

# Domestic cats' reactions to their owner and an unknown individual petting a potential rival

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**Abstract:** Jealousy is a second-order emotion, its main function being to protect a valued relationship from a rival. A basic form of jealousy has been described in human infants, and its presence in non-human animals has recently been investigated in domestic dogs. The current study assessed whether a primitive form of jealousy can be observed in domestic cats tested using similar procedures to those used with infants and dogs. Fifty-two cats were recruited from either Japanese households or cat cafés. The cats' behaviors were recorded while they saw their owner petting a "social" object (i.e. potential rival: a realistic-looking soft-toy cat) and a non-social object (furry cushion). As jealousy should be expressed in the context of a valued relationship, cat behaviors were also recorded when an unknown experimenter petted the same two objects. Results indicated that cats -- especially household pets -- reacted more intensely toward the soft-toy cat previously petted by their owner. However, cats did not respond differentially toward the two human actors. The absence of other behaviors indicative of jealousy reported in infants and dogs precludes drawing firm conclusions about the existence of jealousy in domestic cats. We consider the existence of some cognitive bases for jealousy to emerge in cats, and the potential effect of cats' living environment on the nature of their attachment to their owner. More ecologically valid procedures are required for further study of these issues.

**Keywords:** Jealousy; Cat; Cat-human bonds; Secondary emotions; Stimulus enhancement

## HIGHLIGHTS

- This is the first study to investigate whether domestic cats show behavioral signs of jealousy concerning their owner.
- Although cats' overall behavior did not correspond to a typical jealousy-like reaction, the data suggest the presence of potential cognitive bases for jealousy in cats.

## INTRODUCTION

Jealousy is defined as a secondary emotion that arises when an important relationship is perceived to be under threat from a potential rival (Hart and Legerstee 2010; Dillon 2013). Jealousy is expressed through an array of behaviors aimed at protecting and maintaining the relationship, and in a variety of contexts including friendship and romance (DeSteno et al. 2006; Harris 2003; Hart and Legerstee 2010; Panksepp 2010b). Due to the supposed complexity of the cognitive abilities required for jealousy to emerge (Leary 2003), this secondary emotion has for long been considered unique to adult humans (Lewis 2008, 2010).

Accumulative evidence from developmental psychology suggests that in infants a primordial and much simpler form of jealousy may exist (for a review see Hart 2016). Several studies (Hart et al. 2004; Hart and Carrington 2002; Mize et al. 2014) have investigated infants' reactions when their mothers interacted with a potential social rival (a realistic-looking doll) compared to a non-social object (a book). They observed that especially with the doll, infants as young as 6 months displayed behaviors indicative of jealousy, including negative affect (angry and sad facial expressions, negative vocalizations), and seeking proximity to the mother (gaze, approach). Moreover, Hart et al. (1998) reported that these jealousy-related behaviors were more evident when the mother (i.e. the attachment figure) interacted with the doll, rather than an unknown individual. These findings provide evidence that infants did not merely react to a loss of the mother's attention, but to the potential threat from a social rival (the doll) to the relationship with the mother.

It has been suggested that jealousy first evolved in humans as simple sibling rivalry (Harris 2004), conferring an advantage for the protection of crucial social relationships and resources (DeSteno et al. 2006; Harris 2004; Panksepp 2010b). In this regard, some authors have argued that rather than being a predetermined and specific emotional state, jealousy might be better construed as a cluster of primary emotions (Abdai et al. 2018; Harmon-Jones et al. 2009; Parrot and Smith 1993). Given that many other non-human animals show primary emotions (Panksepp 2010a; Panksepp and Watt 2011), which have survival value (Dunbar and Schultz 2010; Massen et al. 2010; Mitani 2009), it is conceivable that jealousy might have evolved in other social species (Forbes 2010).

Domesticated animals (e.g. dogs (*Canis lupus familiaris*), cats (*Felis silvestris catus*)) with long-running relationships with humans are good candidate non-human species to study a simple form of jealousy within an inter-specific context (Arahori et al. 2017; Martens et al. 2016; Morris et al. 2008). In the Ainsworth Strange Situation Procedure (ASSP; Ainsworth et al. 1978), dog-owner bonds reflected the "secure attached style" (Palmer and Custance, 2008; Topal et al. 1998), comparable to the attachment of most human infants to their mother (Prato-Previde and Valsecchi 2014). Harris and Prouvost (2014) compared domestic dogs' behaviors when their owners demonstrated affection towards a potential "social" rival (fake dog) and towards non-social objects (jack-o-lantern, book). They reported more jealousy-related behaviors (e.g. attention, attempts to separate, aggression) in the case of the fake dog, which they interpreted as evidence of a primordial form of jealousy in dogs. However, Prato-Previde et al. (2018a) argued that the dogs in Harris and Prouvost (2014) might have been showing territorial behavior, as the tests took place in the dogs' home surroundings. In a laboratory setting, Prato-Previde et al. (2018a) found that dogs showed more interest in a fake dog (potential rival) than other



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objects (puppet, book), but no clear behavioral differences when it was the owner (attachment figure) or a stranger who interacted with these objects. In addition, no other behaviors indicative of jealousy were reported, such as interrupting the owner's interaction with the rival.

Two recent laboratory studies (thus controlling for territoriality) compared dogs' reactions when the owner interacted with a real dog (potential rival) vs. a non-social object. In Abdai et al. (2018) several jealousy-related behaviors (e.g. owner-directed behaviors and attempts to separate the owner from the object) were expressed more often with the real dog (either familiar or unfamiliar), showing a primary form of jealousy. However, in Prato-Previde et al. (2018b) the use of a cohabiting dog as a rival was suggested to be one potential reason why dogs did not show strong evidence of jealousy-like behaviors.

Overall, some slight but potentially important procedural differences across recent attempts to study jealousy in dogs might have led to the inconsistent results. In addition, as jealousy serves to protect a valued relationship, it is a critical to use an unknown individual (with no social bond with the dog) to rule out reactions due to the mere loss of human attention. So far, only Prato-Previde et al. (2018a) have reported on dogs' reactions when a stranger vs. the owner were interacting with various objects.

Domestic cats have shown a preference for their owner over an unknown individual when tested in the ASSP (Potter and Mills 2015). However, it is still unclear whether cats are like dogs in showing secure attachment with their owner (Edwards et al. 2007; Potter and Mills 2015). Potentially distinctive attachment styles between dogs and cats have been related to their different domestication histories (Bradshaw 2016; Jongman 2007). Nevertheless, cats are social animals that establish bonds and relationships with their owners (for a review see Bradshaw 2016). Similar to dogs (see Miklosi 2015 for review), cats are attentive to human attentional states (Ito et al. 2016), discriminate human emotions (Galvan and Vonk 2016), and show signs of distress during involuntary separation from their owners (Schwartz 2002). Moreover, cats can discriminate their owner's voice from a stranger's voice (Saito and Shinozuka 2013) and they show increased interaction with their owner after a long separation (Eriksson et al. 2017).

Interestingly, it has recently been reported that cats' living environment influences their relationships with humans. For example, Saito et al. (2019) reported that cats living in traditional households, as opposed to cat cafés (establishments where customers can freely interact with resident cats), discriminate their own names from those of cohabiting cats. Takagi et al. (2019) found that café cats, but not house cats, anticipated their owner's face after having heard the owner's voice. Overall, although cats clearly do form close social relationships with their owners, the nature of these relationships remains understudied (Eriksson et al. 2017; Rehn and Keeling 2016) compared to those seen in dogs (Mertens 1991; Potter and Mills 2015).

The current study investigated whether cats, despite the unclear nature of their bonds with humans, show a primitive form of jealousy to their owners. Based on studies of infants (Hart et al. 1998; Hart and Carrington 2002) and dogs (Harris and Prouvost 2014; Prato-Previde et al. 2018a), we observed how domestic cats reacted when their owners petted a potential rival (i.e. a "social" object: soft-toy cat) and a non-social object (i.e. furry cushion). In addition, we also observed cats' reactions when a stranger (an unknown experimenter) petted the same two kinds of objects. Finally, to take the living environment into consideration, cats were tested either in conventional households or in cat



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cafés. We expected that if cats possess some kind of jealousy, they should express at least some jealousy-related behaviors (e.g. increased attention, attempts to intervene between the actor and the object) more frequently when their owner petted the social object.

## METHODS

### Subjects

Fifty-seven domestic cats and their owners participated. However, five cats were excluded from the final sample (one because the owner failed to follow the procedure, one due to a video recording problem, and three due to fussiness during the testing procedure). The final sample consisted of 52 domestic cats ranging from 9 months to 17 years of age (mean age = 5.9 years, SD = 4.35; 23 females and 29 males of different breeds; see details in Table S1 in the supplementary information). Cats were individually tested either in their owner's house (N = 25, mean age = 7.3 years, SD = 4.35; 13 females) or in cat cafés where they lived (N = 27; mean age = 4.8 years, SD = 3.64; 10 females). For tests in cat cafés, cats were isolated from the other resident cats, and the café manager played the role of owner.

Inclusion criteria were the same as those used in Eriksson et al. (2017): cats had to be over 6 months old and to have spent most of their life indoors. Also, cats had to have lived with their owners for over 6 months, and to support being manipulated by an unknown human. Owners were recruited from personal acquaintance networks, and prior to testing they gave signed informed consent to their participation. Cats were never food or water deprived during the study, which adhered to the ethical guidelines of Kyoto University and which was approved by the Animal Experiments Committee of the Graduate School of Letters, Kyoto University.

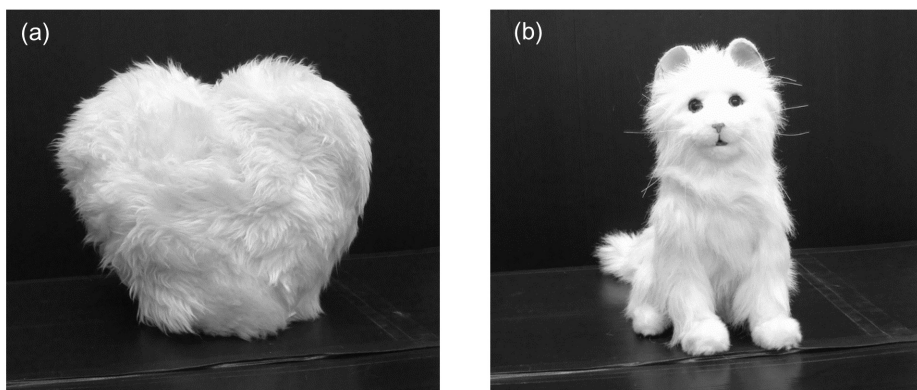
### Objects

Two types of unfamiliar objects, matched for size, color and texture, were used. One was a "non-social" object, consisting of two identical white, furry, heart-shaped cushions (38 x 40 x 20 cm; hereafter referred to as "cushion;" see Figure 1(a)) (one for the owner and one for the stranger). The other type was a "social" object (i.e. the potential rival), in the form of two identical, white, realistic-looking soft-toy cats in a sitting position (Yume Neko by Segatoys; 35 x 18 x 18 (tail excluded) cm; hereafter referred to as "stuffed cat;" see Figure 1(b)).



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**Figure 1. The two kinds of objects used in the present experiment. (a) Furry cushion: the non-social object; (b) Soft-toy cat: the social object**



### Procedure

Before testing, the experimenters explained the procedure to the owner and obtained signed consent. Note that the owner stayed blind to the experimental hypothesis until the end of the entire testing procedure. During the explanations the three experimenters and the owner interacted freely with the cat, and testing only began after approximately 10 min, when the cat showed no signs of anxiety. The experimenter assigned to the role of the stranger was the same sex as the owner.

A 2 (actor identity: owner, stranger)  $\times$  2 (object type: cushion, stuffed cat) within-subjects design was used in which every cat witnessed both actors petting the two different kinds of objects. In total, each cat participated in 8 trials, divided into two conditions. The non-social condition consisted of 4 trials during which the actors petted their cushion, two times per actor and in alternating order (e.g. stranger 1st time, owner 1st time, stranger 2nd time, owner 2nd time). The social condition followed the same procedure and consisted of 4 trials during which the actors alternately petted their stuffed cat twice. The 4 trials in each condition were conducted in a continuous sequence, while the two conditions were separated by a 3-min interval to suppress any carryover effect. During the inter-condition interval, the cat, experimenters and owner were all free to interact. The identity of the first actor to pet the object and the first condition tested were counterbalanced amongst subjects, although the identity of the first petting actor was the same between the two conditions for each subject.

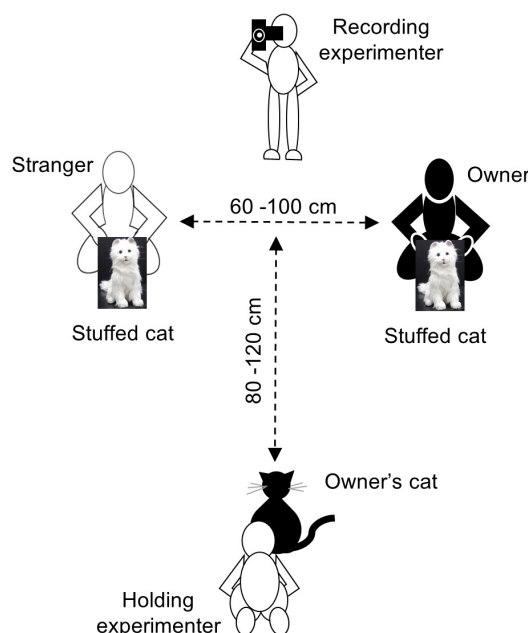
During each trial, the two actors remained seated on the floor next to each other, 60-100 cm apart (see Figure 2), each with an object (a cushion or a stuffed cat) within reach in front of them. When using the stuffed cat, actors were asked to orient its face toward the subject cat. To avoid inadvertent cueing, all experimenters and the owner were asked to ignore the subject cat throughout the trials (i.e. no looking at or touching the cat, or calling its name)

Each trial lasted 45 sec, divided into two phases: a 15-sec observation phase and a 30-sec exploration phase. During the observation phase an actor interacted



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**Figure 2. Illustration of the testing procedure: example of a trial in the social condition. The stranger and the owner alternately pet their stuffed cats in front of the subject cat. The recording experimenter videotaped each trial and the holding experimenter maintained the cat in position only during the petting action**

with (petted) the object for 15 sec, including gently stroking and talking freely and affiliatively (e.g. “Kawaii!”, “Ii ko” which translate into English as: “How cute!”, “Good boy!”) to the object, as if it was a real cat. While one actor was petting, the other maintained a neutral, passive posture (i.e. looking at the floor ahead and without touching the object). During the petting period, the cat was lightly restrained by a second experimenter, centered and facing toward the two actors, 80-120 cm away (see Figure 2). When the petting period ended, the exploration phase immediately started: the cat was released to explore while both actors and the holding experimenter maintained a neutral, passive posture. After the exploration phase ended the cat was returned to its holding place and a next trial started, switching the petting actor.

All trials were video recorded with a digital video camera (Sony DCR- TRV27) by a third experimenter, standing behind the two actors (see Figure 2). Using a stopwatch, the third experimenter also guided the actions of the two actors during the trials.

#### *Behavioral coding*

The videos of all 8 trials per cat were analyzed using Adobe Premiere CS6 (USA) at a rate of 30 frames per sec. Cat behaviors were divided into two categories: oriented towards the objects (of the owner and the stranger), and oriented towards the two actors. Behaviors were coded continuously in term of duration according to the ethogram presented in Table 1.

The ethogram was based on the one used for dogs by Prato-Previde et al. (2018a), but adjusted to suit the current procedure as well as cats’ natural behaviors. As the actors sat on the floor just behind their object during the trials, attention focused on the actor was difficult to distinguish from attention towards the object. Therefore, only attention toward objects was coded, although this potentially also included attention towards the actor. No attempted interventions (moving between the actor and the objects), aggressive behaviors (such as scratch or hiss) or vocalizations occurred during testing; therefore, these behaviors are not presented in the ethogram and were not analyzed.

To assess inter-rater reliability of behavioral coding, two collaborators, blind to the hypothesis, coded different behavioral samples. One collaborator coded attention to the objects and looking at the objects for a random sample of 11 cats (21% of the total sample size), and the other coded proximity to and interaction with the objects and actors for a random sample of 13 cats (25% of the total sample size). Inter-rater reliability was assessed by Pearson’s correlation coefficients;  $r$  values are presented in Table1. Despite a relatively low score for proximity to the stranger ( $r = 0.666$ ), all  $p$  values were significant and less than 0.001.

#### *Statistical Analysis*

For analysis only behavior towards the petting actor’s object or the petting actor was taken into consideration. Moreover, given that in each condition cats were tested twice with the same actor (e.g. cat witnessed the stranger petting the cushion twice) the data for these two trials were averaged and the result was used as the final score duration in each condition. For each behavior a three-way repeated measures ANOVA was performed, with a 2 (environment: cat café, household)  $\times$  2 (actor: owner, stranger)  $\times$  2 (object: cushion, stuffed cat) factor design. Post-hoc pairwise comparisons using Tukey (HSD) tests were used to analyze differences more specifically. Data analysis was conducted



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Table 1. Ethogram used in the current study and coders' inter-reliability

Category	Behavior	Description	Inter-reliability
Object-oriented behavior	Attention to object*	The cat is oriented with the head toward one object and gazes at it, while restrained by the holding experimenter.	$r^{OO} = 0.911$ $r^{SO} = 0.919$
	Looking at the object	The cat gazes at one object with its head oriented toward it, while being able to move freely.	$r^{OO} = 0.925$ $r^{SO} = 0.935$
	Proximity to object	The cat's body (tail excluded) enters an imaginary circle around an object, with a radius of the cat's head length. (Excluding the location between an object and its corresponding actor).	$r^{OO} = 0.978$ $r^{SO} = 0.965$
	Interaction with object	The cat physically contacts an object, including behaviors such as touching (with any body parts except the tail), sniffing, and licking.	$r^{OO} = 0.997$ $r^{SO} = 0.944$
Actor-oriented behavior	Proximity to actor	The cat's body (tail excluded) enters an imaginary circle around an actor, with a radius of the cat's head length. (Excluding the location between an actor and her/his object).	$r^O = 0.869$ $r^S = 0.666$
	Interaction with actor	The cat physically contacts an actor, including behaviors such as touching (with any body parts except the tail), sniffing, and licking.	$r^O = 0.961$ $r^S = 0.778$

\* Attention to object is the only behavior recorded during the observation phase

<sup>OO</sup> Inter-rater reliability for the behavior concerning the owner's object

<sup>SO</sup> Inter-rater reliability for the stranger's object

<sup>O</sup> Inter-rater reliability for the owner

<sup>S</sup> Inter-rater reliability for the stranger



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using R software (version 3.4.2. for Windows, R, R Core Team 2017), and ANOVAs were run using "anovakun" in R software (version 4.8.2)."

## RESULTS

Statistical values of the three-way repeated measures ANOVAs for the six investigated behaviors are reported in Table 2.



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Table 2 Statistical values for main and interaction effects of the three-way repeated measures ANOVAs

Factors	Attention to object*		Looking at object		Proximity to object		Interaction w. object		Proximity to actor		Interaction w. actor	
	F <sub>(1,50)</sub>	P value	F <sub>(1,50)</sub>	P value	F <sub>(1,50)</sub>	P value	F <sub>(1,50)</sub>	P value	F <sub>(1,50)</sub>	P value	F <sub>(1,50)</sub>	P value
Environment (E)	1.85	0.179	0.24	0.628	0.00	0.983	0.13	0.721	2.14	0.149	3.39	0.071
Actor (A)	7.40	<b>0.009</b>	2.66	0.109	9.07	<b>0.004</b>	2.58	0.114	8.31	<b>0.005</b>	1.79	0.186
Object (O)	1.42	0.239	5.39	<b>0.024</b>	1.10	0.299	0.83	0.36	1.43	0.236	0.11	0.745
E x A	0.40	0.527	4.73	<b>0.034</b>	0.23	0.633	0.21	0.653	0.99	0.322	1.18	0.281
E x O	1.10	0.299	1.11	0.298	0.27	0.601	0.47	0.492	0.06	0.797	0.17	0.681
A x O	0.01	0.910	4.98	<b>0.030</b>	2.17	0.146	5.36	<b>0.025</b>	1.61	0.209	1.25	0.269
E x A x O	0.17	0.685	1.11	0.298	0.28	0.599	0.05	0.814	1.29	0.261	1.38	0.246

Significant p-values are indicated in bold

\*Attention to object is the only behavior recorded and analyzed during the observation phase



### *Observation Phase*

As cats were physically restrained during the observation phase, only their attention to the petting actors' objects was analyzed. Analysis of variance for attention revealed only a significant main effect of actor ( $F_{1,50} = 7.40$ ;  $P = 0.009$ ): cats paid significantly more attention to objects petted by their owner ( $M = 179.36$ ;  $SD = 105$ ) than by the stranger ( $M = 146.5$ ;  $SD = 96.28$ ). In addition, we observed that cats paid overall more attention toward the petted objects during the first trial, possibly due to loss of interest when the procedure was repeated. We therefore performed a subsequent ANOVA adding the factor "trial" (first trial, second trial) and testing for interactions with the three previous factors. This analysis again revealed a significant effect of actor ( $F_{1,50} = 7.01$ ;  $P = 0.011$ ), even when trial order was controlled.

These results indicate that during the exploration phase, although cats paid overall more attention to objects petted by their owner, their attention did not vary with the kind of object being petted.

### *Exploration Phase*

During the exploration phase, cats were free to explore, allowing us to code and analyze all five behaviors described in Table 1.

#### *Looking at the object.*

Data for looking at the petting actor's object are presented Figure 3. The ANOVA revealed a significant main effect of object ( $F_{1,50} = 5.39$ ;  $P = 0.024$ ). Moreover, the interaction between environment and actor was significant ( $F_{1,50} = 4.73$ ;  $P = 0.034$ ). Post-hoc analysis showed a significant effect of actor for the house cats ( $F_{1,24} = 9.16$ ;  $P = 0.006$ ): they looked significantly longer at objects petted by their owner ( $M = 119.54$ ;  $SD = 105.93$ ) than objects petted by the stranger ( $M = 64.65$ ;  $SD = 92.86$ ). In addition, the interaction between object and actor was also significant ( $F_{1,50} = 4.98$ ;  $P = 0.030$ ). Post-hoc analysis revealed a significant effect of condition only for the owner ( $F_{1,50} = 12.27$ ;  $P = 0.001$ ). As shown in Figure 3, when the petting actor was the owner, cats looked significantly longer when the object was the stuffed cat ( $M = 130.34$ ;  $SD = 109.25$ ) than the cushion ( $M = 66.08$ ,  $SD = 94.09$ ). Moreover, a significant effect of actor was found for the stuffed cats ( $F_{1,50} = 6.87$ ;  $P = 0.012$ ), which received more attention when petted by the cat's owner ( $M = 130.35$ ;  $SD = 109.25$ ) than when petted by the stranger ( $M = 77.19$ ;  $SD = 108.35$ ).

When controlling for trial order, the same significant effects were found, along with the result that cats looked at the stuffed cat for longer in the first trial than the second one.

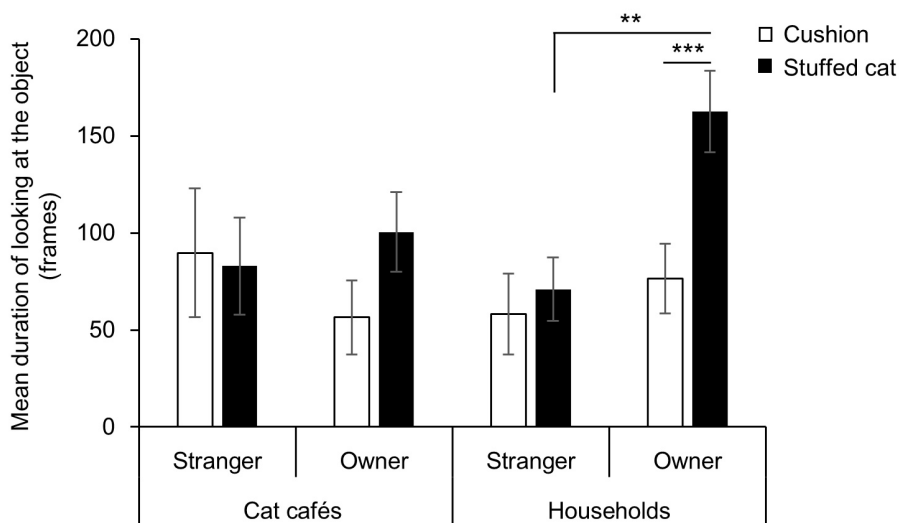
Together, these results indicate that house cats looked longer at the object petted by the owner when it was a stuffed cat than when it was a cushion. Moreover, house cats also looked longer at the stuffed cat when it was petted by their owner than when it was petted by the stranger. This preferential attention is suggestive of a jealousy-type reaction, since house cats' responses were more intense in the case of a potential threat (i.e. stuffed cat) to their relationship (i.e. with the owner).



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**Figure 3.** Mean duration of looking at the petting actors' object in the exploration phase. Mean looking durations (in frames: 30 frames/1s.) are presented for both groups of cats and the two actors (stranger and owner) with the cushion and the stuffed cat. Error bars depicted SE. \*\*\*  $P < 0.001$ ; \*\*  $P < 0.01$ , in 3-way repeated measures ANOVA

*Proximity to object.*

The ANOVA revealed only a significant main effect of actor ( $F_{1,50} = 9.07$ ;  $P = 0.004$ ): cats stayed longer in proximity to objects petted by their owner ( $M = 116.54$ ;  $SD = 192.32$ ) than objects petted by the stranger ( $M = 56.44$ ;  $SD = 125.53$ ). When controlling for trial order same results were found, with the additional result that cats stayed near the petted objects for longer in the first than the second trial.

*Interaction with object.*

Mean interaction times with the objects are presented in Figure 4. Although, analysis of variance showed non-significant effects of the three main factors, the interaction between object and actor was significant ( $F_{1,50} = 5.36$ ;  $P = 0.025$ ). Post-hoc analysis showed a non-significant effect of object for the owner ( $F_{1,50} = 3.39$ ;  $P = 0.072$ ), although when the owner was the petting actor, cats tended to interact longer with the stuffed cat ( $M = 79.17$ ;  $SD = 134.74$ ) than the cushion ( $M = 38.82$ ;  $SD = 106.75$ ). Moreover, a significant effect of actor was found for the stuffed cat ( $F_{1,50} = 6.97$ ;  $P = 0.011$ ), with cats contacting it for longer if it was previously petted by the owner ( $M = 79.17$ ;  $SD = 134.74$ ) than the stranger ( $M = 24.65$ ;  $SD = 56.56$ ). Analysis controlling for trial order yielded the same significant effects, and again cats interacted overall longer with the objects in the first than the second trial.

*Proximity to actor.*

The ANOVA revealed only a significant main effect of actor ( $F_{1,50} = 8.31$ ;  $P = 0.005$ ). Regardless of the object petted, cats stayed significantly closer to their owner ( $M = 51.15$ ;  $SD = 103.74$ ) than the stranger ( $M = 19.91$ ;  $SD = 59.76$ ). Analysis controlling for trial order produced similar results.

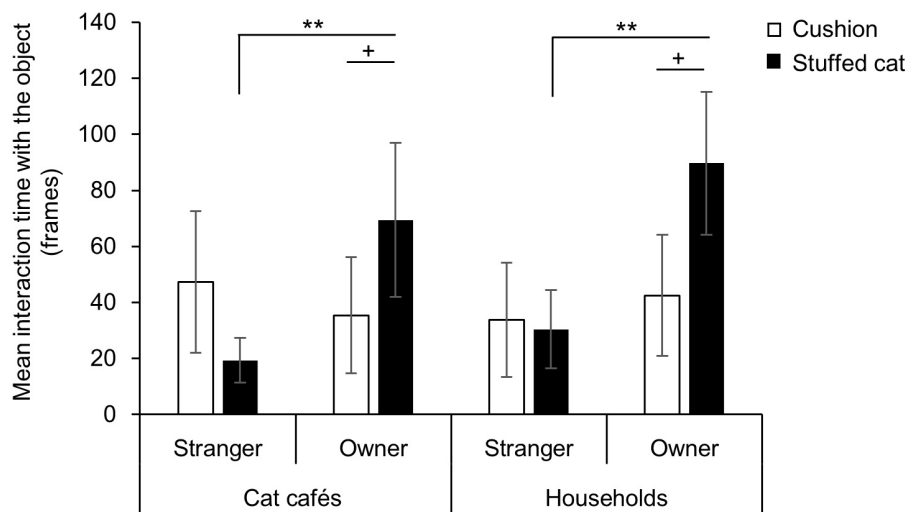


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**Figure 4. Mean duration of interaction with the petting actor's object in the exploration phase. Mean interaction times (in frames: 30 frames/1s.) are presented for both groups of cats and the two actors (stranger and owner) with the cushion and the stuffed cat. Error bars depicted SE. \*\*  $P < 0.01$ ; +  $P < 0.1$ , in 3-way repeated measures ANOVA**

#### *Interaction with actor.*

Although, the ANOVA revealed a non-significant effect of environment ( $F_{1,50} = 3.39$ ;  $P = 0.071$ ), café cats tended to interacted longer with the actors ( $M = 8.86$ ;  $SD = 39.32$ ) than did house cats ( $M = 1.27$ ;  $SD = 5.51$ ). However, interactions with the petting actors were relatively rare; only eight café cats (approximately 30% of all café cats) interacted with at least one of the petting actors, as did only six house cats (24% of all house cats). Similar results were found when controlling for trial order.

#### *Owner bias*

We asked whether cats' behaviors might be driven by a general bias toward the owner, causing the cats to attend preferentially to the owner even when the stranger was petting an object (while the owner simply sat passively near her). To do so, we analyzed two behaviors separately: attention to the objects during the observation phase, and looking toward the objects during the exploration phase.

For each behavior we compared attending to the object associated with the passive owner with the object petted by the stranger. For this, we conducted a three-way repeated measures ANOVA, with a 2 (environment: cat café, household)  $\times$  2 (object: cushion, stuffed cat)  $\times$  2 (actor: owner passive, stranger petting) factor design. Statistical values for these analyses are reported in Table 3.

#### *Observation phase.*

First, we compared attention to objects associated with the passive owner with attention to objects petted by the stranger; the data are presented Figure 5. A three-way repeated measures ANOVA revealed only a significant main effect of



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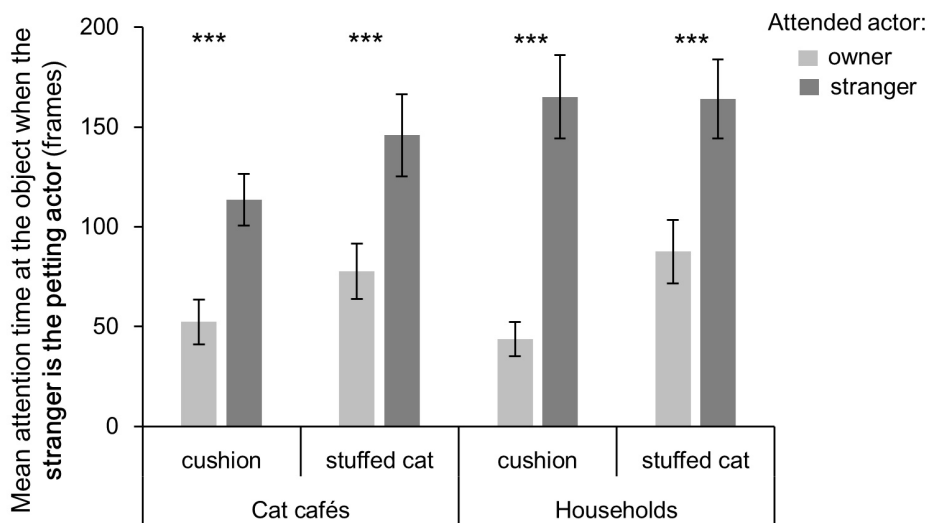
actor ( $F_{1,50} = 87.14$ ;  $P < 0.001$ ). As shown in Figure 5, cats paid more attention to objects petted by the stranger than objects in proximity to the passive owner. These results indicate that petting by the stranger during the observation phase increased cats' attention to the stranger's object.

**Table 3** Statistical values for main and interaction effects of the three-way repeated measures ANOVAs.

Factors	Observation phase Attention to objects *		Exploration phase Looking at objects*	
	$F_{(1,50)}$	<i>P value</i>	$F_{(1,50)}$	<i>P value</i>
Environment (E)	2.42	0.125	0.11	0.734
Object (O)	3.31	0.074	3.41	0.071
Actor (A)	87.14	<b>&lt; 0.001</b>	2.00	0.162
E×O	0.07	0.078	0.11	0.737
E×A	3.80	0.057	1.07	0.305
O×A	0.81	0.374	3.30	0.075
E×O×A	1.50	0.226	0.03	0.846

Significant p-values are indicated in bold

\* Comparing the behavior attended toward the passive owner and the petting stranger



**Figure 5** Mean attention time to the objects during the observation phase when the stranger is the petting actor and the owner is passive. Mean attention times (in frames: 30 frames/1s.) are presented for the two groups of cats and the two objects Error bars depict SE. \*\*\*  $P < 0.001$  in 3-way repeated measures ANOVA

*Exploration phase.*

We then compared looking time toward the objects associated with the owner when previously passive and toward the objects previously petted by the stranger; the data are presented Figure 6. Analysis revealed non-significant effects of the three factors and their interactions. Although the interaction between object and actor ( $F_{1,50} = 3.30$ ;  $P = 0.075$ ) fell short of significance, post-



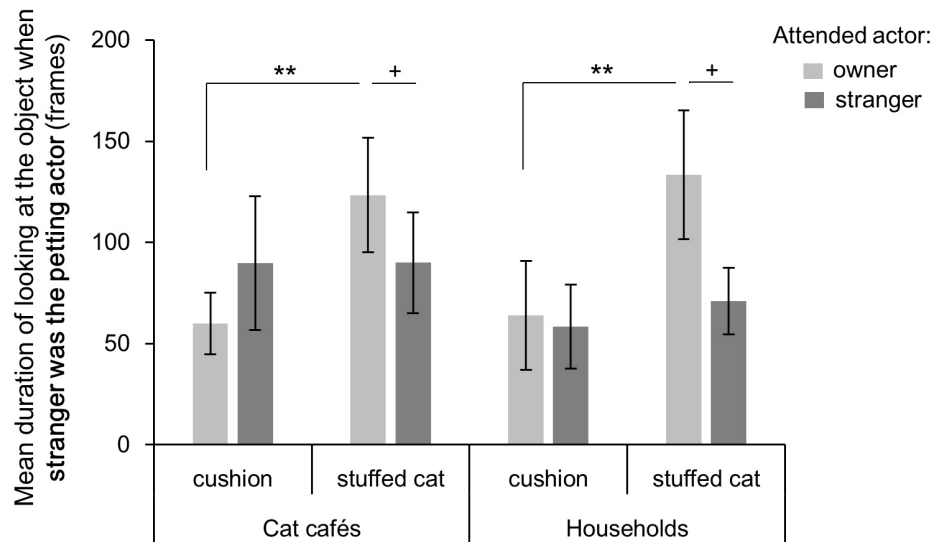
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hoc analyses on this interaction were conducted, and revealed a significant effect of object for the owner resting ( $F_{1,50} = 8.21$ ;  $P = 0.006$ ). As shown in Figure 6, cats looked longer at the owner's stuffed cat than the owner's cushion when the owner was previously passive. The same post-hoc analyses revealed a non-significant effect of actor for the stuffed cat ( $F_{1,50} = 3.82$ ;  $P = 0.056$ ), although as shown in Figure 6, cats tended to look longer at the stuffed cat associated with the passive owner ( $M = 128.17$ ;  $SD = 152.02$ ) than the stuffed cat previously petted by the stranger ( $M = 77.19$ ;  $SD = 108.34$ ).



**Figure 6** Mean duration of looking at the objects during the exploration phase when the stranger was the petting actor. Mean looking durations (in frames: 30 frames/1s.) are presented for both groups cats, the two objects, and when cats attended to the owner's object and the stranger's object. Error bars depict SE. \*\*  $P < 0.01$ ; +  $P < 0.1$ , in 3-way repeated measures ANOVA

These results indicate that although the stranger's petting action caught cats' attention during the observation phase, this did not carry over to the exploration phase (during which the stranger was passive). Instead, despite the owner's inactivity during both phases, cats tended to look longer at the owner's stuffed cat during the exploration phase, although the difference did not reach significance. These findings suggest a relatively strong attraction toward the stuffed cat merely in proximity to the owner.

## DISCUSSION

We investigated whether cats would show detectable jealousy-like behaviors when their owners or an unfamiliar person ignored the cat to pet a potential rival (a stuffed cat) or a non-social object (furry cushion). In addition, we asked whether cats' behaviors might differ between two living environments: cat cafés and households.

During the observation phase cats were gently physically restrained, to increase the chance that they witnessed the petting action. Although the petting action seems to have caused cats to pay attention to the petted object, they did not attend differentially to the two types of objects being petted. However, they paid more attention to objects petted by their owner than by the stranger. These results suggest a bias for attending preferentially to their owner, concurring



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with previous findings that cats can discriminate between their owner's and a stranger's voice (Saito and Shinozuka 2013), and prefer the owner to a stranger in the ASSP (Potter and Mills 2015).

Following the petting action, cats were released at the start of the exploration phase. Some behaviors toward the petted object appeared suggestive of a jealousy-like type of reaction, whereas behaviors toward the actors did not. Looking at the petted object showed a potentially interesting difference as a function of the cats' living environment, with only house cats' conforming to anything like a jealousy-type reaction. House cats looked significantly longer at the stuffed cat previously petted by their owner, although the owner probably also attracted attention. Similar preferential attention to the petted objects was included in a cluster of behaviors considered as a form of jealousy in human infants (Hart et al. 1998, 2004; Hart and Carrington 2002; Mize et al. 2014) and dogs (Abdai et al. 2018; Harris and Prouvost 2014) tested with a similar procedure. Interestingly, this jealousy-like type of reaction in cats might not have entirely due to the owner's petting action, as the stuffed cat merely near the owner also appeared attractive, although the effect was not significant.

A potential effect of living environment on the cats' looking behavior might be because café cats witness not only their owner but also strangers (customers) interacting with other resident cats on a daily basis; this wider circle of social contacts might diminish any jealousy-like reaction. It is also conceivable that the relationship between café cats and their owner differs from that between household cats and their owner. However, the effect of living environment requires confirmation, as we found a significant difference only for one behavior. Recent studies have started to focus on cats' living environment difference (Saito et al. 2019; Takagi et al. 2019), and it is hoped that they might clarify the nature of the bonds with owners in the two cat populations.

Regardless of living environment, cats interacted significantly longer with the stuffed cat petted by their owner than by the stranger, and they tended to interact more with the stuffed cat than the cushion after these objects were petted by the owner. This behavioral pattern recalls the behavior of dogs that were considered to show a form of jealousy (Harris and Prouvost 2014), but it could also be an expression of territoriality or playfulness (Prato-Previde et al. 2018a). Territoriality seems unlikely to account for the present findings because a similar reaction would have been expected when the stuffed cat was petted by the stranger. Moreover, contrarily to Harris and Prouvost (2014) no aggression toward the stuffed cats was observed. Playfulness can also be excluded as a causal factor as both objects were unfamiliar and matched for general appearance.

Although cats' looking behaviors and heightened interaction with the stuffed cat petted by the owner might be tentatively interpreted as a jealousy-like reaction, we cannot rule out an alternative and simpler mechanism, namely stimulus enhancement. Observing an actor petting an object or simply sitting near the object might have increased cats' attention toward and subsequent interaction with that object (Spence 1937). The presence of possible attention-capturing social features on the stuffed-cat (e.g. eyes, whiskers), combined with a general preference for looking at the owner could explain the present results. Nonetheless, this specific form of potential stimulus enhancement (to the stuffed cat associated with the owner) might also represent a basic cognitive mechanism underlying possible jealousy reactions in cats.

However, our cats' responses to the actors did not conform to the primary form of jealousy described in human infants (Hart et al. 1998, 2004) and dogs (Abdai



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et al. 2018; Harris and Prouvost 2014). Although they stayed closer to their owner than a stranger, this was independent of the type of object petted by the owner, and further physical interaction was rare. Importantly, cats made no attempt to separate the owner from the social object, which is reportedly a typical behavior of jealousy in dogs (Abdai et al. 2018; Harris and Prouvost 2014). Moreover, although stress-related behaviors may potentially indicate a jealousy-like state in human infants (Hart and Carrington 2002), stress-related behaviors were rare in the cats, nor were they considered important in the four studies of jealousy in dogs (Abdai et al. 2018; Harris and Prouvost 2014; Prato-Previde et al. 2018a, 2018b).

The lack of specific owner-directed behavior or other signs of jealousy precludes any firm conclusion about a basic form of jealousy in cats, and has at least two possible explanations. First, it is unclear whether the cat-owner attachment is similar to the secure attachment style typical of human infant-mother and dog-owner pairs (Potter and Mills 2015; Prato-Previde and Valsecchi 2014). It would be interesting to study the emergence of a primary form of jealousy in cats in a different context, for instance when sibling kittens are competing for their mother's attention and resources. Second, it is conceivable that the stuffed cats used in the present study were not sufficiently realistic. For instance, they neither moved nor purred, therefore lacking important signals used by cats during intraspecific encounters (Bradshaw 2016). As suggested by Barnard et al. (2012) in dogs, it is likely that after an initial interaction with the stuffed toy, cats quickly realized that it was not real and therefore not a potential threat. Indeed, some authors have argued for the use of a real conspecific instead of realistic-looking models to study jealousy in dogs (Abdai et al. 2018; Harris and Prouvost 2014; Prato-Previde et al. 2018a, 2018b); we call for the same in future studies in domestic cats.

## CONCLUSIONS

Only two of our behavioral measures yielded any possible evidence of a jealousy-like reaction in cats. In addition, the lack of any reaction such as attempted interruption precludes concluding in favor of a primitive form of jealousy in cats. However, our results do suggest the presence in cats of some of the cognitive capacities and a mechanism (stimulus enhancement) that might enable a basic form of jealousy to emerge. Further studies using more ecologically valid procedures are required to further our understanding of this phenomenon.

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