How do owners perceive dominance in dogs?

Enikő Kubinyi*, Lisa Wallis

Department of Ethology, Eötvös Loránd University, Pázmány Péter sétány 1/c, 1117, Budapest, Hungary

Keywords: dominance, submission, deference, domestic dog, intraspecific communication, animal personality

1. Summary

Dominance is a well-established phenomenon in ethology, however the dog-owning 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, dominant dogs (87%) have priority access to resources (resting place, food, and rewards), undertake certain tasks (defend the group during perceived or actual threats, bark more when a stranger comes to the house, and lead the group during walks), display dominance (lick the other's mouth less, win fights, and mark over the other's urine), have a certain personality (smarter, more aggressive and impulsive), and were 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 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 displays. Size and physical condition were unrelated to dominance. Surprisingly, in mixed-sex dyads, females were more frequently dominant than males. For future studies that wish to allocate dominance status using owner report we offer a novel 6-item survey.

* Corresponding author: Enikő Kubinyi, eniko.kubinyi@ttk.elte.hu

25

26 2. Introduction

27 The term "dominance" when used in reference to dogs, has often been misunderstood in the
28 popular media, which suggests that the public (and therefore the average dog owner) maybe unsure
29 what dominance really is. For example, a dog is often referred to as dominant if it shows a
30 particularly assertive personality, and very often dominance is used to describe the relationship
31 between the dog and the owner, rather than the relationship between dogs living in multi dog
32 households. To address the misuse and misunderstanding of the word in the general vocabulary of
33 dog owners and trainers, we aimed to evaluate whether the dog-owning public recognised dominant
34 individuals in multi-dog households, and what attributes they associated with dominance.
35 In ethology, the term dominance describes long-term dominant-subordinate social relationships
36 within a dyad or group. Dominant individuals usually have priority access to key resources such as
37 food, and reproductive partners, due to the consistent winning of agonistic interactions [1,2] or
38 deference, during which one individual consistently gives way to another [3,4]. Based on
39 observations in macaques, de Waal distinguishes agonistic dominance, established through force in
40 agonistic interactions, and formal dominance, based on the acceptance of the dominant individual by
41 the group, signalled through for example ritualistic greetings [5].
42 Although dominance hierarchies have previously been described in free-ranging dogs [6–8], in dogs
43 living in packs in enclosures [9–11], and in neutered pet dogs at a dog day care centre [12,13], the
44 existence and validity of linear dominance hierarchies in these animals is highly debated (mainly
45 because they are rare and have only been detected by examining submissive behaviours such as
46 mouth licks) [11,14–20]. Thus, dominance hierarchies in dogs can be detected without agonistic
47 interactions (i.e. aggression). For example, in multi-dog households one dog might defend a
48 particular toy while another is not interested in that toy but instead values sleeping in a particular
49 bed. Because these dogs defer to the priority of the other, there are no agonistic interactions

between them. If these dogs peacefully co-exist without social interactions (they avoid each other) there is no dominance hierarchy between them, and their relationship is 'non-interactive' according to the definition of Trisko et al. [13]. If dogs affiliate regularly (e.g. play with each other) without agonistic behaviour and exhibiting dominance, their relationship is 'egalitarian'. However, it is also possible that dogs living together both affiliate and exhibit dominance (and thus show 'formal' dominance), or do not affiliate but exhibit dominance (known as 'agonistic' dominance) [13]. In a group of 24 neutered companion dogs at a day-care facility, most dogs formed dominance relationships with other dogs. Dominance hierarchies were identified based on frequent submission (e.g. muzzle lick and low posture) and infrequent, low intensity aggression (threat andf attack). Older dogs out-ranked younger dogs, but size was unrelated to dominance rank. Dominance relationships were most commonly found in same-sexed pairs [12].

Although problem behaviours such as jumping or excessive humping are sometimes interpreted by the public, including dog trainers, as the dog's desire to be the "alpha", or the head of the household, dominance is not "misbehaviour". According to our present knowledge, dogs are unlikely to have a concept of "hierarchy", as they lack the cognitive processes that would be necessary for such a strategy. Instead, dogs' relationships with other dogs (and with people) are built up progressively through associative learning [20]. Bradshaw et al. [18,20] have stressed that intra-specific dominance should not be used to support the concept of inter-specific hierarchy, such as the outdated "alpha dog" myth, which stipulates that owners should maintain their leadership over their dog through force and intimidation if necessary, in order to become the "alpha" or "pack leader". Such obsolete beliefs have often been used to justify the use of abusive training techniques, and were based on erroneous models of wolf pack organisation, which were used to explain aspects of dog behaviour [18]. Indeed, the use of positive punishment and negative reinforcement training techniques can cause increased stress, fear and mistrust, and are associated with increased aggression towards other dogs in the household [21], and towards human family members [22]. Behavioural

75 modification based on operant and classical conditioning can provide an effective intervention for
76 inter- and intra-specific aggression problems [17].
77 Dominance describes social relationships, therefore, according to ethologists, it is not a personality
78 trait. Personality is largely independent of context and it is stable over time [23], while dominance
79 status depends on the interacting partners. However, some dog owners describe dogs that often
80 show dominant behaviour towards other dogs as having a "dominant personality". This
81 misunderstanding can be partly explained by the fact that based on a literature review on canine
82 personality, psychologists have identified a broad dimension labelled as 'Submissiveness', and
83 defined it as the opposite of dominance. According to the authors, "Dominance can be judged by
84 observing which dogs bully others, and which guard food areas and feed first. Submission can also be
85 reflected by such behaviors as urination upon greeting people" [24]. Thus, even in the scientific
86 literature there are inconsistencies regarding dominance as a personality trait. Moreover, dominance
87 status has been found to be associated with some personality traits (e.g. aggression towards people)
88 and also with leadership [7,25], which suggests that certain personality traits affect dominance ranks.
89 Leadership, in contrast to dominance, cannot be forced or demanded, as it requires followers who
90 choose to follow for their own benefit. More technically, leadership is a non-random differential
91 effect on group activities. Using directional correlation analysis on high-resolution spatio-temporal
92 GPS trajectory data from a group of six dogs, leader and follower roles in dyads were found to be
93 dynamically interchangable. However, on a longer timescale, leader and follower tendencies to lead
94 became clearer. The dogs' positions in the leader-follower network positively correlated with
95 dominance rank, trainability, controllability, aggression, and age [25].
96 Because of the commonly found link of dominance with age, Bradshaw et al. [26] suggested that a
97 simple rule of thumb could help to explain formal dominance in dogs: "in order to be allowed to stay
98 in the group, perform affiliative behaviour towards all the members of the group older than you are".
99 This hypothesis could also explain unidirectional hierarchical relationships found in companion dogs
100 living in multi-dog households. Indeed, a body of literature using field observations, suggests that

among dogs and the closely related wolf, older individuals are more likely to be dominant and/or leaders [6,7,12,27,28]. 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 [7], suggesting that it is not an inherent characteristic of individuals, similarly to dominance.

As mentioned previously, dominance relationships differ between same-sexed and mixed-sexed dyads, as mixed-sex dyads are more likely to affiliate and less likely to show dominance than same-sex pairs [12]. 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 [29,30]. In wolves, separate male and female age-graded dominance hierarchies have been observed in captive packs [31]. Male wolves were on average found to be more often dominant and/or leaders of the pack [27,32,33]. 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 [6].

Dog breeds and breed groups differ greatly in morphology and typical behaviour [34,35][19]. Therefore, social interactions and the types of relationships found in pet dogs may also be highly dependent on the breed composition of the group [36]. Based on the literature cited above, dominance hierarchies do exist among dogs living in the same household, albeit the characteristics of the social relationships are influenced by multiple factors, such as breed, personality, sex, and age.

We conducted a questionnaire study to better understand how dog owners perceive dominance ranks, and which behavioural/physical traits and other demographic factors influence the assumed rank between dogs living in the same household. Both the benefits and the challanges of using a "citizen science" model, relying on the dog-owning public, are well-known [37]. The quality of data produced by citizen scientists has proved to be satisfactory not only in recognising dog behaviours but also for conducting behavioural experiments [37].

Several studies have utilised owner questionnaires in order to determine dominance rank in multi-dog households [25,38,39]. Pongrácz et al. [38] used a four item questionnaire to measure dogs' dominance levels in dyads, and related them to differences in social learning in response to a human or dog demonstrator. The questions focused on social behaviours that can be easily recognized and do not require assumptions from the owner regarding the dominance rank of the dog. The four questions were the following: (1) "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)?", (2) "Which dog licks the other dog's mouth more often?" (reverse scored), (3) "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?", (4) "If the dogs start to fight, which dog wins more frequently?" Dogs were identified as dominant if they displayed at least three behaviours (e.g. barks more/longer, eats first, and wins fights). Dominant dogs were less likely to learn from observing other dogs and more likely to copy a human demonstrator. Subordinate dogs showed better learning in the dog demonstrator condition. Dominant dogs also performed better than subordinates in a problem solving task but only when observing a human demonstrator [39]. Results indicate that owner questionnaires could be a valid method to determine the dominance rank of individuals within dog dyads.

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. In the questionnaire, we integrated items from previous studies [38,39], and added more items that might be linked to an individual's ability to win in contests over resources, or asymmetry in experience. 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 [2,6,40,41].

We hypothesized that dominance as perceived by the owners is related to specific behaviours such as controlling resources, and to demographic and specific behavioural trait factors. We also tested

153 the age related hypothesis suggested by Bradshaw et al. [26] by comparing which factor best
154 explained behavioural and demographic differences between the dyads, owner reported hierarchical
155 status or age status.
156
157

158 3. Materials and Methods

159

160 Subjects

161 Between 25th June and 13th August 2017, 1156 owners of two or more dogs filled in a questionnaire
162 in Hungarian, which was advertised in a social media Dog Ethology group. We identified the dogs
163 using their given names, to ensure that no duplicate entries were included in the analysis. After
164 deleting questionnaires with missing data, 1151 responses remained, which detailed owners'
165 responses for unique individual pairs of dogs. Owners indicated the sex and reproductive status of
166 each dog in the dyad, after allocating them to either Dog A or Dog B (based on their own choice).
167 Both dogs were male in 23% of the pairs, both were females in 28%, both dogs were neutered in 37%
168 of the pairs, and 30% of pairs were both intact. Counting each dog separately, N = 2302 individuals,
169 there were 47.13% males, and 53.87% neutered individuals.
170

171 Procedure

172 The questionnaire consisted of 21 items (Table 1). In the case of items 1-19, owners indicated which
173 of the two dogs best fits the description: Dog A, or Dog B. Owners could also select "Similar" if both
174 dogs fitted the description, or "N/A". When the owners marked "N/A" we assumed that they could
175 not answer the question as the dog/dogs did not display that behaviour, or that situation did not
176 occur (e.g. the dogs never fight with each other or they do not go for walks together), or they were
177 unsure/did not fully understand the question, or the answer was not known to them (e.g. they could

178 not assess which of the dogs was in better physical condition). Items 2-4 and 6 were the same as
179 those used in [38]. In the case of items 20 and 21, the owner could also indicate "both" or "neither"
180 dogs (Table 1).
181

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	pee	Which dog marks over the other's pee?
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?

182

183 Table 1. Questionnaire items. Owners were asked to fill out the questionnaire for two of their dogs
184 ('A' and 'B') and indicate which dog corresponds better to the description. They could also select
185 "Similar" if both dogs fitted the description or "N/A" if the question did not apply to the dog dyad.
186

187 Statistical Analysis

188 Analyses were performed in SPSS 22.0 and R. Descriptive statistics were calculated for the sample
189 and summarised in the results section. To investigate the certainty of owners in their answers, and
190 the usefulness of each item in terms of whether they might be suitable to scrutinise status
191 differences in behaviour/demographics, we examined which "N/A" and "Similar" proportions were
192 one standard deviation below or above the mean.
193
194 Binomial tests using Dominance Status on the full sample
195 To investigate the owners' responses for each item (1 to 21), we calculated the percentage allocation
196 of the dogs to each possible category: "Differ" (the dogs in a particular dyad differed in that
197 behaviour/characteristic), "Similar" (the dogs' behaviour was similar) and "N/A" (the owner was not
198 able to determine if the dogs differed). Next, for the dogs that were allocated a "dominant" or a
199 "subordinate" status (the response of the owner to item 1 ("Which of your dogs is the
200 boss/dominant?")), binomial tests were used to compare the distribution of observations between
201 the dogs for each of the replies to items 2 to 21. Please note we did not consider dyads where
202 owners indicated in item 1 ("Which of your dogs is the boss/dominant?") that their dogs were
203 "Similar" in status, or where they marked "N/A" (N=148). Then, for items (2-21), dyads were also
204 excluded from the analysis pairwise, if the owner marked them as "Similar" or "N/A" in that
205 particular behaviour or characteristic (sample sizes are indicated in Figure 1).
206 We examined whether each behaviour/physical attribute was equally likely to occur in dominants
207 and subordinates (derived from item 1) using a two-tailed test. We lowered the p level to 0.0023
208 from 0.05 as suggested by a Bonferroni correction for the 22 comparisons.
209
210 Binomial tests using Age Status on the full sample
211 We then repeated the binomial analyses but instead of dominance status, we used the response of
212 the owner to Age ("Which of your dogs is older?", item 19), to assess differences between dogs
213 allocated an "older" or "younger" status (dogs which were "Similar" in age, or that where marked

214 "N/A", N=72, were excluded). Next, we used two-sample tests for equality of proportions with
215 continuity correction in order to determine which factor (Dominance status or Age status) best
216 explained the behavioural and demographic differences between the dogs.
217
218 Binomial tests on the mixed-sex and same-sex dyads
219 In order to examine any effect of the dyad composition on dominance status allocation, we created
220 subsets of data including mixed sex dyads (N=491), and same-sex dyads (N=512), and ran additional
221 binomial tests to inspect possible associations for items 2 – 21. We again adjusted for multiple
222 comparison using Bonferroni correction, and lowered the significance level to 0.0025.
223
224 Dominance Score and Difference Score
225 Next, we aimed to examine how large the difference in ranks between same-sexed, mixed-sexed,
226 neutered, and intact dyads. We created a "Dominance Score", by summing all the items that were
227 significantly associated with a "dominant" status (see below: bark, lick mouth, eat first, reward, fight,
228 walk first, resting place, pee, defend group, smart, aggressive, and impulsive) for each dog in every
229 dyad. Then we created a "Difference score" by subtracting the subordinates' "Dominance score"
230 from the dominants' for each dyad. After a power transformation to achieve normal distribution
231 (Boxcox, lamda = 0.67, three outliers removed) the "Difference score" was then used as the response
232 variable in a General linear model that was performed in R, to identify the key variables associated
233 with Dominance score. The sixteen possible sex and neuter status combinations of the dominant and
234 subordinate dyads were entered as a fixed factor (dyad), as well as the age status of the dominant
235 (the first two letters characterise the dominant's sex and neutered status, last two letters
236 characterise the subordinate's sex and neutered status: MIFI: dominant = male intact, subordinate =
237 female intact (N = 45); MIFN: male intact female neutered (N = 50); MIMI: male intact male intact (N
238 = 100); MIMN: male intact male neutered (N = 14); MNFI: male neutered female intact (N = 36);
239 MNFN: male neutered female neutered (N = 66); MNMI: male neutered male intact (N = 41); MNMN:

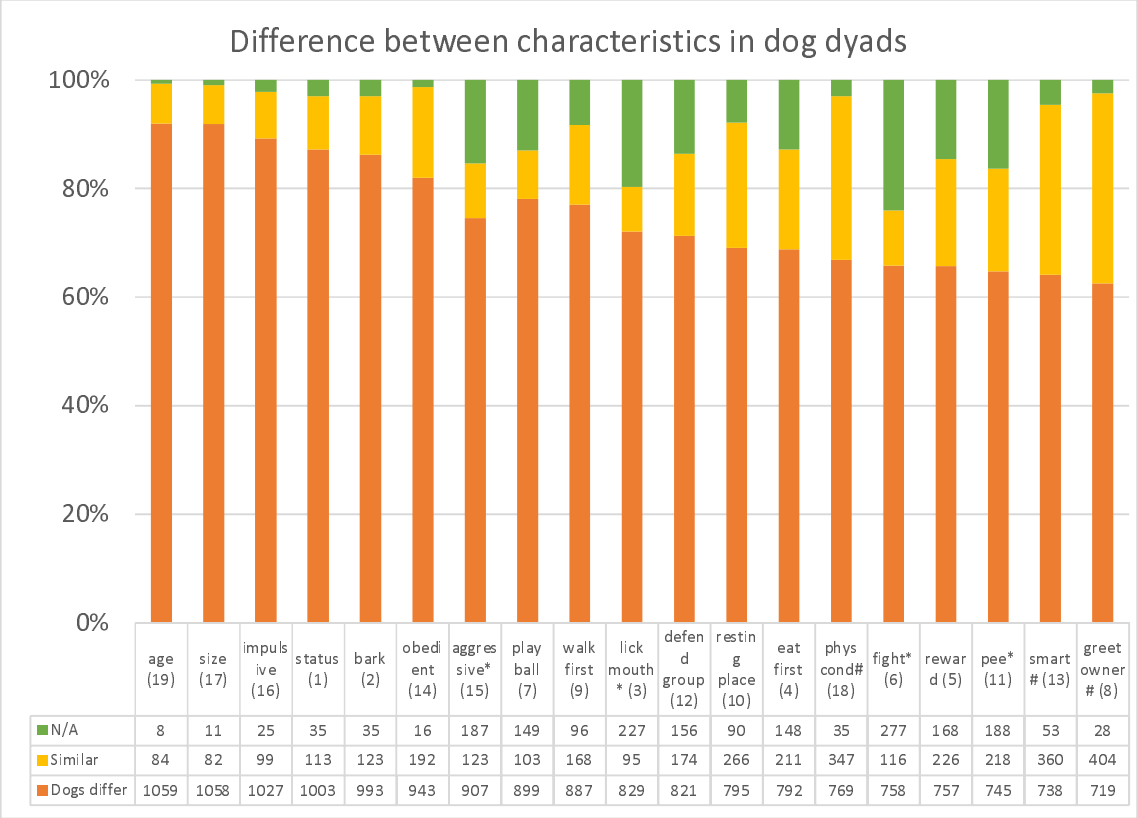
male neutered male neutered (N = 44); FIFI: female intact female intact (N = 89); FIFN: female intact female neutered (N = 45); FIMI: female intact male intact (N = 45); FIMN: female intact male neutered (N = 20); FNFI: female neutered female intact (N = 40); FNFN: female neutered female neutered (N = 128); FNMI: female neutered male intact (N = 86); FNMN: female neutered male neutered (N = 98)). We also included the order the dogs were entered into the questionnaire (Dog A and Dog B) to examine order effects. We included only the dyads where an asymmetry in dominance was detected by the owner (N= 931). We set Male Intact Female Intact (MIFI) as the comparison for the dyad factor as this combination had the highest Difference score.

4. Results

Descriptive statistics

The descriptive statistics are presented in Figure 1. 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”. Dogs were designated as “Similar” more often than the mean + SD (16.1 + 8.6 = 24.7%) in three items: greeting the owner, smartness, and physical condition. Only 7.1-7.3 percent of owners claimed that their dogs were similar in size and age (which is lower than the mean – SD: 16.1 – 8.6 = 7.5, Fig. 1).

The owners marked four items as “N/A” more often than the mean + SD (8.8 + 7.3 = 16.1): lick mouth, fight, pee, and aggressive (16.2-24.3%). Most respondents could assess differences between their dogs regarding size, age and obedience, as only around 0.7-1.4% of owners indicated “N/A” (which is lower than the mean – SD: 8.8 – 7.3 = 1.5).



	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.

268

	Dominance Status					Age Status					Prop. diff	2-sample test for equality of proportions			
Item	Count	Total	Prop	Z	P	Count	Total	Prop	Z	P		X2	P	95% CI	
Bark	547	884	0.619	7.03	<0.0001*	512	920	0.557	3.40	<0.0001*	0.062	6.953	0.008	0.016	0.109
Lick mouth	259	737	0.351	-8.03	<0.0001*	218	779	0.280	-12.25	<0.0001*	0.071	8.669	0.003	0.024	0.120
Eat first	473	717	0.660	8.51	<0.0001*	400	746	0.536	1.94	0.0261	0.124	22.662	<0.0001*	0.072	0.175
Reward	497	684	0.727	11.81	<0.0001*	386	714	0.541	2.13	0.0164	0.186	51.141	<0.0001*	0.135	0.237
Fight	606	700	0.866	19.31	<0.0001*	443	703	0.630	6.86	<0.0001*	0.236	101.920	<0.0001*	0.190	0.281
Play ball	404	793	0.509	0.50	0.7150	349	835	0.418	-4.71	<0.0001*	0.091	13.330	<0.0001*	0.042	0.141
Greet owner	352	644	0.547	2.32	0.0100	295	674	0.438	-3.20	<0.0001*	0.109	15.194	<0.0001*	0.054	0.164
Walk first	532	795	0.669	9.50	<0.0001*	430	824	0.522	1.22	0.1114	0.147	35.819	<0.0001*	0.099	0.196
Resting place	517	716	0.722	11.85	<0.0001*	425	754	0.564	3.46	<0.0001*	0.158	39.352	<0.0001*	0.109	0.208
Pee	400	669	0.598	5.03	<0.0001*	372	697	0.534	1.74	0.0407	0.064	5.465	0.019	0.010	0.118
Defend group	527	739	0.713	11.55	<0.0001*	437	760	0.575	4.10	<0.0001*	0.138	30.545	<0.0001*	0.089	0.187
Smart	433	665	0.651	7.76	<0.0001*	410	692	0.592	4.83	<0.0001*	0.059	4.710	0.030	0.651	0.593
Obedient	415	838	0.495	-0.24	0.6221	477	879	0.543	2.50	0.0063	-0.048	3.679	0.055	-0.096	0.001
Aggressive	524	762	0.688	10.32	<0.0001*	392	780	0.503	0.11	0.4572	0.185	53.997	<0.0001*	0.136	0.235
Impulsive	512	908	0.564	3.82	<0.0001*	313	952	0.329	-10.53	<0.0001*	0.235	103.120	<0.0001*	0.190	0.280
Size: heavier	497	929	0.535	2.10	0.0178	575	999	0.567	5.43	<0.0001*	-0.032	3.051	0.081	-0.086	0.005
P Cond: Better	353	687	0.514	0.69	0.2461	209	734	0.285	-11.63	<0.0001*	0.229	76.941	<0.0001*	0.175	0.280
Age: Older	615	931	0.661	9.77	<0.0001*										
Sex: Male	427	927	0.461	-2.36	0.0090	503	990	0.508	0.48	0.3168	-0.047	4.128	0.042	-0.093	-0.002
Sex: Female	576	1078	0.534	2.22	0.0131	556	1128	0.493	-0.45	0.6936	0.041	3.621	0.057	-0.001	0.080
Neutered	580	1073	0.541	2.63	0.0043	613	1133	0.541	2.73	0.0031	0	0.000	1.000	-0.043	0.042
Intact	423	933	0.453	-2.82	0.0024	446	985	0.453	-2.93	0.0017*	0	0.000	1.000	-0.045	0.046

Table 2. Results of the binomial tests using the owners' allocation of the dogs to "dominant" or "subordinate" status (item 1) and "older" or "younger" status (item 19) as the predicted variables and the 21 items. Bold type indicates that status was associated with the characteristic after Bonferroni correction (for the Binomial tests all p values are ≤ 0.0022 and significant results are indicated with a *). Two-proportion z-tests were used to determine whether the proportion of "dominant" and "older" dogs were equal for each item. P Cond= Physical condition, Prop = Proportion, Prop Diff = Proportion difference, and 95% CI=95% Confidence intervals.

Binomial tests using Dominance Status on the full sample

We tested which items (from items 2-21) were associated with the perceived dominance rank. 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 pee, 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 ($p < 0.0001$; see Table 2 for an overview of the results).

Binomial tests using Age Status on the full sample

We examined which items (from item 1-18, 20-21) were associated with age status (item 19). According to the binomial tests, older dogs bark sooner/more, lick the other's mouth less, win most fights, and play with the ball and greet the owner less (Table 2). They more often obtained better resting places and defended the group in case of perceived danger. "Older" dogs were also reported to be smarter and less impulsive than their partner dog, and they were less often intact, were in worse physical condition and more often the larger dog in the dyad ($p < 0.001$; see Table 2 for an overview of the results).

295

296 Comparison of Dominance Status and Age Status as predictor variables

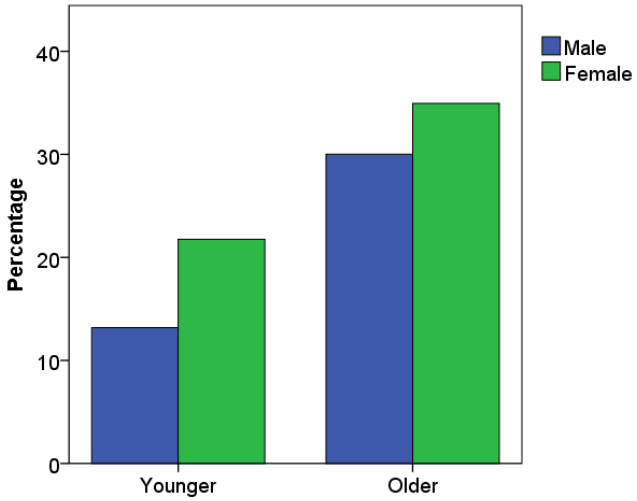
297 Results from two-sample tests for equality of proportions with continuity correction revealed that
298 dominance status was a stronger predictor of eat first, reward, fight, walk first, resting place, defend
299 group, aggressive, and impulsive, in comparison to age status. For one variable, age status tended to
300 be a stronger predictor, lick mouth. However, after correction for multiple comparison the difference
301 between the two proportions was no longer significant (Table 2).

302

303 Binomial tests on the mixed-sex dyad sample

304 In mixed-sex pairs (N = 491), females were more often dominant over males (57% females, binomial
305 test $z = 3.249$, $p < 0.001$; Fig. 2). There was also a higher proportion of neutered individuals compared
306 to intact (58.7% neutered). After correction for chance probability, we found a trend for neutered
307 dogs to be more often dominant than intact dogs (binomial test $z = 1.95$, $p = 0.025$, not significant
308 after Bonferroni correction). Moreover, as in the main sample, in mixed-sex dyads dominant
309 individuals were more often older than the subordinates (N=296 dyads, 65% older, binomial test $z =$
310 6.38, $p < 0.001$). All of the remaining items that were found to describe dominant individuals in the
311 full sample (bark, lick mouth, eat first, reward, fight, walk first, resting place, defend group, smart,
312 aggressive, and impulsive), were also significant after Bonferroni correction in the mixed pairs
313 subsample, apart from pee; dominant and subordinate individuals were found to mark over each
314 other's urination equally (51% dominants). Please refer to Supplementary Table S1 for more
315 information.

316



317

318 Figure 2. Percentage distribution of dominant dogs living in mixed sex pairs (N=491) based on their
319 relative age compared to their partner. Females were reported more often to be dominant than
320 males (p=0.001) and dominant dogs were more often older than the subordinates (p<0.001).

321

322 Binomial tests on the same-sex dyad sample

323 In same-sex pairs (N = 512 dyads, 48.5% neutered in the total sample), there was no significant
324 difference between the number of neutered and intact dominant animals (53% neutered, z = 1.86, p
325 = 0.063). Dominant individuals were again more often older than subordinates (N=319 dyads, 67%
326 older, binomial test z = 7.38 p < 0.001, Figure 3). As in mixed-sex pairs all the items that best
327 described dominant individuals also remained significant in the same-sex pairs subsample, with the
328 addition of pee (dominant individuals marked over subordinates more often in same-sex pairs), and
329 apart from the item impulsive (i.e. there was no difference in impulsivity between dominants and
330 subordinates in same-sex pairs). Results can be found in Supplementary Table S1.

331

332

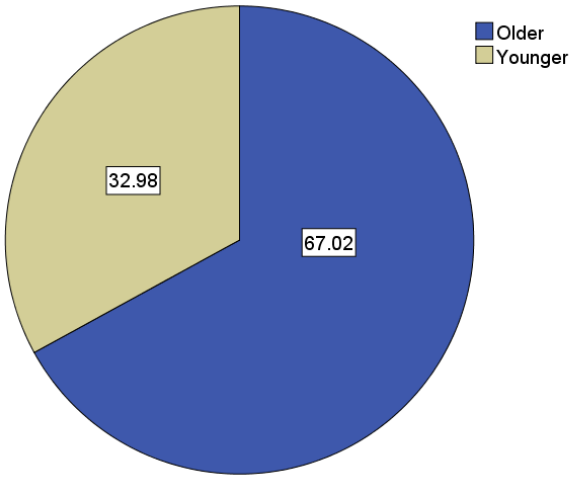


Figure 3. Distribution of age in dominant dogs living in same-sex (male-male, female-female) pairs (N=512), based on their relative age compared to their subordinate partner. Older dogs were more often dominant than young dogs ($p < 0.001$).

Comparison of dominants in mixed-sex dyads and same-sex dyads

Since there were a few differences between mixed-sex and same-sex dyads, we compared the dominants proportion of each item of each group using a z score calculation. Again, we used Bonferroni correction for multiple comparisons. Results revealed that dominant individuals in same-sex dyads do indeed mark over subordinate urinations more often than dominants from mixed-sex dyads (same-sex 69% and mixed-sex 51%; please refer to Supplementary Table S1). In addition, dominant individuals were more often neutered in mixed-sex dyads in comparison to same-sex dyads (mixed-sex 63%, same-sex 53%).

Comparison of male and female dominants in mixed-sex dyads

In our analysis of the mixed-sex subsample, we found that females were more often dominant than males. In order to determine whether there were differences between the dominant males and females in each item measured, we compared the dominants proportion of each group (dominant male and dominant female in mixed-sex group) using a z score calculation. Results are displayed in

352 Table 3. When a male was dominant in a mixed-sex pair, he more often marked over his female
353 partner and defended the group in case of perceived danger. In addition, he was often larger in size
354 than the female subordinate. Finally, when a female was the dominant individual, she was more
355 often neutered than when the male was the dominant (female neutered 72%, male neutered 51%).
356

	Dominant female			Dominant male			Proportion	Proportion comparison	
Item	Count	Total	Prop	Count	Total	Prop	difference	Z	P
Bark	162	248	0.65	106	176	0.60	0.05	1.07	0.2846
Lick mouth	125	201	0.62	102	155	0.66	-0.04	-0.70	0.4839
Eat first	128	201	0.64	86	147	0.59	0.05	0.98	0.3271
Reward	137	187	0.73	97	142	0.68	0.05	0.98	0.3271
Fight	177	205	0.86	112	133	0.84	0.02	0.54	0.5892
Play ball	111	220	0.50	81	163	0.50	0.01	0.15	0.8808
Greet owner	96	175	0.55	86	139	0.62	-0.07	-1.25	0.2113
Walk first	137	222	0.62	116	153	0.76	-0.14	-2.87	0.0041
Resting place	154	197	0.78	92	143	0.64	0.14	2.82	0.0048
Pee	39	193	0.20	138	153	0.90	-0.70	-12.93	<0.0001*
Defend group	127	212	0.60	128	150	0.85	-0.25	-5.22	<0.0001*
Smart	118	183	0.64	87	138	0.63	0.01	0.27	0.7872
Obedient	114	228	0.50	88	176	0.50	0.00	0	1.0000
Aggressive	126	206	0.61	114	153	0.75	-0.13	-2.66	0.0078
Impulsive	158	255	0.62	94	180	0.52	0.10	2.03	0.0424
Size: heavier	106	257	0.41	128	193	0.66	-0.25	-5.27	<0.0001*
Physical Condition	89	184	0.48	79	141	0.56	-0.08	-1.37	0.1707
Age: Older	159	258	0.62	137	197	0.70	-0.08	-1.75	0.0801
Neutered	203	282	0.72	107	210	0.51	0.21	4.78	<0.0001*

357

358 Table 3: Results for mixed-sex dyads by the sex of the dominant. Bold type indicates that social status
359 was associated with the characteristic after Bonferroni correction (for the Binomial tests all p values
360 are ≤ 0.0026 and significant results are indicated with a *). Prop= Proportion.
361

362 Dominance Score and Difference Score

363 Dominant dogs had higher dominance scores than subordinates (dominant mean ± SD = 6.03±2.46,
364 range = 0-12 vs. 2.92±1.91, range = 0 – 8, Mann-Whitney U test = -27.326, P <0.001). In comparison,

365 dogs that were rated as similar in status had similar scores (3.23±2.01, range = 0 – 9 for Dog A, and

366 3.46±2.10, range = 0 – 11 for Dog B, Mann-Whitney U test = 0.837, P =0.403).

367

368

	Estimate	Standard error	T value	F	P	Partial eta
Dyad				2.2029	0.005	0.035
FNMI	-0.948	0.268	-3.540		0.000	
FIMI	-0.875	0.308	-2.837		0.005	
FNMN	-0.694	0.262	-2.647		0.008	
FNFN	-0.577	0.252	-2.286		0.022	
FIMN	-0.703	0.344	-2.042		0.041	
MIMI	-0.495	0.261	-1.896		0.058	
MNFN	-0.515	0.281	-1.829		0.068	
MIFN	-0.401	0.299	-1.342		0.180	
MNMN	-0.377	0.309	-1.220		0.223	
FIFI	-0.280	0.266	-1.050		0.294	
FIFN	-0.406	0.393	-1.033		0.302	
FNFI	-0.272	0.317	-0.858		0.391	
MNFI	-0.272	0.325	-0.836		0.404	
MNMI	0.174	0.314	0.555		0.579	
MIMN	-0.161	0.445	-0.360		0.719	
MIFI	-	-	-		-	
Order: Dog B	-0.407	0.138	-2.941	8.6522	0.003	0.010
Dog A	-	-	-		-	
Dom age: Younger	0.320	0.127	2.520	6.3501	0.012	0.010
Older	-	-	-		-	

369

370 Table 4: Results of the general linear model showing the direction and magnitude of effects and the

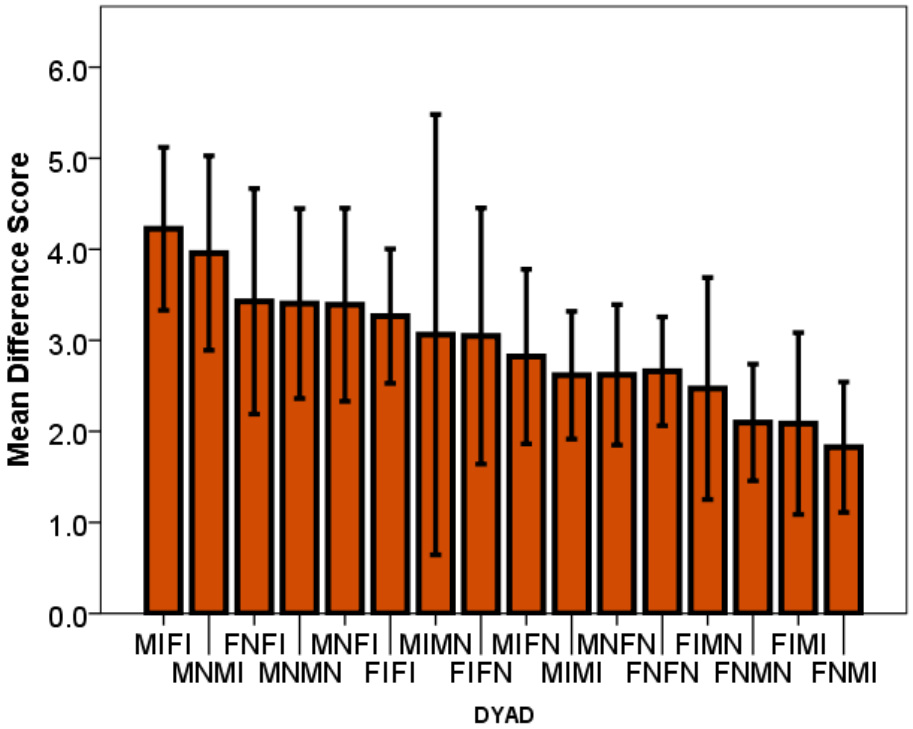
371 significance level of the terms in the demographic variables associated with “Difference score”.

372 Significant P values (in bold) indicate which group differs from the reference value in the respective

373 analysis. (The reference value for categorical variables was set to the last category in the group, and

374 is denoted by “-“).

375



376

377 Figure 4: Mean and 95% confidence intervals of the "Difference score" of the sixteen possible sex and
378 neuter status combinations of the dyads listed in descending order. The final five combinations
379 (FNFN, FIMN, FNMN, FIMI, and FNMI) are all significantly different from the comparison group (MIFI)
380 $p<0.05$.

381

382 Results of the general linear model utilising the "Difference score" as the response variable revealed
383 significant effects of dyad combination, order, and dominant age (Table 4,). However, the overall
384 variance explained by the model was low (Multiple R-squared: 0.04477, F-statistic: 2.517 on 17 and
385 913 DF, $P < 0.001$). When using the combination MIFI as the reference category, five dyad
386 combinations had a significantly lower "Difference score": FNFN, FIMN, FNMN, FIMI, and FNMI
387 (Figure 4). Interestingly, when the dominant was the younger animal the "Difference score" was
388 higher, regardless of dyad combination. There was also a significant order effect. Dominant Dog A-s
389 differed more from their partners than Dominant Dog B-s.

390

5. Discussion

In this study, we investigated dominance rank predictors in dog dyads using an owner questionnaire. 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, which supports that dominance relationships are a robust and well-perceivable component of companion dog behaviour.

We found that within dyads, dominant dogs (1) have priority access to certain resources, (2) undertake specific tasks, (3) display dominance, (4) have characteristic personality traits and (5) are usually older than subordinates. More specifically, dominant dogs bark sooner/more, lick the other's mouth less, eat food and obtain rewards first, win most fights, walk in the front during walks, obtain better resting places, mark over the other's pee, defend the group in case of perceived danger, are smarter, more aggressive, more impulsive, and older than their partner. Physical condition, obedience, sequence of greeting the owner and retrieving balls were unrelated to dominance. Results were the same in the full sample and in the subsamples of mixed-sex and same-sex dyads, except for pee (mark over), which did not differ between dominants and subordinates in mixed-sex dyads.

In contrast to the age related hypothesis, which suggests that age explains formal dominance in dogs [26], we found that dominance status, as perceived by the owner, was a better predictor than age status for 11 of the items examined.

Thirteen percent of owners were unable to determine a clear rank order between their dogs. This may be because (1) the owner has more than two dogs and these two are closer in rank or have a non-interactive or 'egalitarian' relationship; (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, preventing situations in which rank could form from happening (e.g. chasing away the dominant dog from the better resting place, not allowing the dominant to feed first, prevented

416 fights, and favouring the loser dog, etc.); (4) the owner does not accept/understand the concept of
417 dominance.
418 Items that previously were convincingly associated with dominance, such as bark first or more often,
419 lick mouth (reverse coded), eat first and fight [38], predicted the owner's estimate of dominance in
420 the present study too. Note however, that 28-34.1% of owners indicated that their dogs do not lick
421 each other's mouths and never fight with each other (or are similar in this regard); therefore, these
422 items are not predictive in a third of the population.
423 Items related to obtaining resources (resting place, eating first, and getting food rewards first) square
424 with the classical definition of dominance by [42], which maintains that dominant individuals have
425 priority access to resources. However, items that examined control over other resources, such as a
426 ball and the owner (greeting), were not different between "dominant" and "subordinate" dogs.
427 Three of the items used in the current study, mouth licking, pee, and win fights are related to
428 dominance displays established through ethological fieldwork that are easy to observe for lay people.
429 These displays were associated with the owner's estimate of the dog's rank, indicating that owner-
430 derived reports about dominance ranks have external validity.
431 Mouth licking was more often observed among subordinate dogs. This behaviour may be derived
432 from food begging behaviour and it is part of the submission ritual, most often during greetings, both
433 in wolves [43,44], and dogs [6,11].
434 Owners indicated that dogs higher in status over mark lower ranking dogs. One previous study
435 reported that dogs' rate of countermarking indicated high status in both male and female dogs [45].
436 However, in the current study, detailed analysis showed that dominants in same-sex dyads mark over
437 subordinate urinations more often than dominants from mixed-sex dyads. However, when a male
438 was dominant in a mixed-sex pair, he more often marked over his female partner (and also defended
439 the group in case of perceived danger). Results suggests that for females intra-sexual competition
440 may be prioritised over intersexual competition.

441 According to their owners, 24.1% of dyads never fight, a result which is in harmony with the finding
442 that aggression in companion dogs is rare and usually of low intensity [12]. However, 65.9% of dyads
443 do fight. Aggression between dogs in the same household has been interpreted as disputes over
444 dominance by several authors [17,46]. In free-ranging dogs, dominance relationships were based on
445 agonistic interactions, and were correlated with priority access to food [47].
446 Aggression levels are likely to increase when there is direct competition for resources (which can
447 include the owner), and previous experiences have led to success in agonistic interactions. In
448 addition, aggression towards other dogs in the household has been associated with increasing age in
449 previous studies, number of dogs in the household, and with the type of training techniques used by
450 the owner [21]. Context-specific associative learning can help to clarify the complexities of social
451 interaction, and provides an explanation of why the relationship between dyads of dogs can change
452 from one situation to another (for example when competing for access to food, and over a favourite
453 toy) [48,49]. Additionally, context-specific associative learning can explain why dogs do not tend to
454 show aggression in multiple contexts [21].
455 Items theoretically concerning the responsibilities that come with a higher status were also
456 associated with dominance. According to the owners, dominant dogs defend the group during
457 perceived or actual threats, bark more when a stranger comes to the house, and lead other dog/s
458 during walks, in harmony with previous findings on dominance-leadership associations [25].
459 Dominant dogs were reported to have certain personality traits: they were more aggressive,
460 impulsive and smarter than subordinates were. In a small group of dogs aggression towards people,
461 controllability, and leadership were associated with dominance [25]. Results suggest that these
462 personality traits influence social relationships.
463 Aggressivity as a personality trait increases the likelihood of exhibiting dominance via agonistic
464 interactions. Depending on whether dogs in the dyad affiliate or not, they can form formal or
465 agonistic dominance (see also [5]). Unfortunately in our study affiliation was only measured using the

466 item "lick mouth", which is also a signal of submission, therefore we could not distinguish between
467 these two dominance types [12].
468 Impulsivity is also associated with dominance in the full and the mixed-sex sample. Without utilising
469 a multi-dimensional assessment of impulsivity (for example, as used in [50]), impulsivity is difficult to
470 distinguish from aggression, although it can alternatively co-vary with anxiety, too [51]. The fact that
471 impulsivity did not differ between dominant and subordinate individuals in same-sex pairs indicates
472 that intrasexual competition may influence impulsivity in dogs, or there is a sex difference in
473 impulsivity.
474 'Smartness' could be an important mediator of both dominance and leadership. In smaller packs (i.e.
475 nuclear families in wolves), apparent dominance can be observed as the parents exert parental
476 guidance over their offspring. Mathematical models predict, that the fitness of group members
477 increases if the dominant individual is experienced with the group's surroundings, thus it is
478 advantageous for the group if the knowledge of dominant individuals exceeds that of other members
479 [40,41]. Based on the data on free-ranging dogs, Bonanni et al. [7] assumed that age and experience
480 play a part in maintaining the rank of dominants. If the owner's estimate of dog-smartness is a good
481 reflection of the dog's knowledge and cognitive skill, the association between leadership and
482 dominance could be based on the underlying association between smartness and dominance.
483 However, it is also possible that owners attribute higher intellect to the dominants or alternatively,
484 subordinate dogs do not show their full potential (e.g. they are stressed and or inhibited by the
485 dominant).
486 As predicted, older individuals were more often allocated a higher status by owners in the full
487 sample, and in both subsamples (mixed and same-sex pairs). Previous studies in wolves, free ranging
488 dogs, and pet dogs confirm that older individuals are more likely to be dominant and/or leaders
489 [6,7,12,28,44,52]. In addition, older dogs have usually stayed within the family home for longer than
490 younger dogs, a factor, which contributes to their level of experience and knowledge.

491 An interesting and unexpected finding in the current study is that females were perceived by owners
492 as more dominant than males in mixed-sex dog dyads. This is surprising, because in captive wolves,
493 formal submission (see definition by de Waal [5]) was found to be consistently asymmetrical in
494 favour of males (i.e. females submitted more to their male partners [27]). Some authors have
495 concluded that among wolves the breeding male is more dominant [32,33]. However sex had no
496 clear effect on dominance in a family pack of captive arctic wolves, although sex separated linear
497 hierarchies showed a stronger linearity than female-male hierarchies [44]. Male free-ranging dogs
498 are usually also dominant over females [47].
499 One reason why female dogs dominate males more often in mixed-sex dyads could be due to the fact
500 that dominant females were more often neutered than dominant males. Previous studies have
501 determined that hormonal activity influences inter-dog aggression [29]. Aggression has been found
502 to increase in neutered females [53], so that the observed effect of reproductive status in our study
503 may present an aggression-based amplification of the female dominance behaviour. Females were
504 able to dominate males even though in 59% of the dyads they were smaller in size than their male
505 partner. Note that dominant females were not observed to be more aggressive than dominant
506 males. There does not appear to be a similar effect of neutering on males; in mixed-sex dyads,
507 dominant males were equally likely to be neutered or intact. Our results are in line with previous
508 data, which indicated that hierarchy formation did not seem to be affected by even prepubertal
509 castration [54]. However, in the current study, dominant males were more likely to defend the group
510 and to mark over their subordinate, than dominant females. Which indicates that dominant females
511 may be taking on only some of the characteristics of a dominant animal. Future studies should
512 examine whether neutered female dogs usually lean towards the agonistic dominance style.
513 On average, individuals that were labelled as “dominant” expressed the traits and features that were
514 identified as those that are characteristic of a dominant animal to a greater extent than
515 subordinates, as measured through the dominance difference score. Although there was quite some
516 variation in both dominant and subordinate individuals, which reflects the complex nature of social

517 relationships, and the influence of context and previous experience on behaviour. The dyad that
518 showed the greatest difference score between the dominant and subordinate (and therefore the
519 clearest status or relationship difference) was in a mixed sex dyad when an intact male was dominant
520 over an intact female. Which partially collaborates the suggestion that mixed sex dog dyads tend to
521 have more defined relationships, in comparison to same sex pairs [19]. However, in the current
522 study, when a male was dominant in a mixed sex pair, he more often marked over his female partner
523 and defended the group in case of perceived danger, than when a female was dominant. Therefore,
524 male dominants received a higher dominance score than female dominants in mixed sex groups.
525 Which points to a possible sex influence on some dominance related behaviours.
526 This assumption is further supported when comparing the difference score of dyads with an intact
527 male dominant and an intact female subordinate with all other possible dyads. Results revealed that
528 mixed-sex dyads with dominant females (FIMI, FNMI, FNMN, and FIMN), had significantly lower
529 difference scores. Dominant males may be performing mate-guarding behaviour in an attempt to
530 control intact females mating opportunities. This behaviour includes increased urine marks on or
531 near a females urine spots, which serves to hide the odour trail of an oestrous female from other
532 dogs [55]. When female free-ranging dogs are in heat, males tend to become more aggressive
533 towards each other, and hierarchies become more pronounced during this time [56]. However, this
534 does not explain why for some owners of intact mixed sex dyads the female was perceived as
535 dominant. There is evidence from humans that socially dominant males and females are more similar
536 in behavioural profiles (regardless of age), than is commonly believed [57]. Biologists have
537 underrated overt competitiveness in females, as evolutionary and biological approaches suggested
538 that social dominance is predominately an aspect of male social organization.
539 In pre-schoolers, caretaker assessments of dominance status was found to be a valid means to divide
540 children into dominant and subordinate groups, as those designated as socially dominant were more
541 likely to control a desired resource in a play situation [58]. Age, but not sex was found to predict
542 social dominance; however, in a similar result to the current study, caretakers did not merely order

543 the children by age, as additional factors such as personality traits (assertiveness and extraversion),
544 and friendship modulate dominance behaviour. Hawley [58] concludes that social dominance is not a
545 single-indicator construct, as individuals vary in their resource-directed behaviour and are not equal
546 in their abilities and/or motivation to pursue resources in the presence of others.
547 Although McGreevy et al. [19] suggested that mixed-sex dog dyads tend to have more defined
548 relationships, in comparison to same-sex pairs, we did not find any differences in the behaviour of
549 dominants in mixed-sex and same-sex pairs, apart from in the proportion of dogs that marked over
550 subordinates (see above), and the number of neutered individuals. Dominant individuals were more
551 often neutered in mixed-sex dyads in comparison to same-sex dyads. This is not surprising when we
552 consider the difficulties of keeping intact males and females together in the same household.
553 An additional confound is that as dogs age, the chance of reproductive problems increases especially
554 in females, which leads to an increase in neutered individuals with age. Pyometra (an infection in the
555 uterus), is one of the most common diseases affecting over 50% of all intact females before 10 years
556 of age [59]. Older intact male dogs have an increased risk of prostatic disorders, which affects more
557 than 80% of male dogs over 5 years of age [60]. Therefore, older individuals are more likely to be
558 neutered than younger individuals among groups of dogs where the owners' common practice is to
559 keep them sexually intact for as long as possible (for example breeders and people who show their
560 pedigree dogs). In line with this fact, we found that dominant individuals in the full sample were
561 more often neutered and older, than intact and older.
562 In the full sample and in both subsamples (same-sex and mixed-sex dyads), size was unrelated to
563 dominance ranks, as has previously been found in pet dogs [12]. However, when we examined the
564 differences between dominant males and dominant females in mixed-sex dyads, we found that
565 dominant males were more often larger than their partner. The domestic dog is the most
566 morphologically variable mammalian species [61]. Male-larger sexual size dimorphism is present in
567 most dog breeds and in larger breeds is comparable to their wolf ancestor [62]. Therefore, larger,
568 heavier males have an advantage over smaller, lighter females, which can result in males successfully

569 out competing females for resources, and potentially becoming dominants. However, since sexual
570 size dimorphism becomes smaller with decreasing body size (a pattern termed Rensch's rule [62]),
571 smaller breeds are nearly monomorphic, which could result in increased numbers of females
572 attaining a dominant position.
573 By examining the proportion of dyads found in each of the sixteen possible dominance, sex and
574 neuter status combinations, we were able to determine common patterns in keeping practices within
575 our sample. Either owners tended to keep all their dogs intact and in same-sex dyads, or they were
576 all neutered. This finding could indicate that owners kept multiple pedigree dogs, that need to
577 remain intact for breeding and showing purposes, or they kept multiple mixed breed dogs possibly
578 obtained from shelters, where it is the common practice to neuter the individuals. Alternatively, it
579 could reflect differences in owner attitudes to neutering [63]. Unfortunately, we did not obtain
580 information on either the breed, the origin of the dog, the age at acquisition, or the reason for
581 neutering, and therefore further studies are necessary to elucidate the relationship between early
582 life experiences, owner breed preferences, neutering attitudes, and dominance relationships
583 between same and mixed-sex groups.
584

585 # 6. Conclusion

586 Our study has several limitations, such as the fact that only relationships between single dyads were
587 examined. Previous work has determined that individuals can and do establish different types of
588 relationships including "friendships", when paired with different individuals, and these relationships
589 can also change over time, suggesting high social complexity in dogs [13]. Future studies should
590 examine how individuals' relationships differ within multi-dog households. Unfortunately, we did not
591 include items on affiliative behaviour in the questionnaire, so it was not possible to classify the
592 dominance relationships further into formal (affiliation and dominance), and egalitarian (affiliated
593 with no dominance) types. Additionally, we were not able to examine breed differences in

dominance relationships because larger sample sizes would be necessary. Finally, due to time constraints, we applied single item statements to describe personality traits.

However, our study opens up the way for a better understanding of dominance in dogs and highlights the usefulness of citizen science when studying animal behaviour. Based on our data, we suggest for future studies that wish to allocate dominance status using owner report, to include the following six items: Which dog starts to eat first, obtains the reward, walks in the front, acquires the better resting place, defends the group, and is more aggressive. However, asking which dog wins fights or which dog licks the mouth of the other might also be useful as both were highly predictive of social status if they do occur (in approx. 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.

620 **Data Accessibility**

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

622

623 **Competing Interests**

624 The authors declare that they have no conflict of interest.

625

626 **Authors' Contributions**

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

628 Lisa Wallis – final analysis, writing

629

630 References

631 1. Clutton-Brock TH, Albon SD, Gibson RM, Guinness FE. 1979 The logical stag: Adaptive aspects
632 of fighting in red deer (Cervus elaphus L.). *Anim. Behav.* **27**, 211–225. (doi:10.1016/0003-
633 3472(79)90141-6)
634 2. Drews C. 1993 The Concept and Definition of Dominance in Animal Behavior. *Behavior* **125**
635 **(3)**, 283–313. (doi:10.1017/CBO9781107415324.004)
636 3. Lorenz K. 1966 *On Aggression*. London: Methuen.
637 4. Smith JM, Price GR. 1973 The Logic of Animal Conflict. *Nature* **246**, 15–18.
638 (doi:10.1038/246015a0)
639 5. de Waal FBM. 1989 Dominance 'style' and primate social organization. In *Comparative*
640 *Socioecology: The Behavioural Ecology of Humans and other Mammals*, pp. 243–263.
641 6. Cafazzo S, Valsecchi P, Bonanni R, Natoli E. 2010 Dominance in relation to age, sex, and
642 competitive contexts in a group of free-ranging domestic dogs. *Behav. Ecol.* **21**, 443–455.
643 (doi:10.1093/beheco/arq001)
644 7. Bonanni R, Cafazzo S, Valsecchi P, Natoli E. 2010 Effect of affiliative and agonistic relationships
645 on leadership behaviour in free-ranging dogs. *Anim. Behav.* **79**, 981–991.

(doi:10.1016/j.anbehav.2010.02.021)

8. Bonanni R, Cafazzo S. 2014 The Social Organisation of a Population of Free-Ranging Dogs in a Suburban Area of Rome. In *The Social Dog*, pp. 65–104. Elsevier. (doi:10.1016/B978-0-12-407818-5.00003-6)

9. Dale R, Range F, Stott L, Kotrschal K, Marshall-Pescini S. 2017 The influence of social relationship on food tolerance in wolves and dogs. *Behav. Ecol. Sociobiol.* **71**. (doi:10.1007/s00265-017-2339-8)

10. Range F, Ritter C, Viranyi Z. 2015 Testing the myth: tolerant dogs and aggressive wolves. *Proc. R. Soc. B Biol. Sci.* **282**, 20150220. (doi:10.1098/rspb.2015.0220)

11. Van Der Borg JAM, Schilder MBH, Vinke CM, De Vries H, Petit O. 2015 Dominance in domestic dogs: A quantitative analysis of its behavioural measures. *PLoS One* **10**. (doi:10.1371/journal.pone.0133978)

12. Trisko RK, Smuts BB. 2015 Dominance relationships in a group of domestic dogs (Canis lupus familiaris). *Behaviour* **152**, 677–704. (doi:10.1163/1568539X-00003249)

13. Trisko RK, Smuts B, Sandel AA. 2016 Affiliation, dominance and friendship among companion dogs. *Behaviour* **153**, 693–725. (doi:10.1163/1568539X-00003352)

14. Schilder MBH, Vinke CM, Borg JAM Van Der. 2014 Dominance in domestic dogs revisited: useful habit and useful construct? *J. Vet. Behav.* (doi:10.1016/j.jveb.2014.04.005)

15. Westgarth C. 2016 Why nobody will ever agree about dominance in dogs. *J. Vet. Behav. Clin. Appl. Res.* **11**, 99–101. (doi:10.1016/j.jveb.2015.02.004)

16. Overall KL. 2016 Special issue: The “dominance” debate and improved behavioral measures—Articles from the 2014 CSF/FSF. *J. Vet. Behav. Clin. Appl. Res.* **11**, 1–6. (doi:10.1016/j.jveb.2015.12.004)

17. van Kerkhove W. 2004 A Fresh Look at the Wolf-Pack Theory of Companion-Animal Dog Social Behavior. *J. Appl. Anim. Welf. Sci.* **7**, 279–285.

18. Bradshaw JWS, Blackwell EJ, Casey RA. 2009 Dominance in domestic dogs-useful construct or

672 bad habit? *J. Vet. Behav. Clin. Appl. Res.* **4**, 135–144. (doi:10.1016/j.jveb.2008.08.004)

673 19. McGreevy PD, Starling M, Branson NJ, Cobb ML, Calnon D. 2012 An overview of the dog-
674 human dyad and ethograms within it. *J. Vet. Behav. Clin. Appl. Res.* **7**, 103–117.
675 (doi:10.1016/j.jveb.2011.06.001)

676 20. Bradshaw JWS, Blackwell E, Casey RA. 2016 Dominance in domestic dogs—A response to
677 Schilder et al. (2014). *J. Vet. Behav. Clin. Appl. Res.* **11**, 102–108.
678 (doi:10.1016/j.jveb.2015.11.008)

679 21. Casey RA, Loftus B, Bolster C, Richards GJ, Blackwell EJ. 2013 Inter-dog aggression in a UK
680 owner survey: Prevalence, co-occurrence in different contexts and risk factors. *Vet. Rec.* **172**,
681 127. (doi:10.1136/vr.100997)

682 22. Casey RA, Loftus B, Bolster C, Richards GJ, Blackwell EJ. 2014 Human directed aggression in
683 domestic dogs (Canis familiaris): Occurrence in different contexts and risk factors. *Appl. Anim.*
684 *Behav. Sci.* **152**, 52–63. (doi:10.1016/j.applanim.2013.12.003)

685 23. Jones AC, Gosling SD. 2005 Temperament and personality in dogs (Canis familiaris): A review
686 and evaluation of past research. *Appl. Anim. Behav. Sci.* **95**, 1–53.
687 (doi:10.1016/j.applanim.2005.04.008)

688 24. Fratkin JL, Sinn DL, Patall EA, Gosling SD. 2013 Personality Consistency in Dogs: A Meta-
689 Analysis. *PLoS One* **8**, e54907. (doi:10.1371/journal.pone.0054907)

690 25. Ákos Z, Beck R, Nagy M, Vicsek T, Kubinyi E. 2014 Leadership and Path Characteristics during
691 Walks Are Linked to Dominance Order and Individual Traits in Dogs. *PLoS Comput. Biol.* **10**.
692 (doi:10.1371/journal.pcbi.1003446)

693 26. Bradshaw JWS, Blackwell E, Casey RA. 2016 Dominance in domestic dogs - A response to
694 Schilder et al. (2014). *J. Vet. Behav. Clin. Appl. Res.* **11**, 102–108.
695 (doi:10.1016/j.jveb.2015.11.008)

696 27. Mech LD. 1999 Alpha status, dominance, and division of labor in wolf packs. *Can. J. Zool.* **77**,
697 1196–1203. (doi:10.1139/z99-099)

698 28. Bonanni R, Cafazzo S, Abis A, Barillari E, Valsecchi P, Natoli E. 2017 Age-graded dominance
699 hierarchies and social tolerance in packs of free-ranging dogs. *Behav. Ecol.* **28**, 1004–1020.
700 (doi:10.1093/beheco/arx059)
701 29. Sherman CKC, Reisner IRIIR, Taliaferro LA, Houpt KA. 1996 Characteristics, treatment, and
702 outcome of 99 cases of aggression between dogs. *Appl. Anim. Behav. Sci.* **47**, 91–108.
703 (doi:10.1016/0168-1591(95)01013-0)
704 30. Wrubel KM, Moon-Fanelli AA, Maranda LS, Dodman NH. 2011 Interdog household aggression:
705 38 cases (2006–2007). *J. Am. Vet. Med. Assoc.* **238**, 731–740. (doi:10.2460/javma.238.6.731)
706 31. Packard JM. 2003 Wolf behaviour: reproductive, social and intelligent. In *Wolves: Behavior,*
707 *Ecology and Conservation* (eds LD Mech, L Boitani), pp. 35–65. Chicago, IL: University of
708 Chicago Press.
709 32. Clark K. 1971 Food habits and behavior of the tundra wolf on central Baffin Island.
710 33. Haber G. 1977 Socio-ecological dynamics of wolves and prey in a subarctic ecosystem.
711 34. Starling MJ, Branson N, Thomson PC, McGreevy PD. 2013 Age, sex and reproductive status
712 affect boldness in dogs. *Vet. J.* **197**, 868–872. (doi:10.1016/j.tvjl.2013.05.019)
713 35. Turcsán B, Kubinyi E, Miklósi Á. 2011 Trainability and boldness traits differ between dog breed
714 clusters based on conventional breed categories and genetic relatedness. *Appl. Anim. Behav.*
715 *Sci.* **132**, 61–70. (doi:10.1016/j.applanim.2011.03.006)
716 36. van der Borg J a M, Schilder MBH, Vinke CM. 2012 Dominance and its behavioural measures in
717 a pack of domestic dogs. *Proc. Canine Sci. Forum* , 15.
718 37. Hecht J, Spicer Rice E. 2015 Citizen science: A new direction in canine behavior research.
719 *Behav. Processes* **110**, 125–132. (doi:10.1016/J.BEPROC.2014.10.014)
720 38. Pongrácz P, Vida V, Bánhegyi P, Miklósi Á. 2008 How does dominance rank status affect
721 individual and social learning performance in the dog (Canis familiaris)? *Anim. Cogn.* **11**, 75–
722 82. (doi:10.1007/s10071-007-0090-7)
723 39. Pongrácz P, Bánhegyi P, Miklósi Á. 2012 When rank counts — dominant dogs learn better

724 from a human demonstrator in a two-action test. *Behaviour* **149**, 111–132.
725 (doi:10.1163/156853912X629148)
726 40. Conradt L, Roper TJ. 2005 Consensus decision making in animals. *Trends Ecol. Evol.* **20**, 449–
727 456. (doi:10.1016/j.tree.2005.05.008)
728 41. Conradt L, Roper TJ. 2003 Group decision-making in animals. *Nature* **421**, 155–158.
729 (doi:10.1038/nature01294)
730 42. Schjelderup-Ebbe, T. 1922 Beiträge zur Sozialpsychologie des Haushuhns. *Zeitschrift für*
731 *Psychol. und Physiol. der Sinnesorgane. Abt. 1. Zeitschrift für Psychol.*
732 43. Schenkel R. 1967 Submission: Its features and function in the wolf and dog. *Integr. Comp. Biol.*
733 **7**, 319–329. (doi:10.1093/icb/7.2.319)
734 44. Cafazzo S, Lazzaroni M, Marshall-Pescini S. 2016 Dominance relationships in a family pack of
735 captive arctic wolves (Canis lupus arctos): the influence of competition for food, age and sex.
736 *PeerJ* **4**, e2707. (doi:10.7717/peerj.2707)
737 45. Lisberg AE, Snowdon CT. 2011 Effects of sex, social status and gonadectomy on
738 countermarking by domestic dogs, Canis familiaris. *Anim. Behav.* **81**, 757–764.
739 (doi:10.1016/j.anbehav.2011.01.006)
740 46. Landsberg GM, Hunthausen WL, Ackerman LJ. 2003 The effects of aging on behavior in senior
741 pets. In *Behavior Problems of the Dog and Cat* (ed Saunders), pp. 269–280. Philadelphia, PA:
742 Elsevier Health Sciences.
743 47. Cafazzo S, Valsecchi P, Bonanni R, Natoli E. 2010 Dominance in relation to age, sex, and
744 competitive contexts in a group of free-ranging domestic dogs. *Behav. Ecol.* **21**, 443–455.
745 (doi:10.1093/beheco/arq001)
746 48. Mertens PA. 2002 Canine aggression. In *BSAVA Manual of Canine and Feline Behavioural*
747 *Medicine* (eds DF Horwitz, DS Mills, S Heath), pp. 195–215. Quedgeley, UK: BSAVA.
748 49. Shepherd K. 2002 Development of behaviour, social behaviour and communication in dogs. In
749 *BSAVA Manual of Canine and Feline Behavioural Medicine* (eds DF Horwitz, DS Mills, S Heath),

pp. 8–20. Quedgeley, UK: BSAVA.

50. Wright HF, Mills DS, Pollux PMJ. 2011 Development and validation of a psychometric tool for assessing impulsivity in the domestic dog (Canis familiaris). *Int. J.* , 210–225.

51. King C, Smith TJ, Grandin T, Borchelt P. 2016 Anxiety and impulsivity: Factors associated with premature graying in young dogs. *Appl. Anim. Behav. Sci.* **185**, 78–85. (doi:10.1016/j.applanim.2016.09.013)

52. Peterson RO, Jacobs AK, Drummer TD, Mech LD, Smith DW. 2002 Leadership behavior in relation to dominance and reproductive status in gray wolves, Canis lupus. *Can. J. Zool.* **80**, 1405–1412. (doi:10.1139/z02-124)

53. Wright JC, Nesselrote MS. 1987 Classification of behavior problems in dogs: Distributions of age, breed, sex and reproductive status. *Appl. Anim. Behav. Sci.* **19**, 169–178. (doi:10.1016/0168-1591(87)90213-9)

54. Le Boeuf BJ. 1970 Copulatory and aggressive behavior in the prepuberally castrated dog. *Horm. Behav.* **1**, 127–136. (doi:10.1016/0018-506X(70)90005-X)

55. Dunbar I, Buehler M. 1980 A masking effect of urine from male dogs. *Appl. Anim. Ethol.* **6**, 297–301. (doi:10.1016/0304-3762(80)90030-9)

56. Daniels TJ. 1983 The social organization of free-ranging urban dogs. II. estrous groups and the mating system. *Appl. Anim. Ethol.* **10**, 365–373. (doi:10.1016/0304-3762(83)90185-2)

57. Hawley PH, Little TD, Card NN. 2008 The myth of the alpha male: A new look at dominance-related beliefs and behaviors among adolescent males and females. *Int. J. Behav. Dev.* **32**, 76–88. (doi:10.1177/0165025407084054)

58. Hawley PH. 2002 Social dominance and prosocial and coercive strategies of resource control in preschoolers. *Int. J. Behav. Dev.* **26**, 167–176. (doi:10.1080/01650250042000726)

59. Egenvall A, Hagman R, Bonnett BN, Hedhammar A, Olson P, Lagerstedt A-S. 2001 Breed Risk of Pyometra in Insured Dogs in Sweden. *J. Vet. Intern. Med.* **15**, 530–538. (doi:10.1111/j.1939-1676.2001.tb01587.x)

776 60. Johnston S., Kamolpatana K, Root-Kustritz M., Johnston G. 2000 Prostatic disorders in the dog.
777 *Anim. Reprod. Sci.* **60–61**, 405–415. (doi:10.1016/S0378-4320(00)00101-9)
778 61. Drake AG, Klingenberg CP. 2010 Large-Scale Diversification of Skull Shape in Domestic Dogs:
779 Disparity and Modularity. *Am. Nat.* **175**, 289–301. (doi:10.1086/650372)
780 62. Frynta D, Baudyšová J, Hradcová P, Faltusová K, Kratochvíl L. 2012 Allometry of Sexual Size
781 Dimorphism in Domestic Dog. *PLoS One* **7**, 5–10. (doi:10.1371/journal.pone.0046125)
782 63. Blackshaw JK, Day C. 1994 Attitudes of dog owners to neutering pets: demographic data and
783 effects of owner attitudes. *Aust. Vet. J.* **71**, 113–6. (doi:10.1111/j.1751-0813.1994.tb03351.x)