 2006a; Jørgensen et al., 2009) but behaviors included and relevant densities differed.

Age had no effect on agonistic rate as an actor or on the subcategories. Houpt et al. (1978) and York and Schulte (2014) also found no correlation between dominance and age. However, in other studies, dominance rank correlated positively with age (Clutton-Brock et al., 1976; Keiper and Sambraus, 1986; Van Dierendonck et al., 1995; Sigurjonsdottir et al., 2003; Rho et al., 2004; Van Dierendonck et al., 2004; Heitor et al., 2006a; Heitor and Vicente, 2010). Giles et al. (2015) found a quadratic relationship between age and dominance rank.

Density had a borderline positive effect on agonistic interactions and a significant effect on the subcategories of contact and threat aggression but not on passive aggression. Flauger and Krueger (2013) found a negative correlation of −0.3 between log-transformed enclosure size and the rate of agonistic interactions. Jørgensen et al. (2009) reported that higher density was associated with higher number of aggressive interactions. New Forest ponies concentrated more in certain areas in the summer, an observation that was associated with a higher rate of agonistic interactions than in winter (Tyler, 1972). The lack of effect of density on passive

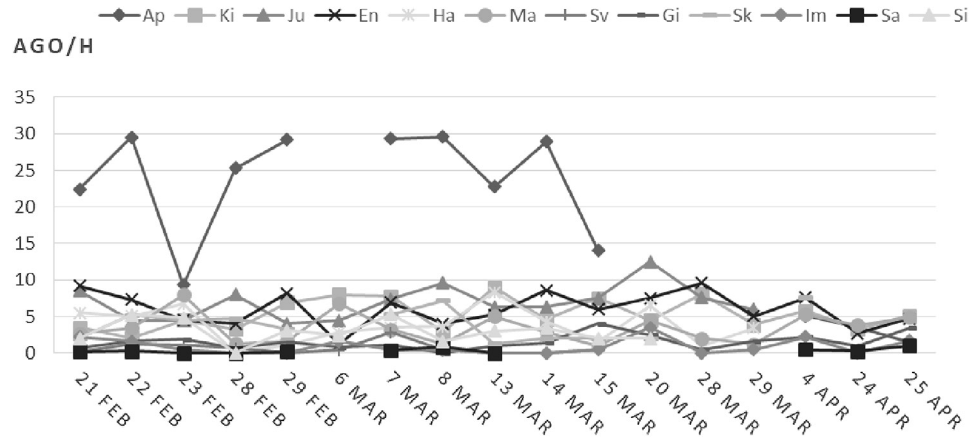

Figure 2. Rate of agonistic interactions per hour (AGO/H) as actor for each horse on each observation day, based on individual time present during observations, foals not included. Ap, Appleby; Ki, Kyra; Ju, Juan; En, Eniec; Ha, Havanna; Ma, Magic; Sv, Shiva; Gi, Gipsy; Sk, Shakira; Im, Impala; Sa, Shana; Si, Sissy.

aggression could indicate that avoidance is influenced less by actual density than by actual distances between horses and the distribution of resources.

The 3 subcategories of agonistic interactions were highly correlated, suggesting the distribution of behaviors within these subcategories is similar among different horses. Likewise, York and Schulte (2014) found no difference between dominant, middle, and subordinate horses and the type of aggression (contact, noncontact, and position aggression). Our rate of passive aggression was comparable to the median rate for submissive behavior in Flauger and Krueger (2013). Despite using a different ethogram to the current one, Heitor et al. (2006a) found a similar distribution of interactions but with somewhat lower percentages of avoiding, biting, threat kick and chase, and a higher percentage of kick. The relative rates of bites and threat bites in the present study are close to those reported by Rho et al. (2004), while Keiper and Sambraus (1986) found a much higher proportion of bites, relative to threat bites.

Horses in our group showed 27.4% of agonistic interactions as actor toward individuals with higher ranks of relative aggressiveness. When compared to reported agonistic behavior toward horses with higher dominance ranks, this is slightly higher than the 19% reported in Weeks et al. (2000) and much higher than the 4.9% reported in Clutton-Brock et al. (1976), the 7.3% in Keiper and Sambraus (1986), the 2.4% in Rutberg and Greenberg (1990), or the 1.9% in Heitor et al. (2006a). This difference could be associated with the availability of only 2 hay crates and our inclusion of all agonistic interactions, regardless of the reaction of the recipient. The considerable individual variation reported here was also found by Weeks et al. (2000).

Shizuka and Mcdonald (2015), comparing 113 studies across taxa, found that the interaction rate of the highest ranking individual had a major impact on the evident dominance hierarchy. Clutton-Brock et al. (1976) mentioned that the most dominant horse in each group showed more agonistic interactions than the other horses. In the present study, comparing days with and without the most aggressive horse revealed no significant differences. However, looking at only the 4 days when the most aggressive horse was absent exposed a significant positive effect of age and density on agonistic interactions and a significant negative effect of density on affiliative interactions. These significant effects were not found in the overall analyses. The most aggressive horse was 10 years old, so her absence could have changed the age distribution because average age was 9.9 years for the complete original group.

Agonistic and affiliative behaviors were not significantly correlated with one another. However, there was a significant linear and quadratic effect of agonistic interactions on affiliative behavior, suggesting a nonlinear relation. The current results also included a borderline positive effect of affiliative interactions received on agonistic interactions as actor and a borderline negative effect of agonistic behavior received on affiliative interactions as actor. If these effects were confirmed by larger studies, this finding would indicate that horses that receive more affiliative interactions show a higher rate of agonistic acts while those who receive more agonistic acts offer fewer affiliative interactions.

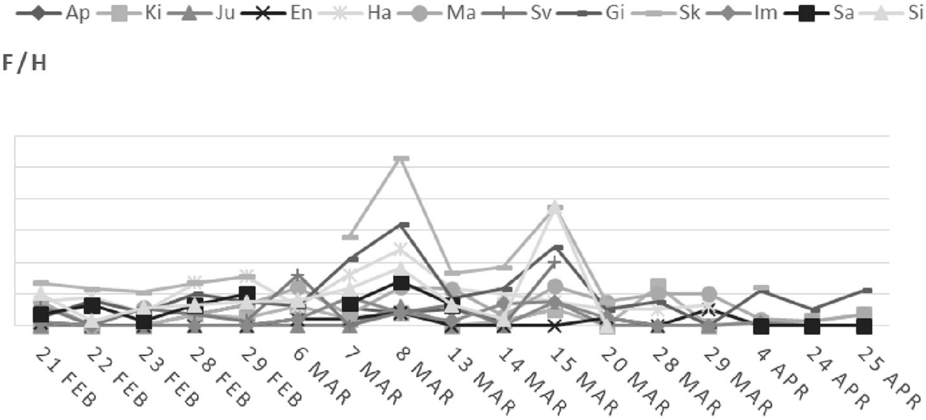

Figure 3. Rate of affiliative interactions per hour (AFF/H) as actor for each horse on each observation day, based on individual time present during observations, foals not included. Ap, Appleby; Ki, Kyra; Ju, Juan; En, Eniec; Ha, Havanna; Ma, Magic; Sv, Shiva; Gi, Gipsy; Sk, Shakira; Im, Impala; Sa, Shana; Si, Sissy.

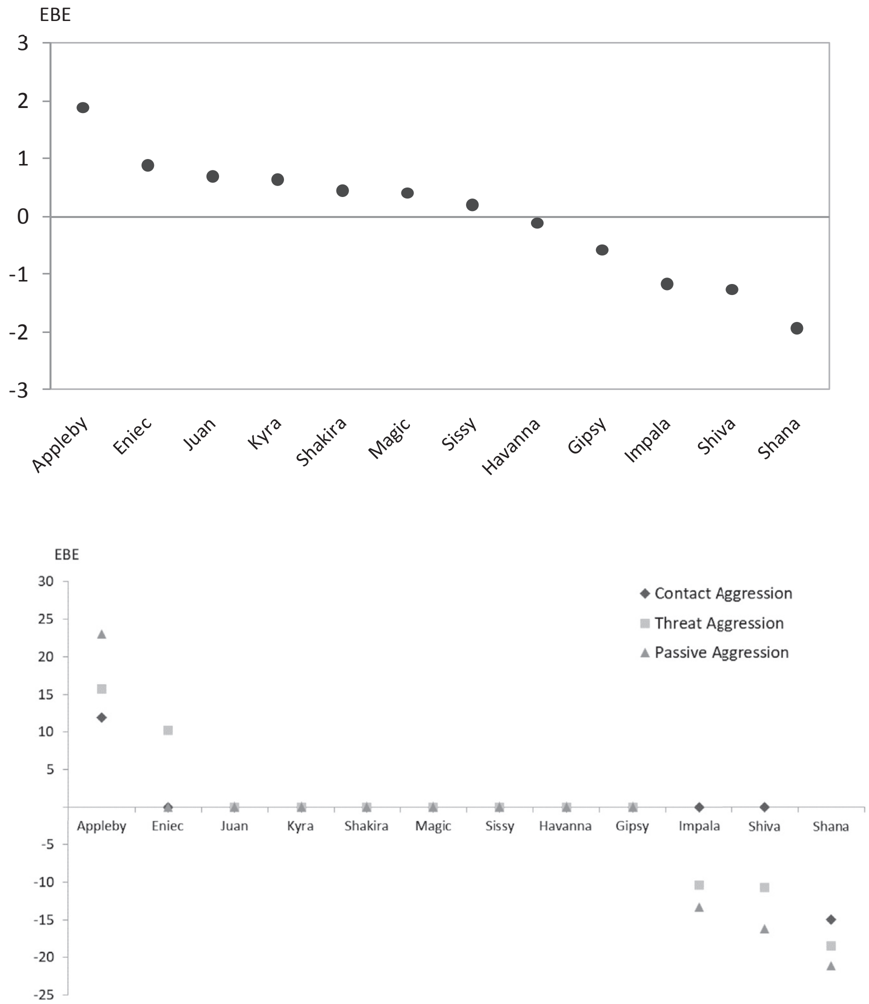

Figure 4. Relative level of aggression, based on Empirical Bayes' estimates (EBE), foals not included. Top graph is based on total agonistic interactions as actor; bottom graph shows results for each subcategory separately.

Rank of relative aggressiveness had no effect on affiliative interactions. Sigurjonsdottir et al. (2003) found no correlation between the number of allogrooming partners and dominance rank but did find a positive correlation between the difference in rank and allogrooming frequency. Heitor et al. (2006b) reported that horses approached lower ranking mares more often than higher

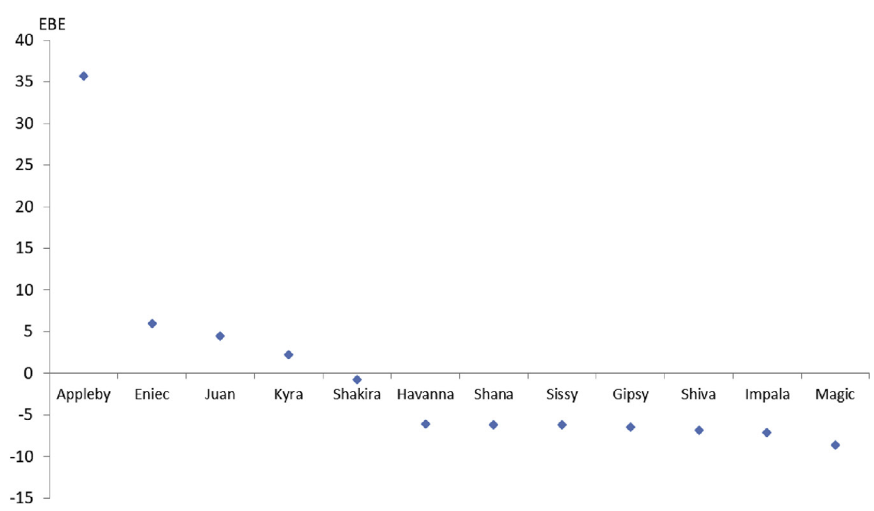

Figure 5. Relative level of aggression, based on Empirical Bayes' estimates (EBE), foals not included, using as basic count the rate of agonistic interactions as actor minus the rate of agonistic interactions as receiver.

ranking ones and that horses with stronger affiliative relations did not show less aggression to each other. In contrast, Van Dierendonck et al. (2004) found no relationship between dominance rank and affiliative interactions. Similarly, Kimura (1998) reported no significant correlation between dominance rank and the rate of allogrooming and Clutton-Brock et al (1976) found no correlation between allogrooming rate and rank, age, or agonistic rate.

The weighted mean rate of affiliative interactions was 1.1 interactions per hour per horse. Because approaching was counted only when a horse moved unequivocally toward another horse and not toward a food source, this system probably underestimated the total number for intended affiliations. Allogrooming was counted for both participants as it was always reciprocated, so the actual number of allogrooming events was only half of the reported measurements, resulting in a rate of 0.44 events per horse per hour, which is higher than the 0.24 in Sigurjonsdottir et al. (2003), the 0.004 in Heitor et al. (2006b), and the 0.13 in Benhajali et al. (2009) but lower than the 0.65 of Clutton-Brock et al. (1976), the 2.7 of Jørgensen et al. (2009), or the 2.6 and 4.8 in Van Dierendonck et al. (2004). Flauger and Krueger (2013) used only approach as evidence of affiliative interactions and reported a median rate of 2.3 approaches per hour per horse, which is tenfold the weighted average rate for approaches in the present study. Our figure of 0.23 approaches per hour per horse is closer to the 0.29 reported by Heitor et al. (2006b).

The rate of allogrooming is influenced by skin irritation, which can show seasonal variations caused by climatic factors, molting patterns, or ectoparasite loads. These factors can differ between horse populations and between years. Studies on Jeju ponies in Korea (Rho and Choe, 2002) and Camargue horses in France (Wells and von Goldschmidt-Rothschild, 1979) mention that allogrooming is more frequent in May than in other months, but they did not observe a full year, with February missing in both studies, and their horses lived in different environmental conditions than those in the present study. Kimura (1998) also reported seasonal variations with the highest rate in August, but observations were restricted to 5 days for both January and August 1988 and 3 days for both May and November 1990. Two studies observed horses over an entire year, in climates comparable to that of the present study: Tyler (1972) studied New Forest ponies in the New Forest and Lamoot and Hoffmann (2004) observed free-ranging Haflinger mares in a Belgian coastal dunes area. Lamoot and Hoffmann (2004) found no seasonal differences for allogrooming, while Tyler (1972) reported 2 peaks in allogrooming rate, one in March-April and a second in July-August. Rates of allogrooming for the New Forest ponies (Tyler, 1972) increased from 0.3 events per hour in February to 0.4 in April. Lamoot and Hoffmann (2004) mention only the overall average rate of 0.33 events per hour.

Comparing different housing areas does introduce potential confounding variables as the resource value of different types of surface may influence the horses' behavior. In the present study, provision of access to the arena increased available surface and provided sunshine and soft ground to roll and lie down but no additional food or water. The shape, complexity, and access points of any area are potentially relevant, as well. The roughage that each area provides can influence what horses do in that space. Benhajali et al. (2009) showed the influence of roughage on social behavior, but Flauger and Krueger (2013) found no difference between paddocks with and without grass. Further research into the importance of the qualities of surfaces and resources is needed.

Allogrooming is usually described as occurring on the dorsal part of the horse, from the neck to the base of the tail and on the shoulder (Tyler, 1972; Clutton-Brock et al., 1976; Feist and McCullough, 1976; Feh and De Mazières, 1993; McDonnell, 2003; Waring, 2003; McGreevy, 2012). In addition, the Irish cobs in this study, but not the Warmblood or the Arabians, were observed allogrooming each other's feathers on the hind limbs. This could be associated with skin irritation under these longer hairs, as indicated by the frequent scratching of this area against elements of the infrastructure.

Comparing studies is sometimes complicated by differences in the behaviors sampled, their definition, and the way in which they have been scored and analyzed. Transparent and comprehensive reporting is crucial to allow meta-analyses and reproduction of results (Pierard et al., 2015). Differences in results are hard to interpret without this.

Conclusion

This study confirmed the feasibility and relative safety of group housing for horses, as already demonstrated in previous projects, even under these challenging circumstances. It highlighted the potential influence of density, age, and top-ranking horse on social behavior within a group, as well as the complicated relationships between agonistic and affiliative interactions. Comparison with existing studies was difficult due to the large variation in results reported in the literature and historic differences in methods applied. Further research will be needed to evaluate the role of different scoring methods and the impact of specific characteristics of each population. In addition, the role of factors such as design of a facility along with the social experience and personality of the horses merits further study.

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Authorship statement: This article was written by all authors who have approved the final version. Marc Pierard designed the protocol and performed all observations. All authors contributed to the analysis and interpretation of the data.

Ethical considerations

This research did not receive any funding. No formal ethical approval was obtained as this was a purely observational study on horses that were kept in good conditions. The practices did respect the ethical guidelines of the International Society for Applied Ethology.

Conflict of interest

None of the authors declared a conflict of interest.

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