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ORIGINAL PAPER

Do dogs exhibit jealous behaviors when their owner attends to their companion dog?

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Abstract

Jealousy appears to have clear adaptive functions across species: it emerges when an important social relationship with a valued social partner is threatened by third-party that is perceived as a rival. Dyads of dogs living together and their owners were tested adapting a procedure devised to study jealousy in young human siblings. Owners at first ignored both dogs while reading a magazine (Control episode), and then petted and praised one of the dogs while ignoring the other, and vice versa (Experimental episodes). We found several differences in the dogs' behavior between the Experimental episodes and the Control episode, even though only monitoring (gazing at the owner) was exhibited for a significantly greater amount of time in the Experimental episodes. Remarkable individual behavioral differences emerged, suggesting that the dogs' reactions could be influenced by the relationships that they establish with their owner and the companion dog. Overall, current results do not clearly support our prediction that the ignored dogs would exhibit more behaviors aimed at regaining the owner's attention when their owner directed attention and care to a companion dog, compared to the control situation. The great intra- and inter-dyad behavioral variability and the choice to test cohabiting dogs could have prevented the emergence of a clear jealous reaction. These findings do not exclude that dogs may exhibit a primordial form of jealousy in a realistic situation, but an additional research is needed to fully gauge which situations, if any, could trigger jealousy in dogs and to rule out alternative explanations.

Keywords Dog · Emotions · Jealousy · Dog–human relationship · Individual differences

Introduction

Despite the increasing interest in understanding emotions in non-human animals, to date, only a limited number of studies have investigated the presence of "secondary emotions" in species other than humans, providing contrasting results (Horowitz 2009; Custance and Mayer 2012; Hetch et al. 2012; Steiner and Redish 2014; Harris and Prouvost 2014; Panskepp and Panskepp 2013; de Waal and Preston 2017; Kujala 2017). Indeed, the belief that "secondary emotions", such as empathy, guilt, and jealousy, are restricted to relatively mature humans and other non-human primates is still widespread (e.g., Lewis 2008), since these emotions seem to require some sense of the self and the ability to interpret social situations (Leary 2003).

However, it is likely that, along with "primary" emotions, at least some "secondary" social emotions have evolved in non-human species to regulate inter-individual social relations (Cubicciotti and Mason 1978; Panskepp 2010; Palagi et al. 2015; de Waal and Preston 2017; Maninger et al. 2017). A growing body of evidence indicates that many social animals form complex social relationships with their conspecifics, which vary in function, duration, exclusivity, and emotional involvement (Mitani 2009; Dunbar and Schultz 2010; Massen et al. 2010). There is also evidence that animals may have knowledge of their own and others' relationships over time and adapt their behavior accordingly (Schino and Aureli 2009; Seyfarth and Cheney 2012). Social relationships are highly adaptive, as they ensure basic (e.g., food and shelter) and social (e.g., emotional support

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and stress alleviation) needs and are mediated by emotional states that are both causes and consequences of social interactions (Aureli and Schino 2004; de Waal 2008; Seyfarth and Cheney 2012).

According to the human psychological literature, jealousy is a complex social emotion that involves an array of more basic emotions and arises in a specific social context, namely when one individual believes or perceives that another individual (a rival) is threatening an affectional relationship that is source of material and psychological benefits (Hart 2010; Pansksepp 2010; Dillon 2013).

Jealousy entails primary emotions (e.g., fear, anger, and sadness), which appear to be present in a variety of mammalian species (Plutchik 2001; Panksepp 2011), and is expressed through overt behaviors (labeled jealous behaviors) aimed at restoring or maintaining the relationships being challenged (Harris 2003; Hart 2010). These emotional processes and behavioral displays appear to characterize jealousy in different types of human social bonds, like the one between friends or peers, romantic partners, and between infant and mother (Harris 2004; DeSteno et al. 2006; Dillon 2013).

Several studies show that human infants, starting from 6 months of age, become troubled and vocalize when their mother directs her attention and care to an infant-like doll or to a sibling, approach and gaze at her maintaining close proximity, and touch/push the social competitor (doll/sibling); in some cases, their response escalates to aggressive reactions directed either towards the social rival or towards the mother (Teti and Ablard 1989; Hart et al. 1998, 2004; Miller et al. 2000; Hart and Carrington 2002; Volling et al. 2010). These behavioral responses are considered expressions of a primordial form of jealousy, as they combine both attention-seeking and protests reactions aimed at regaining the mother's attention (Mize et al. 2014; Hart 2016).

Overall, developmental research provides evidence that jealousy is an early arising emotion and supports the emerging view (Harris 2003; Hobson 2010) that a primordial form of jealousy could exist without entailing a fully fledged sense of the self or complex interpretations of social situations and others' intentions (Harris 2004). Indeed, cognitively immature infants are sensitive to the loss of maternal attention and react to potential threats to the relationship with their attachment figure before reaching the cognitive and representational complexity that characterizes jealousy in older infants and, later, in adults (Frijda 1993; Goldie 2000, p. 45; Hobson 2012). Moreover, authors suggest that this emotion could have evolved to protect material and affective resources within the parent–offspring relationship (Hart 2016), possibly to cope with situations in which the survival/fitness of an individual is threatened by the presence of a rival. The evolutionary/functional view of jealousy in human infants and the possibility that jealousy could exist along with different levels of cognitive complexity has relevant theoretical implications for comparative research. Because social inclusion is essential for the survival of group-living animals, threats to social bonds (e.g., forced separation, being excluded from desired relationships) activate specific emotional responses. Different species show behaviors that allow to reduce the risk of social exclusion and relationship disruption (i.e., post-conflict affiliation, consolation; Aureli et al. 2002; Cools et al 2008; Fraser et al. 2008, 2009; Palagi and Cordoni 2009; Fraser and Bugnyar 2010). Many non-human animals face situations that require defending important social resources from potential rivals (Draghi-Lorenz et al. 2001; Harris 2004; Panskepp 2010), which could explain the existence of a primordial form of jealousy in some social animals (Forbes 2010).

Among domestic animals, dogs (*Canis lupus familiaris*) have rather sophisticated socio-cognitive abilities, which, in some cases, parallel those reported for human infants (Prato-Previde et al. 2003; Lakatos et al. 2009; Tomasello and Kaminski 2009; Marshall et al. 2013), and their emotional life is gradually being uncovered (Kujala 2017). They seem to respond to unequal treatments (Range et al. 2009; Horowitz 2012; Brucks et al. 2016; Essler et al. 2017) and appear to be sensitive to others' distress and social exclusion (Cools et al. 2008; Palagi and Cordoni 2009; Quervel-Chaumette et al. 2016). Dogs live in close contact with humans, rely on them for both material and psychological needs (Miklósi et al. 2000; Merola et al. 2012a, b; Gácsi et al. 2013), and form stable relationships and bonds with specific individuals, showing separation distress and behaviors aimed at regaining and maintaining proximity when involuntary separations take place from the attachment figure (for a review: Prato-Previde and Valsecchi 2014). In this perspective, dogs are suitable subjects to investigate the existence of jealousy in non-primate species and, thanks to their long-lasting relationship with humans, they provide a unique opportunity to investigate jealousy within interspecific social contexts.

If jealousy has evolved to defend exclusive relationships and important resources that flow through them (Harris 2004; Panskepp 2010; Dillon 2013) and jealous behavior has the function to facilitate the maintenance of an important social relationship, its expression in dogs would be adaptive in the human/familiar "niche" to protect the relationship with their human companions. Indeed, pet-owners claim that their dogs show jealousy when they affectionately interact with another dog or another person (Morris et al. 2008, 2012; Martens et al. 2016).

The presence of a primordial form of jealousy in dogs was recently examined using a procedure in which either the owner alone (Harris and Prouvost 2014) or the owner and an unfamiliar person (Prato-Previde and Nicotra et al. 2018) affectionately interacted with a stuffed dog or other objects, while ignoring the experimental dog. These studies provided

contrasting results on whether dogs considered a faux dog as a potential rival and their behavior could be explained in terms of jealousy. In particular, Harris and Prouvost (2014) reported that dogs exhibited a pattern of behavior that could appear indicative of jealousy (e.g., aggressive behavior and pushing/touching the object/owner) when their owner manipulated the stuffed dog, but not the other objects (i.e., a jack-o-lantern and a book). Conversely, Prato-Previde et al. (2018) found no clear evidence that dogs considered the faux dog as real social rival and reported no differentiated response in dogs when the owner (i.e., their attachment figure) and an unfamiliar person manipulated the faux dog compared to other objects (i.e., a puppet and a book). However, both Harris and Prouvost (2014) and Prato-Previde et al. (2018) agreed that a more realistic situation involving a real interloper would have been more appropriate to investigate the existence of a primordial form of jealousy in dogs.

This topic is gaining attention among researchers, since, in only a few months, three studies were carried out simultaneously (Abdai et al. 2018; Prato-Previde et al. 2018; present study). Abdai and colleagues (2018) tested the hypothesis that jealous behavior can be evoked in dogs, using real dogs as social test partners and objects as non-social test partners. Their dogs showed more jealous behavior, i.e., owner-oriented behavior and attempts to interrupt the interaction, in the social (a real dog) compared to the non-social (inanimate objects) situations, and thus, they concluded that "jealous" behavior emerges in dogs and it is functionally similar to that observed in children in similar situations. Although these results are interesting in essence, they are not so different from our previous outcome in which dogs ignored the non-social stimulus (i.e., the book; Prato-Previde et al. 2018). As we argued in the discussion of our data, the use of a real dog, instead of a fake one, elicited more intense jealous behaviors (Abdai et al. 2018).

In the meanwhile, based on our previous findings (Prato-Previde et al. 2018), we chose to investigate whether, in a triadic social context (two companion dogs with their owner), dogs would show jealous behavior when ignored in favor of the companion dog. The testing procedure was adapted from studies conducted on young human siblings to investigate jealousy towards their parent (Miller et. al 2000; Volling et al. 2002). Likewise, our procedure involved two dogs with the same owner; owners at first ignored both dogs while reading a magazine (control episodes), and then petted and praised one of the dogs while ignoring the other, and vice versa (experimental episodes).

We predicted that if the ignored dogs perceived the other dog as a threat to the relationship with their owner, they would engage in behaviors aimed at regaining the owners' attention, such as gazing, vocalizing, and touching/pushing the owner and/or the other dog. As these behaviors may be considered an expression of a primordial form of jealousy (Hart et al. 2004; Morris et al. 2008; Harris and Prouvost 2014; Abdai et al. 2018; Prato-Previde et al. 2018), we expected that they would not occur, or occur to a lesser extent when the dogs were simultaneously ignored by the owner.

Methods

Subjects

The experiment was conducted on 25 dyads of dogs living in the same household with their owner. In 4 dyads, the owner was not able to pet one or both dogs, failing to respect the testing procedure: these dyads were excluded from the analyses, and thus, the final sample included 21 dyads of dogs that accepted to be petted (24 females and 18 males; age range in years = 2–14; age range in months = 24–168; mean age = 72.55 months; SD = 36.22 months; characteristics of dogs are reported in Table 1). Owners were volunteers recruited by personal contact, word of mouth and advertisements distributed within the Università degli Studi di Milano. The criteria for including dogs in the study were: being at least 2 years old, cohabiting with the companion dog and the owner for at least 1 year, being healthy and not aggressive.

Dogs had been living with the owner on average for 5 years (59.76 months; SD = 31.16 months) and with the cohabitant dog for an average of 3.8 years (46.19 months; SD = 25.29 months). One dyad was made of brother and sister, one dyad of mother and son, and one dyad of half-brothers; dogs in the remaining dyads were not blood related.

Setting and procedure

Testing took place in a room (4.5 × 3.5 m) at the "Canis sapiens Lab" of the Università degli Studi di Milano. The room was equipped with one chair for the owner, a small plastic table located next to the chair where a magazine was placed, a water bowl, a computer positioned on a small table, and an HD video camera placed on a wall in a corner of the room to record the test.

Upon arrival, owners signed a consent form and filled up a questionnaire with information about the dogs (e.g., age, breed, training experience, lifestyle, and period of cohabitation). The owner and the two dogs then entered the testing room and, while the experimenter explained the test procedure to the owner, the dogs were free to explore the room for approximately 10 min. Owners were thoroughly illustrated how to behave and were guided throughout the procedure by a PowerPoint presentation that provided timing and written instructions. After the experimenter left the room, the test started according to the following sequence:

Table 1 Breed, age, and sex information about subjects and dyads' composition

Dyad dog 1				Dyad dog 2			
Sex	Age (months)	FCI breeds' nomenclature	Time living with owner (months)	Sex	Age (months)	FCI breeds' nomenclature	Time living with owner (months)
F	58	Mixbreed	56	F	96	Deutscher boxer	90
M	60	Mixbreed	59	M	36	Border collie	34
F	27	Mixbreed	19	F	24	Mixbreed	21
M	36	Mixbreed	31	F	54	Mixbreed	29
F	84	Mixbreed	36	F	96	Segugio italiano a pelo raso	72
F	24	Zwergschnauzer	24	F	84	Bouledogue français	84
F	38	Chihuahueño	35	M	54	Chihuahueño	51
M	65	Piccolo levriero italiano	63	F	55	Piccolo levriero italiano	53
F	84	American cocker spaniel	48	M	144	Cane corso italiano	60
F	24	Weimaraner	23	M	36	Weimaraner	15
F	108	Pug	110	F	132	Mixbreed	138
M	60	Mixbreed	60	M	60	Mixbreed	51
M	96	Border collie	94	F	66	Mixbreed	43
F	168	Mixbreed	30	F	48	Mixbreed	48
F	60	Collie rough	63	F	30	Collie rough	28
M	96	Fox terrier (smooth)	93	M	96	Fox terrier (smooth)	93
F	33	Australian sheperd	30	M	144	Mixbreed	132
M	84	Beagle	61	M	108	Beagle	73
F	109	Labrador retriever	21	F	24	Labrador retriever	21
M	96	English cocker spaniel	96	M	72	Mixbreed	72
M	90	Labrador retriever	90	F	90	Labrador retriever	90

1. Initial episode (1 min): both dogs were ignored and the owner walked around the room paying attention to the posters on the walls;
2. Control episode 1 (1 min, C1): as instructed, the owner sat on the chair reading a magazine, not looking at the dogs nor interacting with them, regardless of their behavior;
3. Experimental episode 1 (1 min, E1): the owner, remaining seated, called one of the two dogs and started to pet and praise him/her, while ignoring the other dog (Ignored Dog 1, hereinafter indicated as ID1). The owner was instructed not to play nor embrace the dog, but could recall the dog if he/she would walk away;
4. Interval episode (1 min): the owner walked away from the chair, called both dogs and greeted them, and then walked around the room ignoring the dogs. This interval was aimed at avoiding, or at least reducing, any potential carryover effects from the Experimental episode;
5. Control episode 2 (1 min, C2): the owner sat on the chair reading the magazine and ignoring both dogs, as in C1;
6. Experimental episode 2 (1 min, E2): the owner acted as in E1, but switched his/her attention to the other dog, while ignoring the dog that received positive attention in the previous Experimental episode (Ignored Dog 2, hereinafter indicated as ID2).

Data collection and analysis

All tests were video recorded and analyzed using Solomon Coder beta® 15.01.13 (ELTE TTK, Hungary). Dogs' behaviors were coded during the C1, C2, E1, and E2 episodes, recording their duration and/or occurrences according to the ethogram reported in Table 2. The ethogram was compiled after a first video analysis and was partially based on studies on jealousy in human infants (Hart et al. 2004; Mize et al. 2014) and dogs (Harris and Prouvost 2014; Prato-Previde et al. 2018). The behavioral analysis was carried out on both dogs in the C1 and C2 episodes, and only on the ignored dog in the E1 and E2 episodes. In the statistical analysis E1 and E2 were considered as a unique episode, and the order of being ignored was used as factor (ID1 and ID2).

The duration of the test episodes slightly varied in length due to the owners' differences in readiness to follow the instructions; therefore, durations and frequencies of all behaviors were transformed in percentages of the total time and of total occurrences, respectively, and used as dependent variables in the statistical analysis.

Inter-observer agreement was assessed by means of independent parallel coding of a random sample of 21 dogs out of 42 (50% of the total number of dogs). Agreement was assessed by Spearman correlation and was significant

Table 2 Behavioral categories recorded during the control episodes (C1 and C2) and the experimental episodes (E1 and E2)

Category	Definition
Dog–dog interplay[a]	Any interaction involving both dogs and being reciprocated such as playing, sniffing, chasing, and physical contact
Interaction with owner[a]	Walking, standing, or sitting between the owner and the other dog, nudging the owner with paw or muzzle, pushing, biting, and jumping on the owner, or sniffing/licking him/her
Interaction with dog[a]	Nudging the other dog with paw or muzzle, pushing, biting and jumping on the other dog or sniffing, licking him/her
Monitor the owner[a]	Gazing at the owner while being close or from a distance
Proximity to owner[a]	Remaining close to the owner without gazing at him/her
Other[a]	Any behavior not included in the ethogram (e.g. exploring, walking around, drinking, looking at the door)
Stress signals[b]	Stress related behaviors, such as paw raising, nose-lip licking, shaking, yawning and scratching
Vocal behavior[b]	All types of vocalizations such as barking, growling and whining
Interaction disrupted[bc]	The interaction between the owner and the other dog was disrupted by the ID

[a]Behaviors recorded as durations

[b]Behaviors recorded as frequencies

[c]Behavior recorded only in experimental episodes

for all behaviors, with ρ_s ranging from 0.65 to 0.967 and p ranging from 0.02 to 0.0001.

Models residuals did not meet the required assumption of normality and homoscedasticity: thus, we chose to run Wilcox's robust statistical analysis, based on trimmed means (Mair et al. 2017). Robust between-groups ANCOVAs were carried out on all behaviors expressed in the Control and Experimental episodes to assess the effect of dog's sex and length of cohabitation of the dogs with their owner (months, used as covariate). Since no significant differences in behavior were found between C1 and C2, the data collected in these episodes were averaged into a single control episode (C) for the following analyses. Robust repeated-measures ANOVAs with order (ID1 and ID2) as between-groups effect and episodes (C and E) as within-subjects effect were carried out.

A K-mean cluster analysis was carried out on the E episode to group our dogs according to their most characterizing behaviors. Robust repeated-measures ANOVAs were carried out to evaluate any difference in the expression of those behaviors emerging from the cluster analysis.

All analyses were performed in R 3.2.5 (R Core Team 2016), using the WRS package functions (Mair et al. 2017) t2way for two-way ANOVAs, ancova for ANCOVAs, bwtrim for two-way mixed repeated-measures ANOVAs, t1way for one-way ANOVAs, rmanova and rmmcp for repeated-measures ANOVAs and pairwise post hoc test, respectively. The effect size was estimated using the robust coefficient (analog to the ξ^2 explicative measure) proposed by Rand, Wilcox, and Tian (2011), based on 20% trimmed mean and Winsorized variance; authors suggest that ESs = 0.15–0.35 and 0.50 should be judged as small, medium, and large effects, respectively.

Results

Dogs reacted to the experimental situation with a high behavioral variability: while almost all subjects showed proximity to the owner and monitor (proximity: 83 and 88% of dogs in the C and E episodes, respectively; monitor: 100% of dogs in both the C and E episodes), interaction with the owner was exhibited by 67 and 64% of the dogs in the E and the C episodes, respectively. A more limited number of dogs (26% in the E episode; 28% in the C episode) interacted with the companion dog either in a gentle manner (sniffing, licking, nudging with paw or muzzle, and gently biting the other dog) or in a more rough way (i.e., pushing, biting, and jumping on the other dog).

Although dogs showed stress-related behaviors in both the E and the C episodes (59 and 57% of dogs, respectively), the frequency of these behaviors was very low (mean E = 1.78 event/min; mean C = 1.63 event/min). Similarly, vocalizations were limited, with only 11 dogs out of 42 (26%) engaging in vocal behavior during the E episode and 9 out of 42 (21%) in the C episode (mean E = 5.28 event/min; mean C = 3.0 event/min). Interplay between dogs, involving both dogs and being reciprocated (i.e., playing, sniffing, chasing, and physical contact) was rare, with only 4 dyads showing it in the E episode and 4 dyads in the C episode.

In the E episode, only 9 out of 42 dogs (21.42%, 5 large size dogs, 3 medium size dogs, and 1 small size dog) caused the interruption of the affectionate interaction between the owner and the companion dog.

The statistical analysis showed that there was no significant effect ($p > 0.05$) of dogs' sex and length of

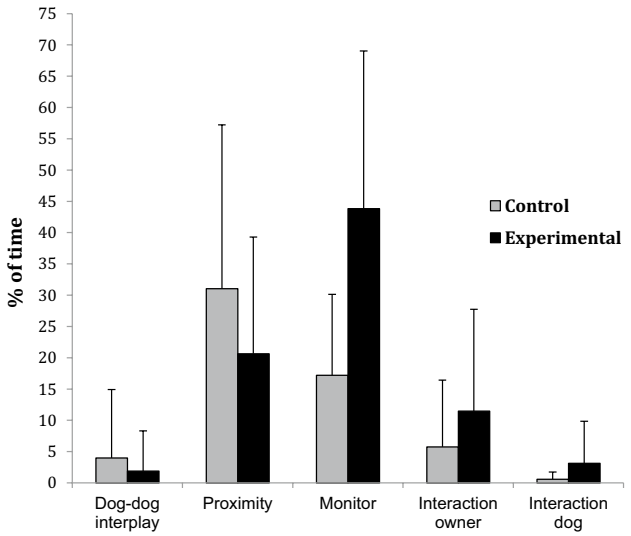

Fig. 1 Mean percentage of time (+SD) spent by dogs in different behaviors in the Control (C) and Experimental (E) episodes

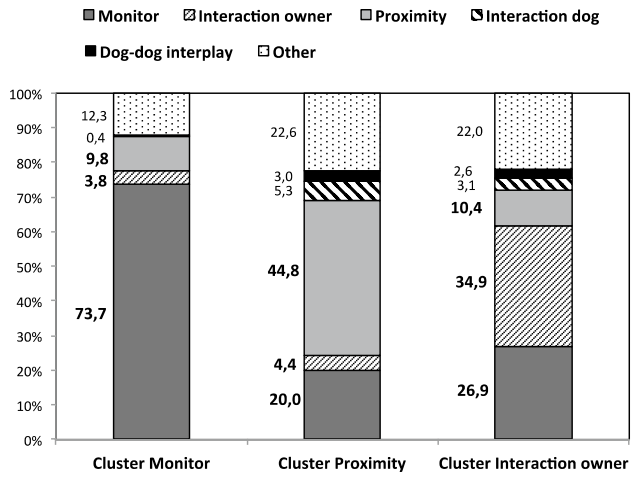

Fig. 2 Behavioral categories measured as duration (% of time) included in Cluster 1 (monitor), Cluster 2 (proximity), and Cluster 3 (interaction with owner)

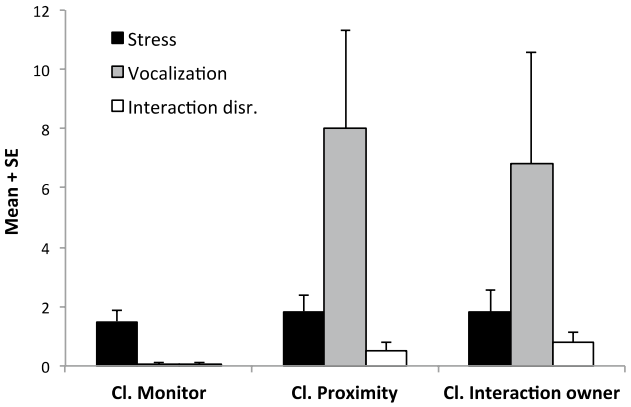

Fig. 3 Mean frequency (+SE) of stress-related behaviors, vocalizations, and interaction disruption included in Cluster 1 (monitor), Cluster 2 (proximity), and Cluster 3 (interaction with owner)

cohabitation of the dogs with the owner for any of the behaviors considered (Robust ANCOVA, trimmed means = 0.2).

As shown in Fig. 1, there were some differences in the expressions of the behaviors between the Control episode (C) and the Experimental episode (E): in particular, dogs remained in proximity of the owner and engaged in dog–dog interplay longer in the C episode than in the E episodes, whereas they spent more time in owner and dog interaction and in monitor in the E episodes than in the C episode. Robust-mixed repeated-measures ANOVAs revealed that the order of being ignored did not affect any behavior. Despite the differences emerged in the expression of proximity, monitor, owner, and dog interaction, a significant principal effect of Episode emerged only for the behavior Monitor [$F(1;39) = 23.0787$, $p = 0.0003$; Fig. 1].

To have an insight on individual behavioral patterns emerging during the Experimental episode, all behavioral variables were scaled and put into a K-mean cluster analysis. The plot of the within cluster sum-of-square suggested that the optimal solution, harmonizing simplicity and sensibility, could be a three clusters partitioning, labeled on the basis of the prevailing behavior as follows: Cluster 1—monitor behavior, Cluster 2—proximity, and Cluster 3—interaction with owner (Fig. 2). As shown in Fig. 3, the occurrence of stress-related signals is similar in the three Clusters; however, differently from Clusters 2 and 3, vocalization and interruption of the interaction between the owner and the petted dog are absent in Cluster 1 (Fig. 3).

Fourteen dogs (33.33%) fitted into Cluster 1 (Monitor behavior), 18 (48.86%) into Cluster 2 (Proximity), and 10 (23.81%) into Cluster 3 (Interaction with owner). In 8 dyads

Table 3 Distribution of dogs' dyad fitting in each of the nine possible combinations of clusters expressed as frequency (%)

	ID2's cluster		
	Monitor (Cl. 1)	Proximity (Cl. 2)	Interaction with owner (Cl. 3)
ID1's cluster			
Monitor (Cl. 1)	2 (9.52)	4 (19.04)	1 (4.76)
Proximity (Cl. 2)	3 (14.28)	4 (19.04)	1 (4.76)
Interaction with owner (Cl. 3)	2 (9.52)	2 (9.52)	2 (9.52)

out of 21 (38,10%), both dogs fitted in the same Cluster (2 dyads included dogs of Cluster 1, 4 dyads included dogs of Cluster 2, and 2 dyads included dogs of Cluster 3), while, in the remaining dyads, all the other possible combinations were found (Table 3).

Robust repeated-measures ANOVAs were carried out on the behaviors identified by the cluster analysis and revealed significant differences in the expression of Proximity, Monitor, and Interaction with owner, for both dogs of dyads [ID1: $F_{t(1.85,22.23)} = 5.33$, $p = 0.014$, ES = 0.16; ID2: $F_{t(1.62,19.44)} = 11.93$, $p < 0.001$, ES = 0.16].

Robust pairwise post hoc comparisons, following Holm's approach to alpha correction, showed, for ID1, a significant difference between Monitor and Interaction with owner, and for ID2 significant differences between Monitor versus Proximity and between Monitor versus Interaction with owner (Table 4).

Discussion

Although the belief that dogs are capable of jealousy is well rooted among people and dog owners (Morris et al. 2008, 2012; Martens et al. 2016), experimental evidence is limited and provides contrasting results (Harris and Prouvost 2014; Abdai et al. 2018; Prato-Previde et al. 2018).

This study aimed at further investigating whether dogs would exhibit jealous behaviors (Hart 2010, 2015; Abdai et al. 2018) in a realistic situation involving a real dog as an interloper. Adapting a procedure devised to assess jealousy towards the mother/father in human infants (Miller et. al 2000; Volling et al. 2002), we assessed the behavioral patterns exhibited by the dogs when they were ignored, while their owners displayed affection to their companion dog. We compared the behaviors of dogs in the experimental situation with their behavior in a control situation in which they were simultaneously ignored by the owner. We expected that if, in the Experimental situation, the dogs perceived their companion dog as a potential rival, they would show patterns of behavior that should not occur, or occur to a lesser extent, when they were simultaneously ignored by the owner.

We found a number of differences in the behavioral patterns exhibited by the dogs: in the Experimental episodes, the dogs showed less proximity to the owner, more monitoring and more interaction with the owner and the other dog, compared to the Control episode; however, these differences did not reach statistical significance, except for monitor behavior and this could be due to the great intra- and inter-dyad variability. Only a minority of dogs attracted their owners' attention by barking and/or whining and this occurred mainly in the E episode, suggesting that vocalizing could be part of an individual attention getting strategy (see below). Frequency of stress-related signals was very low and expressed to a comparable extent across the episodes, providing evidence that dogs did not perceive the testing situation as very stressful.

Even though the behaviors exhibited by the dogs in our Experimental episodes are similar to those observed in human infants when their parent interacts with a sibling (Volling et al. 2002, 2014) and in dogs when disregarded by the owner (Harris and Prouvost 2014; Abdai et al. 2018; Prato-Previde et al. 2018), overall, our results do not clearly support the conclusion that dogs exhibited a primordial form of jealousy. Indeed, differently from what predicted, the behaviors shown by the dogs in the E episodes were exhibited to a certain extent also in the C episode when the owner simultaneously ignored both dogs while reading a magazine.

Human research suggests that during jealousy-evoking situations' infants express various behaviors, including approaching the caregiver, attention-provoking actions, visual attention/gazing at the caregiver, interposing themselves between the caregiver and the rival (Miller et al. 2000; Harmon-Jones et al. 2009; Dillon 2013). In the Experimental episodes, our dogs significantly increased the time spent

Table 4 Statistical values of pairwise post hoc *t* tests

	Δ	95% CI	*p* value	critical *p*	H_0
ID1					
Monitor vs					
Proximity	17.48	− 10.83 to 45.81	0.112	0.025	Accepted
Interaction with owner	26.13	0.14 to 52.39	0.015	0.017	Rejected
Proximity vs					
Interaction with owner	12.29	− 8.31 to 32.90	0.123	0.05	Accepted
ID2					
Monitor vs					
Proximity	25.71	1.88 to 54.29	0.024	0.025	Rejected
Interaction with owner	34.78	14.69 to 54.87	< 0.001	0.017	Rejected
Proximity vs					
Interaction with owner	7.08	− 5.42 to 19.57	0.141	0.05	Accepted

monitoring the owner, a behavior considered to be an indicator of a primordial form of jealousy also in dogs (interest/attention in Harris and Provoust 2014; oriented/looking in Abdai et al. 2018). Although monitoring per se does not provide sufficient evidence that dogs were expressing a primordial form of jealousy, it does indicate sustained social attention, which is considered a component of a jealousy reaction in humans. A more parsimonious explanation could be that dogs' attention and gazing were facilitated by the actions initiated by the owner. Mehrkam et al. (2014) reported an increase in intraspecific affiliative and play behavior in wolf and wolf-dog crosses hosted in a sanctuary when in the presence of a caretaker interacting with them. However, in our opinion, social facilitation is not sufficient to explain why our dogs significantly increased monitoring rather than joining the ongoing interaction between the owner and the companion dog.

Across the entire experiment, it emerged that behaviors such as monitoring and maintaining proximity prevailed over interactive behaviors. It should be underlined that our sample of dogs included well-rooted dyads, composed by adult dogs living together with the owner for at least 1 year. It can be supposed that our dogs were used to attend and monitor the interaction between their owner and their companion dogs, "waiting for their turn". It is also worth noting that, while some subjects actively interacted during the Experimental episodes, they preferentially acted upon their owner than on the companion dog, possibly because the owner is the attachment figure and represents their major source of material and psychological benefits. While there is clear evidence that family dogs form an infant-like attachment with their owner, it is unclear whether the relationship with an adult conspecific conforms to an attachment bond (Mariti et al. 2014; Prato Previde and; Valsecchi 2014). Furthermore, cohabiting dogs, to maintain the existing equilibrium, have probably established social dynamics mainly based on prosociality rather than conflicts (Cools et al. 2008; Dale et al. 2016) and this could explain why we found almost no evidence of aggressive behavior. The best strategy to regain their owner's attention and care would be to act on the owner rather than on the other dog pushing him/her away. It is possible that our choice to engage familiar dogs living together, to avoid potential aggressive reactions between unfamiliar subjects, was too restrictive: the high level of familiarity between dogs might have been a bias greater than expected. Interestingly Abdai et al. (2018) found no differences in the behavior of the ignored dog when the owner interacted with either a familiar or an unfamiliar conspecific: this outcome cannot be considered conclusive, since their study lacks of a control situation, included in our study, in which both dogs were simultaneously ignored by the owner to evaluate the effect that the mere loss of owner's attention could have on dogs' behavior.

An interesting result of the current study is the emergence of striking individual differences in the Experimental episodes: a number of dogs reacted more passively monitoring the third-party interaction without vocalizing to attract their owners' attention; the other two groups of dogs showed a more active pattern of responses vocalizing: interrupting the petting of the companion dog and staying in close proximity or acting on the owner. These findings are in agreement with the previous evidence reporting individual differences in dogs' reactions towards a fake dog (Harris and Prouvost 2014; Prato-Previde et al. 2018), and more generally with the literature showing that non-human animals, including dogs, adopt different behavioral strategies to deal with unpleasant and stressful environmental and social situations (Koolhaas et al. 1999; Korte et al. 2005; Horváth et al. 2007; Passalacqua et al. 2013). There are evidences that also children and toddlers adopt different strategies to face jealousy-evoking situations, i.e., high levels of monitoring, disruptive behaviors, or solitary play (Volling et al. 2002, 2014). It has been suggested that behavioral profiles could reflect the type of attachment that the child has with his/her parent: insecurely attached infants, compared to securely attached ones, protest more when their mother interacts with a sibling (Teti and Ablard 1989), while remain in proximity and physical contact with the mother more when she gives attention to an infant-like doll (Hart and Behrens 2013); securely attached children, on the other hand, show less negative and disrupting behaviors when their parents interact with the sibling (Volling et al. 2002). Given that some studies suggest the presence of different attachment styles in dogs when tested in the Strange Situation (Tòpal et al. 1998; Taggart 2010; Schöberl et al. 2016), it is possible that the differences in dogs' behaviors emerged in this study were influenced by the type of attachment the dogs which establish with their owner (e.g., secure vs. insecure).

Behavioral differences in our Experimental situation were also detectable within dog dyads: only within 8 dyads both individuals had similar reactions, whereas, within the majority of dyads, dogs showed diverse patterns of responses. The quality of the relationship between the two dogs and the way which they interact in their normal environment (e.g. dominance/affiliation relationship and resources management) could play a role in the expression of these individual differences (e.g., being more disruptive vs. more attentive). This is supported by the fact that most owners (90%), at the end of the test, declared that their dogs behaved as they expected on the basis of what usually happens at home under similar circumstances.

Overall, the current results do not provide a clear support to our prediction that dogs would show more behaviors aimed at regaining their owner's attention when ignored by the owner in favor of the companion dog (a situation that could trigger jealousy) compared to a control situation (i.e.,

being simultaneously ignored by the owner). It cannot be excluded that the great behavioral variability both intra- and inter-dyads, together with the choice to test cohabiting dogs, may have prevented the emergence of a more clear jealous reactions in our sample of dogs. An alternative explanation could be that dogs were just searching for interaction and owner's attention without experiencing a primordial form of jealousy. Undoubtedly, in the light of all the available data, more research is needed to deepen this topic and to fully gauge which situations, if any, could trigger jealousy in dogs. One possibility could be to use an unfamiliar or a less familiar dog (known but not cohabiting) as interloper-receiving attentions from the owner: this could possibly trigger a stronger reaction than the one emerged in the present study. Another approach could be to compare the reactions of dogs to an unfamiliar person petting the companion dog in presence/absence of the owner: since the function of jealousy appears to protect a valuable relationship from an intruder, it would be expected that an unfamiliar person petting the companion dog would not elicit, or elicit to a lesser extent, a jealous response. However, a procedure involving an unfamiliar interloper or a stranger requires particular caution, since aggression between unfamiliar dogs is more likely to occur than between familiar dogs, and not all adult dogs appreciate being petted by unfamiliar people.

In sum, the current findings do not exclude that dogs may have a primordial form of jealousy, being aware that assuming its existence does not imply making inferences on the subjective experience of the individual. Furthermore, our results underline the general difficulty of unraveling emotions in non-human animals and of devising procedures that are suitable to investigate them.

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Author contributions VN, EPP, and PV developed the study concept. All authors contributed to the study design. Testing and data collection were performed by SFP and EPP. SFP and VN coded the videos. VN, AP, and PV performed the data analysis. All the authors participated in writing and revising the manuscript and approved the final version of the manuscript for submission.

Compliance with ethical standards

Conflict of interest The authors declared that they had no conflicts of interest with respect to their authorship or the publication of this article.

Ethical statement All procedures were performed in full accordance with Italian legal regulations (National Directive n. 26/14—Directive 2010/63/UE) and the guidelines for the treatments of animals in behavioral research and teaching of the Association for the Study of Animal Behavior (ASAB). A written consent to video-record and use data in an anonymous form was obtained by the owners prior to testing.

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