How do owners perceive dominance in dogs?

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Abstract

Dominance is a well-established phenomenon in ethology, however, in connection with dogs, the public often misuses the term. A questionnaire study was launched to investigate the validity of owner-derived estimates of dominance in dog dyads sharing the same household (N=1151). According to the owners, dogs rated as dominant (87%) have priority access to resources (resting place, food, and rewards), undertake certain tasks (defend and lead the group, bark more), display dominance (win fights, lick the other's mouth less, and mark over the other's urine), have a certain personality (smarter, more aggressive and impulsive), and are older than their partner dog (all $p<0.0001$). An age related hypothesis has been suggested to explain formal dominance in dogs; however, we found that the perceived dominance status was a better predictor than age status for 11 of the items examined. Results suggest that dog owners' estimates of dominance rank correspond to previously established behavioural markers of dominance. Size and physical condition were unrelated to the perceived dominance. Surprisingly, in mixed-sex dyads, females were more frequently rated as dominant than males. For future studies that wish to allocate dominance status using owner report we offer a six-item survey.

Introduction

"Dominance" when used in reference to dogs, has often been misunderstood in the popular media, which suggests that the public (and therefore the average dog owner) maybe unsure what dominance really is. A dog is often referred to as dominant when it "misbehaves", e.g. jumps on the owner. Such beliefs were based on erroneous models of wolf pack organisation, and have often been used to justify the use of abusive training techniques (Bradshaw, Blackwell & Casey, 2009, 2016b), although negative reinforcement training techniques can cause increased stress, fear and mistrust, and are associated with increased aggression towards other dogs in the household (Casey et al., 2013), and towards human family members (Casey et al., 2014).

Some dog owners describe dogs that often show dominant behaviour towards other dogs as having a "dominant personality". This misunderstanding can be partly explained by the fact that based on a literature review on canine personality, psychologists have identified a broad dimension labelled as 'Submissiveness', and defined it as the opposite of dominance. According to the authors, "Dominance can be judged by observing which dogs bully others, and which guard food areas and feed first. Submission can also be reflected by such behaviours as urination upon greeting people" (Fratkin et al., 2013). Thus, even in the scientific literature there are inconsistencies regarding dominance as a personality trait. Moreover, dominance status has been found to be associated with some personality traits (e.g. aggression towards people) and also with leadership (Bonanni et al., 2010; Ákos et al., 2014), which suggests that certain personality traits affect dominance ranks.

However, according to ethologists, dominance describes long-term dominant-subordinate social relationships within a dyad or group, therefore, it is not a personality trait. Personality is largely independent of context and it is stable over time (Jones & Gosling, 2005), while dominance status depends on the interacting partners.

Dominant individuals usually have priority access to key resources such as food and reproductive partners, due to the consistent winning of agonistic interactions (Clutton-Brock

et al., 1979; Drews, 1993) or deference, during which one individual consistently gives way to another (Lorenz, 1966; Smith & Price, 1973). Based on observations in macaques, de Waal distinguishes agonistic dominance, established through force in agonistic interactions, and formal dominance, based on the acceptance of the dominant individual by the group, signalled through for example ritualistic greetings (de Waal, 1989).

Although dominance hierarchies have previously been described in free-ranging dogs (Bonanni et al., 2010; Cafazzo et al., 2010b; Bonanni & Cafazzo, 2014), in dogs living in packs in enclosures (Range, Ritter & Viranyi, 2015; Van Der Borg et al., 2015; Dale et al., 2017), and in neutered pet dogs at a dog day care centre (Trisko & Smuts, 2015; Trisko, Smuts & Sandel, 2016), the existence and validity of linear dominance hierarchies in these animals is highly debated both by the public and some researchers, mainly because agonistic interactions are rare (van Kerkhove, 2004; Bradshaw, Blackwell & Casey, 2009; McGreevy et al., 2012; Schilder, Vinke & Borg, 2014; Van Der Borg et al., 2015; Bradshaw, Blackwell & Casey, 2016b; Overall, 2016; Westgarth, 2016).

When hierarchy was detected, older dogs were found to be more often dominant than young individuals (Mech, 1999; Bonanni et al., 2010; Cafazzo et al., 2010b; Trisko & Smuts, 2015; Bonanni et al., 2017), therefore Bradshaw et al. (Bradshaw, Blackwell & Casey, 2016a) suggested that a simple rule of thumb could help to explain formal dominance in dogs: “in order to be allowed to stay in the group, perform affiliative behaviour towards all the members of the group older than you are”. However, it remained unexplored whether this hypothesis is a better predictor of formal dominance than dominance displays.

Conflicts between dogs living in the same household have been reported to occur more often between members of the same-sex, and more often involve females than males (Sherman et al., 1996; Wrubel et al., 2011). Mixed-sex dyads are more likely to affiliate and less likely to show dominance than same-sex pairs (Trisko & Smuts, 2015).

In wolves, separate male and female age-graded dominance hierarchies have been observed in captive packs (Packard, 2003). Overall, male wolves were found to be more often dominant and/or leaders of the pack (Clark, 1971; Haber, 1977; Mech, 1999). In one study on free-ranging dogs, a sex age graded hierarchy was found, such that males dominate females in each age class, and adults dominate over subadults, and subadults over juveniles. Adult males were on average larger than adult females, but there were no differences in body size among subadults and juveniles (Cafazzo et al., 2010b).

To address the misuse and misunderstanding of the word “dominance”, we aimed to evaluate whether the dog-owning public recognised dominant individuals in multi-dog households, and what attributes they associated with dominance by a questionnaire study.

Utilizing owner questionnaires in order to determine dominance rank in multi-dog households is not novel (Pongrácz et al., 2008; Pongrácz, Bánhegyi & Miklósi, 2012; Ákos et al., 2014). Pongrácz et al. (Pongrácz et al., 2008) used a four item questionnaire to measure dogs’ dominance status in dyads, and related them to differences in social learning in response to a human or dog demonstrator. Dogs were identified as dominant if they displayed at least three behaviours out of four (barked more/longer, licked the other dog’s mouth less, ate first, and won fights). Dominant dogs were less likely to learn from observing other dogs, more likely to copy a human demonstrator. They also performed better than subordinates in a problem solving task, but only when observing a human demonstrator (Pongrácz, Bánhegyi & Miklósi,

2012). Results indicate that owner questionnaires could be a valid method to determine the dominance rank of individuals within dog dyads, similarly to other dog behaviour studies when the quality of data produced by citizen scientists has proved to be satisfactory (Hecht & Spicer Rice, 2015).

We asked owners of multiple dogs, which of the dogs is dominant according to them, and investigated the relationship between the dogs' ranks, behaviour, and demography based on previous studies (Pongrácz et al., 2008; Pongrácz, Bánhegyi & Miklósi, 2012). In addition, we included other factors, which have previously been proposed to be relevant when measuring leadership and dominance, such as age, sex, size, physical condition, leadership and specific behavioural characteristics, including intelligence, obedience, aggressiveness, and impulsiveness (Drews, 1993; Conradt & Roper, 2003, 2005; Cafazzo et al., 2010b). We investigated which items are related to dominance as perceived by the owners. We also tested the age related hypothesis suggested by Bradshaw et al. (Bradshaw, Blackwell & Casey, 2016a) by comparing which factor best explained behavioural and demographic differences between the dyads, owner reported hierarchical status or age status.

Materials and Methods

Subjects

Between 25th June and 13th August 2017, 1156 owners of at least two dogs filled in a questionnaire in Hungarian, which was advertised in a social media Dog Ethology group. We identified the dogs using their given names, to ensure that no duplicate entries were included in the analysis. After deleting questionnaires with missing data, 1151 responses remained, which detailed owners' responses for unique individual pairs of dogs. Owners indicated the sex and reproductive status of each dog in the dyad, after allocating them to either Dog A or Dog B (based on their own choice). We have no information how owners chose which dogs to compare if they had more than two dogs. Both dogs were male in 23% of the pairs, both were females in 28%, both dogs were neutered in 37% of the pairs, and 30% of pairs were both intact. Counting each dog separately, N = 2302 individuals, there were 47.13% males, and 53.87% neutered individuals.

Procedure

The questionnaire consisted of 21 items (Table 1). In the case of items 1-19, owners indicated which of the two dogs best fits the description: Dog A, or Dog B. Owners could also select "Similar" if both dogs fitted the description, or "N/A". When the owners marked "N/A" we assumed that they could not answer the question as the dog/dogs did not display that behaviour, or that situation did not occur (e.g. the dogs never fight with each other or they do not go for walks together), or they were unsure/did not fully understand the question, or the answer was not known to them (e.g. they could not assess which of the dogs was in better physical condition). Items 2-4 and 6 were the same as those used in (Pongrácz et al., 2008). In the case of items 20 and 21, the owner could also indicate "both" or "neither" dogs (Table 1).

Item number	Short form	Questionnaire 1: Relative characteristics
1	status	Which of the dogs is the "boss" (has a dominant status) to the best of

		your knowledge?
2	bark	When a stranger comes to the house, which dog starts to bark first (or if they start to bark together, which dog barks more or longer)?
3	lick mouth	Which dog licks the other dog's mouth more often?
4	eat first	If the dogs get food at the same time and at the same spot, which dog starts to eat first or eats the other dog's food?
5	reward	If they got a special reward (e.g. a marrowbone), which dog obtains it?
6	fight	If the dogs start to fight, which dog wins more frequently?
7	play ball	If you play with a ball with both dogs, which one retrieves it more frequently?
8	greet owner	When you enter your home, which dog greets you first?
9	walk first	Which dog goes in the front during walks?
10	resting place	Which dog acquires the better resting place?
11	overmark	Which dog marks over the other's urination?
12	defend group	If the dog's group is perceived as being under attack, which dog is in the front?
13	smart	Which dog is smarter?
14	obedient	Which dog is more obedient?
15	aggressive	Which dog is more aggressive?
16	impulsive	Which dog is more impulsive?
17	size	Which dog is heavier?
18	physical condition	Which dog is in a better physical condition?
19	age	Which dog is older?
20	sex	Which dog is male?
21	neutered	Which dog is neutered?

Table 1. Questionnaire items. Owners were asked to fill out the questionnaire for two of their dogs ('A' and 'B') and indicate which dog corresponds better to the description. They could also select "Similar" if both dogs fitted the description or "N/A" if the question did not apply to the dog dyad.

Statistical Analysis

Analyses were performed in SPSS 22.0 and R. Descriptive statistics were calculated for the sample and summarised in the results section. To investigate the certainty of owners in their answers, and the usefulness of each item in terms of whether they might be suitable to scrutinise status differences in behaviour/demographics, we examined which "N/A" and "Similar" proportions were one standard deviation below or above the mean.

Binomial tests using Dominance Status on the full sample

To investigate the owners' responses for each item (1 to 21), we calculated the percentage allocation of the dogs to each possible category: "Differ" (the dogs in a particular dyad differed in that behaviour/characteristic), "Similar" (the dogs' behaviour was similar) and "N/A" (the owner was not able to determine if the dogs differed).

Next, for the dogs that were allocated a "dominant" or a "subordinate" status, based on the response of the owner to item 1 ("Which of your dogs is the boss/dominant?"), binomial tests were used to compare the distribution of observations between the dogs for each of the replies to items 2 to 21. Please note we did not consider dyads where owners indicated that their dogs were "Similar" in dominance status, or where they marked "N/A" (N=148). Then, for items (2-21), dyads were also excluded from the analysis pairwise, if the owner marked them as "Similar" or "N/A" in that particular behaviour or characteristic (sample sizes are indicated in Figure 1 for each item).

We examined whether each behaviour/physical attribute was equally likely to occur in dominants and subordinates (derived from item 1) using a two-tailed test. We lowered the p level to 0.0023 from 0.05 as suggested by a Bonferroni correction for the 22 comparisons.

Binomial tests using Age Status on the full sample

We then repeated the binomial analyses but instead of dominance status, we used the response of the owner to Age (item 19, "Which of your dogs is older?"), to assess differences between dogs allocated an "older" or "younger" status (dogs which were "Similar" in age, or that were marked "N/A", N=72, were excluded). Next, we used two-sample tests for equality of proportions with continuity correction in order to determine which factor (Dominance status or Age status) best explained the behavioural and demographic differences between the dogs.

Binomial tests on the mixed-sex and same-sex dyads

In order to examine any effect of the dyad composition on dominance status allocation, we created subsets of data including mixed sex dyads (N=491), and same-sex dyads (N=512), and ran additional binomial tests to inspect possible associations for items 2 – 21. We again adjusted for multiple comparison using Bonferroni correction, and lowered the significance level to 0.0025.

Difference in ranks

We also aimed to examine how large the difference was in ranks between same-sexed, mixed-sexed, neutered, and intact dyads. For more details please see Supplementary Information, page 4-6.

Results

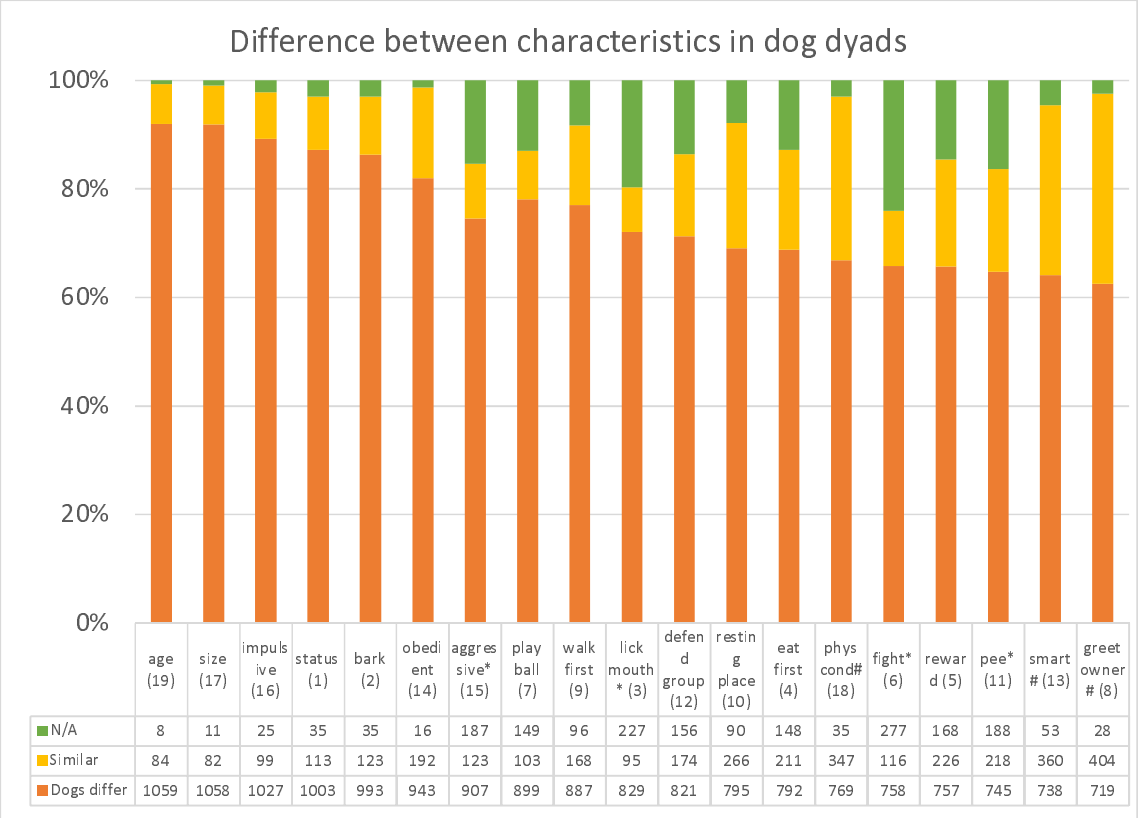
Descriptive statistics

Eighty-seven percent of owners indicated that their dogs differed in their social status, 10% perceived them as similar, and 3% marked the question as "N/A" (Fig. 1).

Approximately third (30.1-35.1%) of the dyads were reported to be similar in greeting the owner, smartness, and physical condition, but only 7.1-7.3% of owners claimed that their

dogs were similar in size and age (percentages are higher and lower than the mean(16.1)±SD(8.6), Fig. 1).

Every 4th-5th owner did not link a particular dog to the items lick mouth, fight, overmark, and aggressive (16.2-24.3%), but most respondents (98.6-99.3%) assessed differences between their dogs regarding size, age and obedience (percentages are higher and lower than the mean(8.8)±SD(7.3), Fig. 1).



	age (19)	size (17)	impulsive (16)	status (1)	bark (2)	obedient (14)	aggressive* (15)	play ball (7)	walk first (9)	lick mouth* (3)	defend group (12)	resting place (10)	eat first (4)	phys cond# (18)	fight* (6)	reward (5)	pee* (11)	smart # (13)	greet owner # (8)
N/A	8	11	25	35	35	16	187	149	96	227	156	90	148	35	277	168	188	53	28
Similar	84	82	99	113	123	192	123	103	168	95	174	266	211	347	116	226	218	360	404
Dogs differ	1059	1058	1027	1003	993	943	907	899	887	829	821	795	792	769	758	757	745	738	719

Figure 1. Descriptive statistics of the sample. Items in which owners responded that the two dogs were "Similar" more often than 1 SD above mean (>24.7%) are indicated with #. Items where owners indicated "N/A" more often than 1 SD above mean (>16.1%) are marked with *. Item numbers are in brackets. Sample sizes are indicated in the table below the graph.

Binomial tests using Dominance Status on the full sample

We tested which items (from items 2-21) were associated with the perceived dominance rank (item 1). The binomial tests revealed that dogs the owners considered as dominant (i.e. the "boss" at home, item 1) bark sooner/more, lick the other's mouth less, eat food and obtain rewards first, win most fights, and walk in the front during walks. They more often obtained better resting places, marked over the other's urination, and defended the group in case of perceived danger. "Dominant" dogs were also reported to be smarter, more aggressive, and more impulsive, than their partner dog, and they were more often the older dog in the dyad ($z=>|5.03|$, $p < 0.0001$; see Fig 2 and Supplementary Table S1 for an overview of the results).

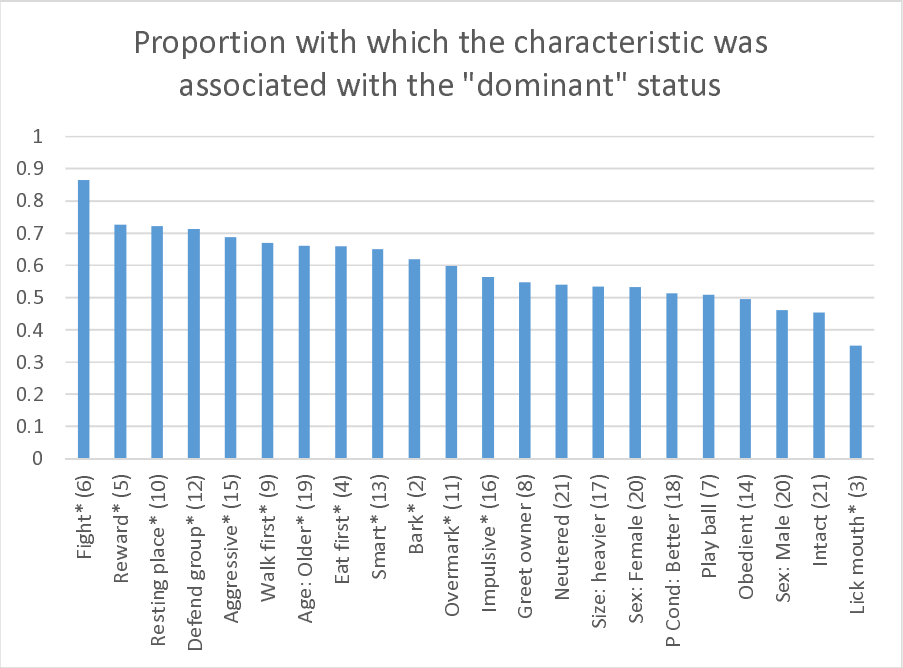


Figure 2. Association between the "dominant" status and the other items (item numbers are brackets). * indicates that "dominant" status was associated with the item after Bonferroni correction (for the Binomial tests all p values are ≤ 0.0022). See Table S1 for more statistical results.

Binomial tests using Age Status on the full sample

Twelve items predicted Age status. Six in the same direction as the "dominance" status (bark, lick mouth, fight, resting place, defend group, and smart), one in the opposite direction, as owners found older dogs to be less impulsive, but „dominant" dogs more impulsive.

Age but not dominance predicted five items. Older dogs bark more, play with the ball less, greet the owner less, are in worse physical condition, are larger, and are less often intact than their partner dog, according to the owners ($p < 0.001$). Dominance status was a stronger predictor of 11 items in comparison to age status (For statistical details see Table S1).

Binomial tests on the mixed-sex dyad sample

In mixed-sex pairs (N = 491), females were more often dominant over males (57% females, binomial test $z = 3.249$, $p < 0.001$). There was also a higher proportion of neutered individuals compared to intact (58.7% neutered). As in the full sample, dominant individuals were more often older than the subordinates (N=296 dyads, 65% older, binomial test $z = 6.38$, $p < 0.001$). All of the remaining items that were found to describe individuals rated as dominant in the full sample were also significant after Bonferroni correction in the mixed pairs subsample, apart from overmark which were the same between "dominant" and "subordinates".

However, when "dominants" were more closely examined regarding their sexes, we found that when a male was dominant in a mixed-sex pair, he more often marked over his female partner, defended the group in case of perceived danger, and he was often larger in size than

the female subordinate. When a female was the dominant individual, she was more often neutered than when the male was the dominant (female neutered 72%, male neutered 51%). Please refer to Supplementary Table S2 and S3 for more information.

Binomial tests on the same-sex dyad sample

In same-sex pairs (N = 512, 48.5% neutered) there was no significant difference between the number of neutered and intact dominant animals ($z = 1.86$, $p = 0.063$). "Dominant" individuals were again more often older than "subordinates" (N=319 dyads, 67% older, binomial test $z = 7.38$ $p < 0.001$, Fig. 3).

The items that best described dominant individuals in the full sample remained significant in the same-sex pairs subsample, apart from the item impulsive which was not different between subjects rated as dominants and subordinates. More results can be found in Supplementary Table S2.

Difference in ranks

The dyad that showed the greatest relationship difference between the "dominant" and "subordinate" individual (and therefore the clearest status difference) was in a mixed sex dyad when an intact male was dominant over an intact female. For more results see Table S4 and Fig S1 in the Supplementary Information.

Discussion

Our study opens up the way for a better understanding of how dominance in dogs is perceived by owners. Results suggest that dominance hierarchies are recognizable among dogs living in the same household by the owners, and the characteristics of the social relationships are associated with multiple factors, such as personality, sex, and age.

Eleven different dog-dog or dog-owner oriented behaviours, five behavioural/personality traits and five demographic factors were examined. Eighty-seven percent of owners labelled one of their dogs as dominant. We found that within dyads, dogs rated as dominant usually (1) have priority access to certain resources such as food, rewards, resting places; (2) are perceived as undertaking specific tasks, such as "guarding" with barking more, walk in the front during walks (i.e. "leads" the group), defend the group in case of perceived danger; (3) display dominance: more frequently accept that the other dogs lick their mouth, win more fights, mark over the other's urination; (4) have characteristic personality traits: smarter, more aggressive, more impulsive; and (5) are older than subordinates according to the owners.

Physical condition, obedience, sequence of greeting the owner and retrieving balls were unrelated to the perceived dominance. Results were the same in the full sample and in the subsamples of mixed-sex and same-sex dyads, except for urination, which did not differ between dogs rated as dominants and subordinates in mixed-sex dyads.

Thirteen percent of owners were unable to determine a clear rank order between their dogs. This may be because: (1) dogs have a non-interactive relationship (partners peacefully co-exist without social interactions, i.e. they avoid each other) or 'egalitarian' relationship (partners affiliate regularly, e.g. play with each other, without agonistic behaviour or exhibiting dominance) (Trisko, Smuts & Sandel, 2016); (2) the dogs may not have lived together long enough to form a clear rank order; (3) the owner might actively work against the

dogs displaying dominance behaviour (e.g. chasing away the dominant dog from the better resting place, not allowing the dominant to feed first, preventing fights, and favouring the loser dog, etc.); (4) the owner does not accept/understand the concept of dominance.

As predicted, older individuals were more often allocated a higher status by owners in the full sample, and in both subsamples (mixed and same-sex pairs). Previous studies in wolves, free ranging dogs, and pet dogs confirm that older individuals are more likely to be dominant and/or leaders (Peterson et al., 2002; Bonanni et al., 2010; Cafazzo et al., 2010b; Trisko & Smuts, 2015; Cafazzo, Lazzaroni & Marshall-Pescini, 2016; Bonanni et al., 2017). In addition, older dogs have usually stayed within the family home for longer than younger dogs, a factor that probably contributes to their level of experience and knowledge. However, in contrast to the age related hypothesis, which suggests that age explains formal dominance in dogs (Bradshaw, Blackwell & Casey, 2016a), we found that dominance status, as perceived by the owner, was a better predictor than age status for 11 of the items examined.

Items that were previously associated with perceived dominance, such as bark first or more often, lick mouth (reverse coded), eat first and fight (Pongrácz et al., 2008), predicted the owner's estimate of dominance in the present study too. Note however, that 28-34% of owners indicated that their dogs do not lick each other's mouths and never fight with each other or are similar in this regard; therefore, these items are not predictive in a third of the population. Relatively infrequent fights are in harmony with the finding that aggression in companion dogs is rare and usually of low intensity (Trisko & Smuts, 2015).

Items related to obtaining resources (food, rewards, resting places) square with the classical definition of dominance (Schjelderup-Ebbe & T., 1922), which maintains that dominant individuals have priority access to resources. However, items that examined control over other resources, such as a ball and the owner (greeting), did not differ between "dominant" and "subordinate" dogs.

Mouth licking, overmark, and win fights are related to dominance/submission displays established through ethological fieldwork that are easy to observe for lay people.

Mouth licking was more often observed among subordinate dogs. This behaviour may be derived from food begging behaviour and is part of the submission ritual, observed most often during greetings, both in wolves (Schenkel, 1967; Cafazzo, Lazzaroni & Marshall-Pescini, 2016), and dogs (Cafazzo et al., 2010b; Van Der Borg et al., 2015).

Owners indicated that dogs higher in status overmark lower ranking dogs. One previous study reported that dogs' rate of countermarking indicated high status in both male and female dogs (Lisberg & Snowdon, 2011). In the current study, detailed analysis showed that "dominants" in same-sex dyads mark over "subordinate" urinations more often than "dominants" from mixed-sex dyads. However, when a male was rated as dominant in a mixed-sex pair, he more often marked over his female partner (and also defended the group in case of perceived danger). Results suggests that for females intra-sexual competition may be prioritised over intersexual competition.

Fighting between dogs in the same household has been interpreted as disputes over dominance by several authors (Landsberg, Hunthausen & Ackerman, 2003; van Kerkhove, 2004). In free-ranging dogs, dominance relationships were based on agonistic interactions, and were correlated with priority access to food (Cafazzo et al., 2010a). Aggression levels are likely to increase when there is direct competition for resources (which can include the

owner), and previous experiences have led to success in agonistic interactions. In addition, aggression towards other dogs in the household has been associated with increasing age in previous studies, number of dogs in the household, and with the type of training techniques used by the owner (Casey et al., 2013).

Items theoretically concerning behaviours viewed by humans as "responsibilities that come with a higher status" were also associated with dominance. According to the owners, dominant dogs defend the group during perceived or actual threats, bark more when a stranger comes to the house, and lead other dog/s during walks. Leadership, in contrast to dominance, cannot be forced, as it requires followers who choose to follow for their own benefit. More technically, leadership is a non-random differential effect on group activities. Using directional correlation analysis on high-resolution spatio-temporal GPS trajectory data from a group of six dogs, leader and follower roles in dyads were found to be dynamically interchangeable. However, over a longer timescale, leader and follower roles became more defined (Ákos et al., 2014). In free-ranging dogs, leaders were more likely to receive submissive displays in both greeting ceremonies and in agonistic contexts from many partners, and leadership was also dependent on group composition (Bonanni et al., 2010), suggesting that it is not an inherent characteristic of individuals, similarly to dominance.

"Dominance" associated with certain personality traits, too. Dogs rated as dominant were reported to be more aggressive, impulsive and smarter than subordinates were. In a previous study aggression towards people, controllability, and leadership were also associated with dominance (Ákos et al., 2014).

Aggressivity increase the likelihood of exhibiting dominance via agonistic interactions. Depending on whether dogs in the dyad affiliate or not, they can form formal or agonistic dominance (see also (de Waal, 1989)). Unfortunately in our study affiliation was only measured using the item "lick mouth", which is also a signal of submission, therefore we could not distinguish between these two dominance types (Trisko & Smuts, 2015).

Impulsivity, without utilising a multi-dimensional assessment, (Wright, Mills & Pollux, 2011) is difficult to distinguish from aggression, although it can alternatively co-vary with anxiety too (King et al., 2016). The fact that impulsivity did not differ between dominant and subordinate individuals in same-sex pairs indicates that intrasexual competition may influence impulsivity in dogs, or there is a sex difference in impulsivity.

'Smartness' could be an important mediator of both dominance and leadership. In smaller packs (i.e. nuclear families in wolves), apparent dominance can be observed as the parents exert parental guidance over their offspring. Mathematical models predict that the fitness of group members increases if the dominant individual is experienced with the group's surroundings, thus it is advantageous for the group if the knowledge of dominant individuals exceeds that of other members (Conradt & Roper, 2003, 2005). Based on the data on free-ranging dogs, Bonanni et al. (Bonanni et al., 2010) assumed that age and experience play a part in maintaining the rank of dominants. If the owner's estimate of dog-smartness is a good reflection of the dog's knowledge and cognitive skill, the association between leadership and dominance could be based on the underlying association between smartness and dominance. Alternatively, subordinate dogs may not show their full potential as they are stressed and/or inhibited by the dominant, and therefore owners view them as less smart.

Females were perceived by owners as more dominant than males in mixed-sex dog dyads. This is surprising, because both n free-ranging dogs and wolves males are usually dominant over females (Clark, 1971; Haber, 1977; Mech, 1999; Cafazzo et al., 2010a). However, sex had no clear effect on dominance in a family pack of captive arctic wolves, although sex-separated linear hierarchies showed a stronger linearity than female-male hierarchies (Cafazzo, Lazzaroni & Marshall-Pescini, 2016). One reason why female dogs dominate males more often in mixed-sex dyads could be due to the fact that dominant females were more often neutered than dominant males. Previous studies have determined that hormonal activity influences inter-dog aggression (Sherman et al., 1996) and aggression has been found to increase in neutered females (Wright & Nesselrote, 1987). Females were able to dominate males even though in 59% of the dyads they were smaller in size than their male partner.

Although McGreevy et al. (McGreevy et al., 2012) suggested that mixed-sex dog dyads tend to have more defined relationships, in comparison to same-sex pairs, we did not find any differences in the behaviour of dominants in mixed-sex and same-sex pairs, apart from in the proportion of dogs that marked over subordinates, and the number of neutered individuals. Dominant individuals were more often neutered in mixed-sex dyads in comparison to same-sex dyads. This is not surprising when we consider the difficulties of keeping intact males and females together in the same household.

Our study has several limitations. We did not measure the dominant behaviour of the dogs, only the dominance perceived by the owner of the dogs. Therefore we have no information about whether the ratings of dominance and behaviour reflect actual rates of behaviour. Moreover, only relationships between single dyads were examined. Previous work has determined that individuals can and do establish different types of relationships including "friendships", when paired with different individuals, and these relationships can also change over time, suggesting high social complexity in dogs (Trisko, Smuts & Sandel, 2016). Future studies should examine how individuals' relationships differ within multi-dog households. We also did not include items on affiliative behaviour in the questionnaire, so it was not possible to classify the dominance relationships further into formal (affiliation and dominance), and egalitarian (affiliated with no dominance) types (Trisko, Smuts & Sandel, 2016). We were also not able to examine breed differences in dominance relationships. Dog breeds and breed groups differ greatly in morphology and typical behaviour (Turcsán, Kubinyi & Miklósi, 2011; McGreevy et al., 2012; Starling et al., 2013), therefore types of relationships may also be highly dependent on the breed composition of the group (van der Borg, Schilder & Vinke, 2012). Finally, due to time constraints, we applied single item statements to describe personality traits.

Conclusion

Owner estimates of dominance rank corresponded to previously established behavioural markers of dominance displays, which supports that dominance relationships are robust and well-perceivable components of companion dog behaviour and owner-derived reports about dominance ranks have external validity (in pre-schoolers see (Hawley, 2002) for similar results).

Based on our data, we suggest that future studies that wish to allocate dominance status using owner reports, should include the following six items: Which dog starts to eat first, obtains the

reward, walks at the front, acquires the better resting place, defends the group, and is more aggressive. Asking which dog wins fights or which dog licks the mouth of the other might also be useful, as both were highly predictive of owner perceived social status if they did occur, in approximately 70% of cases.

Acknowledgement

We thank Borbála Turcsán for her contribution to the design of the questionnaires, and for her helpful comments on an earlier version of the manuscript. Ivaylo B. Iotchev helped with the literature search and discussions during the manuscript writing.

Ethical statement

The procedures applied complied with national and EU legislation and institutional guidelines. Participants were informed about the identity of the researchers, the aim, procedure, and expected time commitment of filling out the survey. Owners filled out the survey anonymously; therefore, we did not collect personal data. Participants could at any point decline to participate.

Funding statement

This project has received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation program (Grant Agreement No. 680040), from the János Bolyai Research Scholarship of the Hungarian Academy of Sciences, and from the ÚNKP-Bolyai+ Scholarship for EK.

Data Accessibility

The datasets supporting this article have been uploaded as part of the Supplementary Information.

Competing Interests

The authors declare that they have no conflict of interest.

Authors' Contributions

Enikő Kubinyi – experimental design, data collection, explorative analysis, writing, final analysis

Lisa Wallis – final analysis, writing

Supplemental Information

Supplemental Tables, Figure and Analysis about "Difference in ranks between same-sexed, mixed-sexed, neutered, and intact dyads"

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