Department of Comparative Cognition
University of Veterinary Medicine, Vienna

Messerli Research Institute
Head: Prof. Ludwig Huber, PhD

Jealous dogs? Dogs' reactions to observing their caregiver interact with someone else

Master thesis

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submitted by

Kristina Anderle, BSc

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Supervisors:

Priv.-Doz. Dr. Zsófia Virányi

Dipl.-Biol. Sabrina Karl

Prof. Ludwig Huber, PhD

Independent evaluator:

Priv.-Doz. Sarah Marshall-Pescini, PhD

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Abstract

Caregivers of dogs kept as companions tend to interpret the behaviour of their dogs by attributing various emotions to them, and jealousy is one of the emotions caregivers most often attribute to dogs. In contrast, however, behavioural studies have not provided clear evidence for dogs' displaying behaviours linked to jealousy so far. Therefore, the objective of the present study was to test companion dogs' reaction to seeing their caregiver interact with another (fake) dog in a more or less affiliative manner (either greeting and petting the fake dog or checking its ears and teeth similar to a vet check). By comparing four groups, we also investigated whether dogs responded differently to such interactions of their caregiver vs. an unfamiliar human. Our goal was to investigate whether dogs react in a jealous way, or they rather synchronize their behaviour towards the fake dog with that of their caregiver, or they simply respond directly to the humans' behaviour.

To address these 3 hypotheses, we examined whether the dogs approached the fake dog first, and whether they showed positive or negative behaviours towards the fake dog and their human partner. Furthermore, we analysed how their relationship with the person and the nature of her interactions with the fake dog affected the dogs' reaction.

We found no evidence that the dogs' behaviour would have aimed at a direct response to human behaviour. Rather we found that the dogs, as long as observing the dyad from a distance, reacted positively to the human-fake dog interaction, and did so especially when the caregiver petted the fake dog. Also, after having been released to join the interaction, the friendly interactions with the fake dog increased with the caregiver and when the fake dog was petted. At the same time, however, 25 or 50% of dogs showed a blocking response, with the stranger and with the caregiver, respectively. Overall, most of our findings were consistent with the hypothesis that dogs responded positively to seeing their caregiver interact with the fake dog, and some of the results suggested that jealousy may have also contributed to the behavioural reaction of the dogs. How much these results were affected by some artificial characteristics of the fake dog (even if it evoked social behaviours in the dogs) or of the test situation itself needs to be further investigated by using a more naturalistic fake dog or a real dog in a more natural setting. Nevertheless, our findings suggest that caregivers provide an essential behavioural and emotional reference to their pet dogs when interacting with a third party.

Zusammenfassung

HundehalterInnen tendieren dazu, das Verhalten ihrer Hunde zu interpretieren, indem sie ihren Hunden verschiedene Emotionen zuschreiben. Eine häufige Annahme ist, dass Hunde in bestimmten Situationen eifersüchtig reagieren können. Ob das Verhalten der Hunde tatsächlich mit Eifersucht, einer sekundären Emotion, in Zusammenhang steht, konnten wissenschaftliche Verhaltensstudien bisher nicht eindeutig belegen. Aus diesem Grund bestand das Ziel dieser Arbeit darin, die Reaktion von Hunden zu untersuchen, wenn diese ihre/n HalterIn beobachteten, während er/sie mit einem Stoffhund interagierte (indem er/sie ihn entweder begrüßte und streichelte oder dessen Ohren und Zähne inspizierte, ähnlich einer veterinärmedizinischen Untersuchung). Zudem wurde getestet, ob die Hunde unterschiedlich auf die beiden Interaktionen reagieren, wenn diese von dem/der HalterIn oder einer für den Hund unbekannten Person ausgeht. Anhand von vier Gruppen wurde untersucht, ob die Reaktionen der Hunde typische Anzeichen von Eifersucht aufzeigen oder, ob die Hunde ihr Verhalten auf die Einstellung ihrer HalterInnen, die sie dem Stoffhund gegenüber zeigen, abstimmen. Eine weitere Möglichkeit wäre, dass sie direkt auf das Verhalten ihrer HalterInnen reagieren. Gemäß dieser drei Hypothesen wurde überprüft, ob sich die Hunde dem Stoffhund zuerst näherten und, ob sie dem Stoffhund und dem Demonstrator (HalterIn, unbekannte Person) gegenüber positiv oder negativ eingestellt waren. Es wurde analysiert, inwiefern die Beziehung des Demonstrators zu dem Hund und die Art seiner Interaktion mit dem Stoffhund, die Reaktion der Hunde beeinflusste. Die Ergebnisse gaben keinen Hinweis darauf, dass die Hunde direkt auf die Handlungen ihrer HalterInnen reagierten. Im Allgemeinen waren die Hunde positiv gestimmt, wenn sie den Demonstrator mit dem Stoffhund aus der Entfernung beobachteten. Positive Reaktionen wurden vor allem gezeigt, wenn der/die HalterIn den Stoffhund streichelte. Nachdem die Hunde abgeleint wurden, nahmen die freundlichen Interaktionen mit dem Stoffhund zu, wenn der/die HalterIn als Demonstrator agierte und der Stoffhund gestreichelt wurde. Im Gegensatz dazu versuchten 25 bzw. 50% aller Hunde die Interaktion zwischen der unbekannten Person bzw. dem/der HalterIn und dem Stoffhund zu behindern, indem sie sich zwischen diesen drängten. Insgesamt stimmten die Ergebnisse jedoch mit der Hypothese überein, dass die Hunde positiv auf die Interaktion ihres/ihrer HalterIn mit den Stoffhund reagierten, wenn sie diese beobachteten. Zum Teil wiesen die Analysen ebenso darauf hin, dass Eifersucht zur Reaktion der Hunde beigetragen haben könnte. Inwieweit diese Ergebnisse von der unechten Erscheinung des Stoffhundes (obwohl soziales Verhalten ihm gegenüber gezeigt wurde) oder der Testsituation an sich beeinflusst wurden, bedarf weiteren Untersuchungen, in denen ein etwas naturalistischerer Stoffhund oder realer Hund in einem natürlicheren Umfeld eingesetzt werden sollte. Dennoch weisen die Ergebnisse darauf hin, dass Hunde das Verhalten ihrer HalterInnen als Referenz verwenden, wenn diese mit anderen interagieren.

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1 Introduction

1.1 Jealous dogs? Caregiver reports and theoretical considerations

Pet dogs are often regarded as valuable social companions: caregivers can be emotionally attached to their dogs and attribute various humanlike emotions to them (Hall et al., 2004). Morris and colleagues (2008) investigated the caregivers' perception of their dogs' emotional experiences and reported that jealousy is one of the emotions most dog caregivers do attribute to their dogs. In response to their questionnaire, 81% of the dogs were reported by their caregivers to react in a jealous way. Such reactions were reported in 50% of the participants when the caregiver interacted with a person, in 45% of the participants in case of interactions with another dog or animal, and even a cuddle toy provoked jealous behaviours, like attention seeking, pushing against or between the caregiver and the third party, vocalization and even aggression in 5% of the participants (Morris et al., 2008). Similarly, a more recent survey also demonstrated that jealousy was the third on the list of emotional behaviours Dutch-speaking caregivers commonly attributed to their dogs (Martens et al., 2016).

This prevalence of jealous behaviours in dogs, as perceived by their caregivers, is especially interesting given that jealousy is thought to be a secondary emotion, and it has been strongly debated whether non-human animals are capable of experiencing such complex, secondary emotions (Lewis, 2008; Morris et al., 2008). In contrast to basic or primary emotions that are direct responses to situations with anger, fear or sadness for instance, secondary emotions are indirect responses to primary emotions, such as feeling guilty about feeling angry. For this reason, it has been suggested that such complex secondary emotions may require higher cognitive abilities (Hart & Legerstee, 2010; Lewis, 2010; White & Mullen, 1989). *Jealousy (experiencing fear, anger or sadness for losing a positive relationship)* is thought to be a secondary emotion that necessitates the understanding of a complex social context of a social triad composed of this individual, her/his social partner and a third individual who may be perceived as a rival threatening the relationship of the first two (Abdai et al., 2018; Prato-Previde et al., 2018).

The advanced cognitive needs of jealousy may, however, be questioned on the basis of a number of psychological studies that have demonstrated jealous behaviours already at the early age of six to twelve months in human infants (Hart & Carrington, 2002; Hart, 2016). These studies have shown that infants aim for closer proximity to their mother when she directs her attention to a realistic looking doll, including increased approach and gaze. Importantly, the infants show also negative expressions and vocalizations, indicating their decrease in joy (Hart & Carrington, 2002; Hart et al., 1998, 2004; Mize et al., 2014; Mize & Jones, 2012). These reactions are specific to situations where the mothers are interacting with a social partner, as the infants show these reactions to a lesser extent when the mothers are holding a book, or a

stranger directs her attention to a doll (Hart et al., 1998). Furthermore, jealous behaviours have recently been observed also in chimpanzees, specifically in a long-established colony when introducing new unfamiliar individuals to the group (Webb et al., 2020). Group members showed significantly more agonistic behaviours and intervention attempts when they had a valuable relationship to only one of the closely interacting group members. These jealous reactions especially occurred during the introduction phase and seemed to be triggered by potential social rivals.

Independent of its cognitive mechanisms, jealousy has been suggested to have *"a clear, strong adaptive value in maintaining and protecting social relationships and bonds (i.e., sibling-parent, sexual, friendship)"* (Prato-Previde et al., 2018, p. 2). On this basis, the domestic dog (*Canis familiaris*) has been suggested to represent a promising species to investigate jealousy in non-human animals for 3 reasons: *"firstly, dogs form stable groups and differentiate social relationships with conspecifics* (Cafazzo et al., 2010; Bonnani et al., 2014; Cimarelli et al., 2019); *secondly, they establish a strong relationship with their caregiver, characterized by dependency for physical and psychological resources which is functionally comparable to an infantile attachment* (Topál et al., 1998*); thirdly, dogs discriminate human emotions* (Müller et al., 2015), *are sensitive to others' attentional states and to unfair treatment*" (Schwab & Huber, 2006; Range et al., 2009; Prato-Previde et al., 2018, p. 2). Even if these considerations are in line with perceptions of the dogs' caregivers (see above), the risk remains that the caregivers' interpretations are biased by their anthropomorphic perceptions of their dogs. Therefore, behavioural studies using more objective observations are needed to investigate the emotional reactions of dogs to their caregiver affiliating with someone else.

1.2 Jealous dogs? Behavioural analyses

As described earlier, jealous reactions typically involve negative emotions (e.g., fear, anger, sadness) and observable behaviours that aim at regaining the social partner's attention or interrupting her/his interactions with someone else (Abdai et al., 2018; Prato-Previde et al., 2018). Investigating the emotional component has been attempted using neurobiological methods: dogs trained to participate in non-invasive brain imaging (functional magnetic resonance imaging: fMRI) watched their caregiver feed a fake dog or place food into a bucket, and their brain activation was measured in the amygdala that is thought to be responsible for affective reactions associated with jealousy, like anger and fear (Cook et al., 2018). This study has found that the amygdala activation of the dogs positively correlated with the general aggressiveness of the dogs, as scored by the caregivers before the experiment. Furthermore, the dogs with high aggressive arousal habituated when they were exposed to the situation repeatedly, and their brain activation dropped. Cook et al. (2018) argued that this may show some parallels to human jealousy.

In regard to the behavioural reactions dogs show when their caregiver affiliates with someone else, a number of studies have compared whether dogs respond differently if their caregiver interacts with another (fake) dog as compared to her/him engaging with objects. At first, Harris & Prouvost (2014) demonstrated jealous behaviours in dogs when the caregiver focused his/her attention on a potential intruder. In their study, dogs showed more behaviours often associated with jealousy (e.g., snapping, getting between the caregiver/object, touching the caregiver/object) when the caregiver interacted with a realistic looking stuffed dog than with non-social items (jack-o'lantern pail and a book). The authors suggested that the dogs might have recognized the stuffed dog as a social partner, based on the finding that most subjects sniffed at the anal region of the stuffed dog and showed agonistic behaviours towards it. Others, however, criticised this study arguing that the behaviours described could also be explained by territorial aggression, since the tests took place in the dogs' home. Another possibility is that the animated stuffed dog might have created an artificial situation, and the stress triggered by this situation might have driven the subjects' behaviour (Abdai et al., 2018). Adding to these concerns, another study by Prato-Previde and colleagues (2018) failed to replicate these findings, as here the dogs did not show evidence for perceiving the fake dog as a real social partner, and also jealous behaviours occurred only to a restricted degree. In this experiment, dogs were confronted with either the caregiver or a stranger directing their attention towards a book, a puppet and a furry or a plastic fake dog. Dogs focused their attention on the caregiver and the stranger to the same extent, and they showed affective behaviours towards the fake dog (Prato-Previde et al., 2018), suggesting that dogs in certain contexts may rather synchronize with their caregivers in their interactions with a third party instead of showing a jealous reaction.

As in these studies it remains unclear how using fake dogs might have affected the reactions of the subjects, Abdai and colleagues (2018) tested dogs in a more natural situation where they could observe the caregiver interacting with a familiar or an unfamiliar real dog or two non-social objects. Results indicated that jealous behaviour (e.g., attention seeking and attempts to separate caregiver and potential intruder) emerged more often when the dogs were involved in the interaction (Abdai et al., 2018). In sum, the results of behavioural studies investigating jealousy in dogs so far are controversial, and no study addressed the question yet whether dogs respond differently to their caregiver interacting with another dog in a positive or neutral manner. To address this question, in the current study, we investigated the dogs' behaviour using a 2x2 design, where we compared whether dogs react differently when their caregiver vs. a stranger interacts with a fake dog in a positive vs. neutral manner. If dogs' behaviour is driven by jealousy in such a situation, we would predict, similarly to former studies, that they react more negatively when the caregiver is engaging in interactions with a third party, as compared to seeing a stranger do so. Furthermore, not addressed by former studies, we

would expect that jealous reactions are more prominent when the human partner engages in positive interactions with a third party, as compared to neutral interactions. That is, both the relationship with the human partner and the nature of her interaction would matter. It is important to realize, however, that both of these factors may affect the dogs' behaviour in such a social context differently and may lead to differences in their behavioural reactions motivated by processes different to jealousy. For instance, as mentioned earlier, it is possible that dogs, instead of interrupting their caregivers' interactions with another dog, rather join these social interactions and try to adopt the humans' reaction to the third party.

1.3 Dog-human synchronization

Behavioural synchronization can be observed in most social species, and has been suggested to have important functions, such as providing protection when being confronted with a threat, as the actions and dynamics of coherent groups are more efficient than those of less synchronized groups (Lakin et al., 2003; Scott & Fuller, 1965). Furthermore, synchronization has been shown to positively correlate with affiliation in social interactions: synchronization leads to affiliation, and affiliation can be communicated through synchronization, thereby helping relationships nourish (Lakin et al., 2003). Importantly, activity synchronization, one type of behavioural synchronization, while playing such important roles, occurs unconsciously, and is described the *"tendency to adopt the postures, gestures and mannerisms of interaction partners"* (Chartrand & Bargh, 1999; Lakin et al., 2003, p. 147).

In line with these general arguments, behavioural synchronization occurs also between dog individuals, and is considered *as "a basic part of social life of dogs"* (Scott & Fuller, 1965; p. 74). Various breeds (for example Basenji, Beagle, Cocker Spaniel, Sheltie, and Fox Terrier) show synchronous behaviour already in early stages of their development, "*as puppies vocalize, sleep, rest, and move together"* (Scott & Fuller, 1965, p. 74), and synchronous behaviours remain also in adult individuals, e.g., when running in dyads (Scott & Marston, 1950; Scott & McGray, 1967). More naturalistic observations in free-ranging dogs have confirmed these old results and found that individuals synchronized (local proximity) with familiar individuals to a higher degree than with others (Bonanni et al., 2010). Also, in interspecific contexts dogs appear to be ready to adjust their reactions to those of others, as dogs demonstrate synchronization with their caregivers by seeking proximity and adapting their movements and walking pace to theirs (Duranton et al., 2017, 2018).

The willingness to dogs to adjust their reactions to that of their caregiver has been described in triadic contexts as well, where the dog-human dyad encounters a novel, scary object. Importantly, in this so-called social referencing task, the effect of relationship on synchronization with humans has also been investigated (Merola et al., 2012). That is, it has been examined whether dogs seek information (behavioural cues) from their caregiver and an

unfamiliar human differently when having to decide how to handle a novel situation. Results indicated that dogs looked at the person (caregiver or stranger) independent from their familiarity, but they adopted their behavioural reaction to the novel object differently. When the caregiver provided a positive cue (facial or vocal), dogs sought more proximity to the object. Contrary to this, when the caregiver gave a negative cue, dogs needed more time approaching the object. However, the same informative cues provided by the stranger did not affect the dogs' reaction to the object. This may lead to the conclusion that dogs synchronize their reaction to a referent with their human partner's reaction depending on the relationship with the informant (Merola et al., 2012).

These results suggest that dogs in our study might show synchronous behaviour to their human partner's reaction and may approach the fake dog in a positive or neutral way instead of being jealous and responding negatively. Furthermore, if their reaction is indeed driven by this motivation, we would predict dogs adjust their behaviour to their caregivers' nature of interaction with the third party. However, dogs would synchronize their behaviour to a lesser extent to the stranger.

1.4 Direct response to human behaviour

Finally, a third possibility is that dogs use the opportunity of observing their human partner interact with the fake dog to decide whether and how they want to interact with this person. Experimental evidence has showed that dogs are highly sensitive to human behavioural signals and solve problems and learn by means of such observations (Kubinyi et al., 2003; Pongrácz et al., 2001). We know that dogs use information from third party-interactions and can adapt their behaviour according to what they have seen (Kundey et al., 2011; Marshall-Pescini et al., 2011; Freidin et al., 2013; Nitzschner et al., 2014). This phenomenon is called social eavesdropping and has already been investigated in many species (Marshall-Pescini et al., 2011). Results showed that even 6-10-month-old infants prefer helpful individuals over others who restrain a third party (Hamlin et al., 2007). According to Marshall-Pescini et al. (2011) dogs show social eavesdropping on human food-sharing interactions. For this, dogs first observed a generous and a selfish person share or not share food with another person. Then they had the chance to approach these persons and ask them for food themselves. Findings demonstrated that they first approached the generous human and spent more time with him/her. Once again, it is possible that also in our study the dogs used the opportunity of having seen their human partner interact with the fake dog in a positive or neutral way to adjust their own behavioural response to the human herself without being interested in and reacting towards the fake dog eventually.

Focusing on the dogs‘ responsiveness to human social behaviour, Vas et al. (2005) investigated dogs‘ reaction to an unfamiliar person who approached the tested dog in a friendly

or threatening manner. In the friendly episode, the stranger approached in a normal speed, talking to the dog, and petted the dog at the end. In contrast, in the threatening episode, the stranger approached slowly, did not talk to the dog, and aimed to direct eye contact with the dog. Generally, dogs reacted in a tolerant and friendly manner to the friendly approach but showed signs of avoidance and aggression in the threatening approach. Responsiveness was shown independent of the order of episodes, which indicated that dogs are highly flexible in their human behaviour (Vas et al., 2005).

Györi and colleagues (2010) went one step further and investigated whether family dogs show behavioural flexibility when a familiar and unfamiliar human (stranger) approach them either in a friendly or a threatening way, similarly to the previous study. Findings pointed out that dogs showed more avoidance and aggressive behaviour (more gaze averting) when the stranger approached them with a threatening intention, as compared to the friendly approach. When the caregiver was closing to the dogs, their behaviour affected the dogs less than that of the stranger (Györi et al., 2010).

According to these findings, one may suggest that in our study the dogs respond directly to the behavioural cues of humans without caring much about the third party she has been interacting with. If so, based on former results we would expect that dogs respond differently when the stranger offers positive vs. neutral interactions whereas their approach to the caregiver would be less dependent on the kind of interaction they have been having with the fake dog.

In the current experiment, we investigated dogs' reaction to observing their caregiver or a stranger interact with a fake dog in a positive or neutral manner. For this, the human demonstrator (caregiver or stranger) interacted with the fake dog either by petting and greeting it (petting condition) or by examining its ears and teeth (medical condition). The "jealousy" hypothesis predicts that, in these 4 contexts, dogs respond more negatively to the fake dog and try to interrupt the persons' interaction with it more when a familiar person, the caregiver, interacts with the fake dog than the stranger. Moreover, this reaction would occur more in the petting than in the medical condition. Alternatively, according to the "synchronization" hypothesis, dogs may rather join the human's interaction with the fake dog. This hypothesis, based on former social referencing studies, predicts that dogs will differentiate between the petting and the medical conditions more when having observed the caregiver than the stranger. That is, the treatment would matter more for the caregiver. Third, the "direct response to human" hypothesis suggests that dogs may enter the interaction by responding to the human behavioural cues. This hypothesis predicts that dogs differentiate between the petting and medical conditions more when interacting with the stranger than with the caregiver. For an overview of our 3 hypotheses and their predictions see Table 1.

Table 1

Overview of hypothesis and predictions

	Jealousy	Synchronization	Direct response to human
Main reaction	Blocking, negative reaction to fake dog	Positive reaction to fake dog	Positive reaction to human
Effect of conditions	Caregiver > stranger Petting > medical	Partner * Treatment interaction: Petting > Medical only for Caregiver	Partner * Treatment interaction: Petting > Medical only for Stranger

2 Methods

2.1 Subjects

Hundred forty-eight adult (11 months and older) pet dogs participated in this study from August to November 2019. Overall, forty-six dogs were excluded from the analyses. We decided to terminate the test appropriately when the dogs showed intense indication of anxiety or stress. Other reasons were instructional mistakes or technical issues during the procedure. Thus, the final sample consisted of 102 adult pet dogs of different sexes (19 intact males, 32 castrated males, 17 intact females, 34 castrated females), ages (mean age: 5.8, range: 11 months to 12 years), and breeds (see Table *10* for details). The dogs and their caregivers were recruited from the Clever Dog Lab (CDL) data base or via social media announcements. Some of them had already participated in other studies at the CDL, while for others this was the first study to take part in (see Table *2*, Table *10*).

The involved participants of each experiment were the subject dog, its caregiver (male or female) and two experimenters (female students), one of them acting as the unfamiliar person (stranger, E1) in the experiment (see below) and the other remotely controlling the fake dog from outside the room (E2). The identity of E1 and E2 was counterbalanced across subjects in each group. The sex, age and breed of the dogs were counterbalanced across the four conditions.

Table 2

Overview of number of dogs, mean age, range, females, males, castration, and lab experiences in dogs per group. The four groups were stranger petting (SP), stranger medical (SM), caregiver petting (CP), and caregiver medical condition (CM).

Groups	**No. of dogs**	**Mean age** (in years)	**Range** (in years)	**Females**	**Males**	**Castration**		**Lab experiences**	
						yes	no	yes	no
CP	25	6.5	1-12	13	12	14	11	13	12
CM	26	5.3	1-10	13	13	16	10	12	14
SP	26	6.2	1-12	13	13	18	8	14	12
SM	25	5.8	1-11	12	13	18	7	13	12

2.2 Experimental setup

All experiments took place in a testing room (length 1: 6.98 m; length 2: 7.21 m, width 1, 2: 5.98 m) of the CDL and were recorded with four video cameras (Computar 2.9-8.2 mm 1/3", JVC GZ-EX315BE) fixed in the four corners of the room. The cameras were connected to a computer and monitor placed outside the room. The room had two doors along

one wall, on the left and the right side. A hook was fixed to the wall on the opposite side of the room, at an equal distance (≈ 6.31 m) from both doors, and a chair was positioned either on the left or right side of the hook for either the caregiver or E1 accompanying the dog during the test. The location of the chair as well as the choice of the door where the fake dog entered were counterbalanced across dogs within each group (see Figure 2). The person sitting on the chair (caregiver or E1) wore sunglasses to reduce her/his possible influence on the dog's behaviour.

Ten marks were taped appropriately to the floor (see Figure 2) to make sure that all participants were placed in the right spot during the tests. As a further guidance, a red X mark was sticked on each door and window. Human participants had to watch the mark during the test to prevent them from looking at the subject dog.

To investigate how the subjects reacted to a human's interaction with another dog, we used a fake dog (Melissa & Doug Labrador, length: 90 cm, withers height: 35 cm) that was installed on a board with wheels and was operated remotely by E2. E2, standing outside, was also provided with a timer to measure the time for each testing phase, and signalled the start and end of each phase to E1 by an "OK" through her headphones. E1 was either interacting with the fake dog or sitting on the chair next to the dog when caregiver was interacting with the fake dog. During the entire test procedure, caregivers were able to observe their dog. They could have terminated the experiment at any point if they had the feeling it was too stressful for their dogs. All dogs wore harnesses during the test procedure to avoid any pressure on their neck when being leashed. Dogs were provided with fresh water before and after the test.

2.3 Experimental design

Each dog was tested in a single trial in one of four different groups: either in the caregiver petting (CP), caregiver medical (CM), stranger petting (SP) or stranger medical (SM) condition (see *Table* 3).

Table 3

Between-subject design of the experiment

		Interaction type	
		Petting condition	Medical condition
Human interacting with fake dog	Caregiver	CP (25)	CM (26)
	E1 (Stranger)	SP (26)	SM (25)

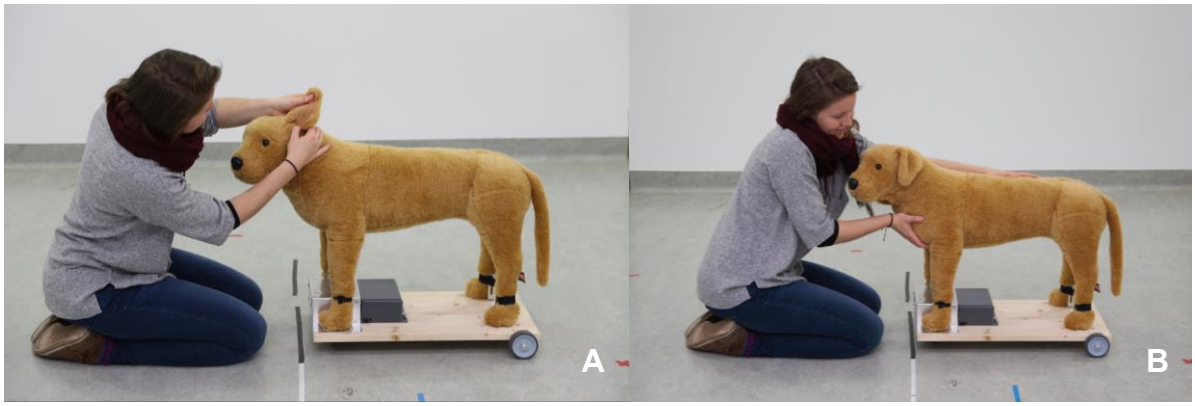

Figure 1. A medical (A) and petting condition (B)

In the caregiver petting (CP) and stranger petting (SP) conditions, either the caregiver or E1 greeted and petted the fake dog (see Figure 1). Therefore, to make sure that the experimenter's way of petting the fake dog in the SP condition was similar to the caregiver's one, the caregiver had been asked to demonstrate how she/he usually petted his/her dog before the test. E1 watched this interaction and tried to interact with the fake with the same style (calm vs. energetic, etc.). In the two medical conditions (CM and SM), either the caregiver or E1 touched, lifted and examined first the fake dog's ears and then its teeth. During each condition, the interacting person was asked to talk continuously with the fake dog and remained in the same position (kneeling or sitting on the floor).

2.4 Procedure

Upon arrival, all caregivers gave written consent for their dog's participation, and were given instructions by explaining each experimental step, demonstrating, and entering the testing room with their leashed dog and showing them an exemplary video of the test with the respective condition. During this introduction, which was always done by the same experimenter, E1 did not interact with the dog. Before the caregiver and the dog arrived, the fake dog was outside the room, out of sight of the subject dog. E1 and 2 placed their headphones, connected their mobile phones, and started the video and the timer. Each trial started when E1 and the caregiver with her/his dog on leash entered the experimental room and consisted of an exploration phase (habituation of 4 minutes), introduction phase (7 seconds), interaction start (10 seconds) and reaction phase (3 minutes).

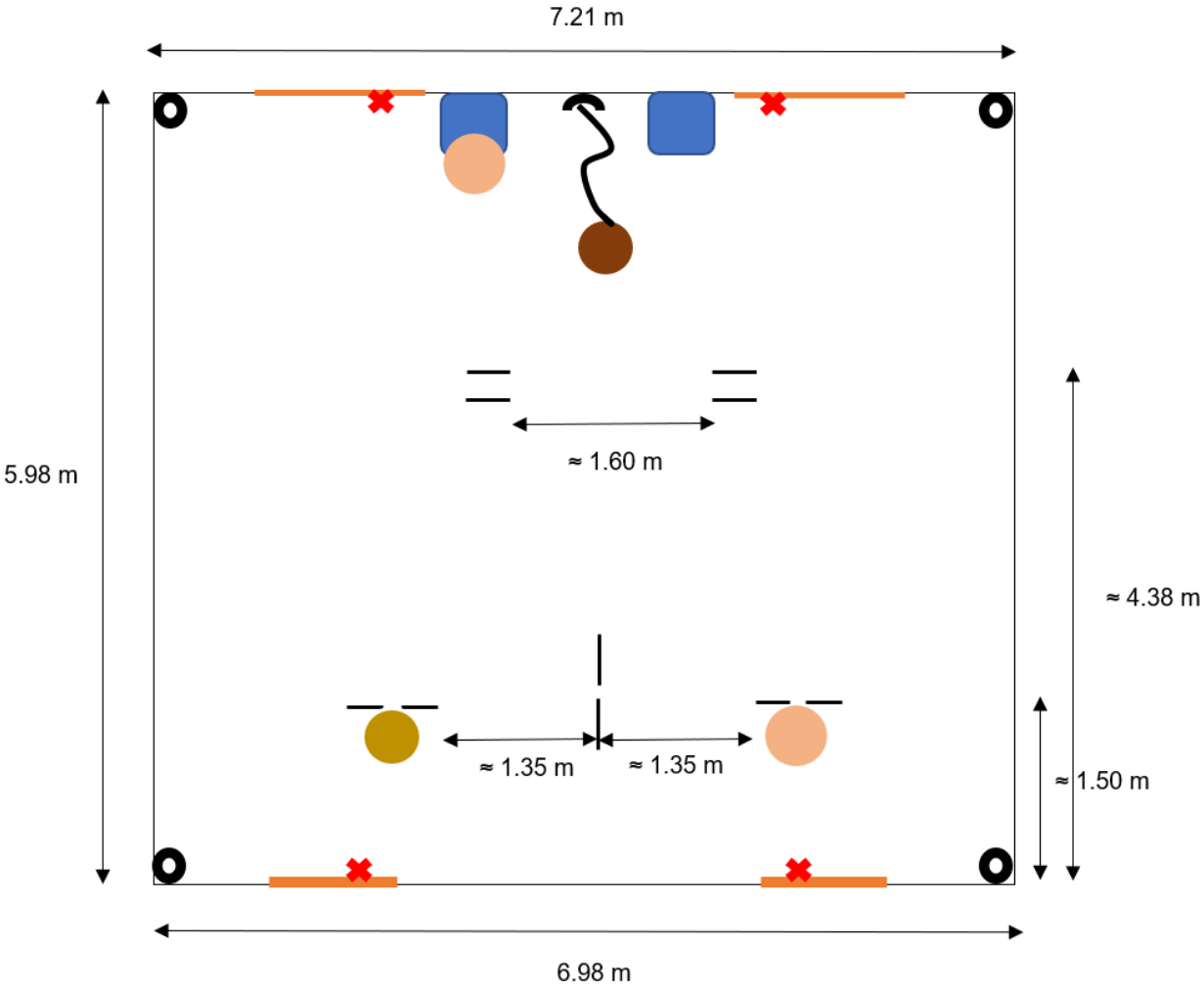

Figure 2. Sketch of the experimental setup in the test room

2.4.1 Exploration phase (4 minutes)

This phase was used to let the dogs familiarize with the room and the situation. E1 and the caregiver with his/her dog entered the room via the left or right entrance (the side was counterbalanced across dogs). As soon as the door was closed by E1, the caregiver unleashed his/her dog and put the leash on the door handle. Then E1 positioned herself on the appropriate marks on the floor (EM) in front of the door the caregiver used to enter the room. The caregiver did the same on the other marks (EM) in front of E1's door. While E1 and the caregiver faced each other, ignored the dog and were talking without gestures, the dog had the opportunity to explore the room off-leash (see Figure 3*).* After 4 minutes, E2 signalled to E1 via phone that the phase had ended, and E1 asked the caregiver to call and attach her/his dog to the leash fixed to the hook.

In the two caregiver conditions (CP, CM), the caregiver then left the room via the same entrance as he/she used to enter the room, and E1 sat down on the chair next to the leashed dog. In the two stranger conditions (SP, SM), after having leashed the dog, the caregiver sat down on the chair and E1 left the room.

As soon as the person, either E1 (SP, SM) or the caregiver (CP, CM), took her/his seat, he/she put the sunglasses on and started looking straight ahead at the red X fixed to the door in front of her and did not interact with the dog.

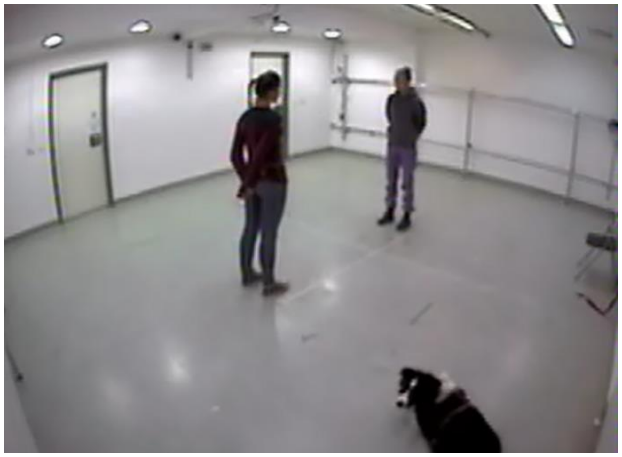

Figure 3. Screenshot of the exploration phase

2.4.2 Introduction phase (7 seconds)

At this point the 2 persons standing outside in front of the 2 doors, E2 and either the caregiver (CP and CM conditions) or E1 (SP and SM conditions) touched the handle of their door and opened the doors simultaneously. E2 stepped then away from the door to stay out of sight of the subject and moved the fake dog into the room operating it with the remote controller. At the same time, also the other person (either the caregiver or E1) also entered the room (using the same door where he/she left had left). After entering, this person closed the door behind her/himself, and E2, simultaneously, also closed the door behind the fake dog. E2 then continued to remotely move the fake dog from the door to the SM spot placed on the floor while watching it on the monitor. Simultaneously, the human partner of the fake dog also moved from the door to her/his predetermined spot (SM), while watching a certain point on the window (red X mark) opposite to her/him in order to prevent the person from looking at the subject dog *(*see Figure 4A).

This phase started as soon as the caregiver/E1 and the fake dog stood still in their positions facing the windows. They stayed in this position for 7 seconds.

2.4.3 Interaction phase (10 seconds)

After the standing phase, E2 started to move the fake dog so that it first turned to and then moved towards its human partner. Watching the fake dog from the corner of her eyes, the caregiver/E1 mirrored its behaviour. The fake dog and the caregiver/E1 moved towards each other until reaching the provided marks in the middle (IRM, see Figure 2). Then the caregiver/E1 kneeled down and started interacting with the fake dog in accordance with the condition (see Figure 4B). After the person interacted with the fake dog for 10 seconds, E2 gave the signal “OK“ to E1 via phone. In the caregiver conditions, E1 at this point released the dog from the leash. In the stranger conditions, where E1 had been interacting with the fake dog, following E2’s signal, E1 nodded with her head to signal the caregiver to unleash the subject dog. The person, who unleashed the dog (either E1 or caregiver), kept sitting on the chair just saying “OK” to the dog as a releasing signal.

2.4.4 Reaction phase (3 minutes)

After being released, the subject dog’s behaviour was recorded for 3 minutes. The caregiver/E1 continued interacting with the fake dog in the same way as during the interaction phase and did not pay attention to the subject dog (see Figure 4C). The end of the phase was demonstrated again by E1 saying “OK“ and either stopping the interaction with the fake dog (SP and SM conditions) or standing up from the chair (CP and CM conditions). As this phase represented the last step of the test, the caregiver leashed his/her dog and left the room. E1 stopped the video recording in the corridor.

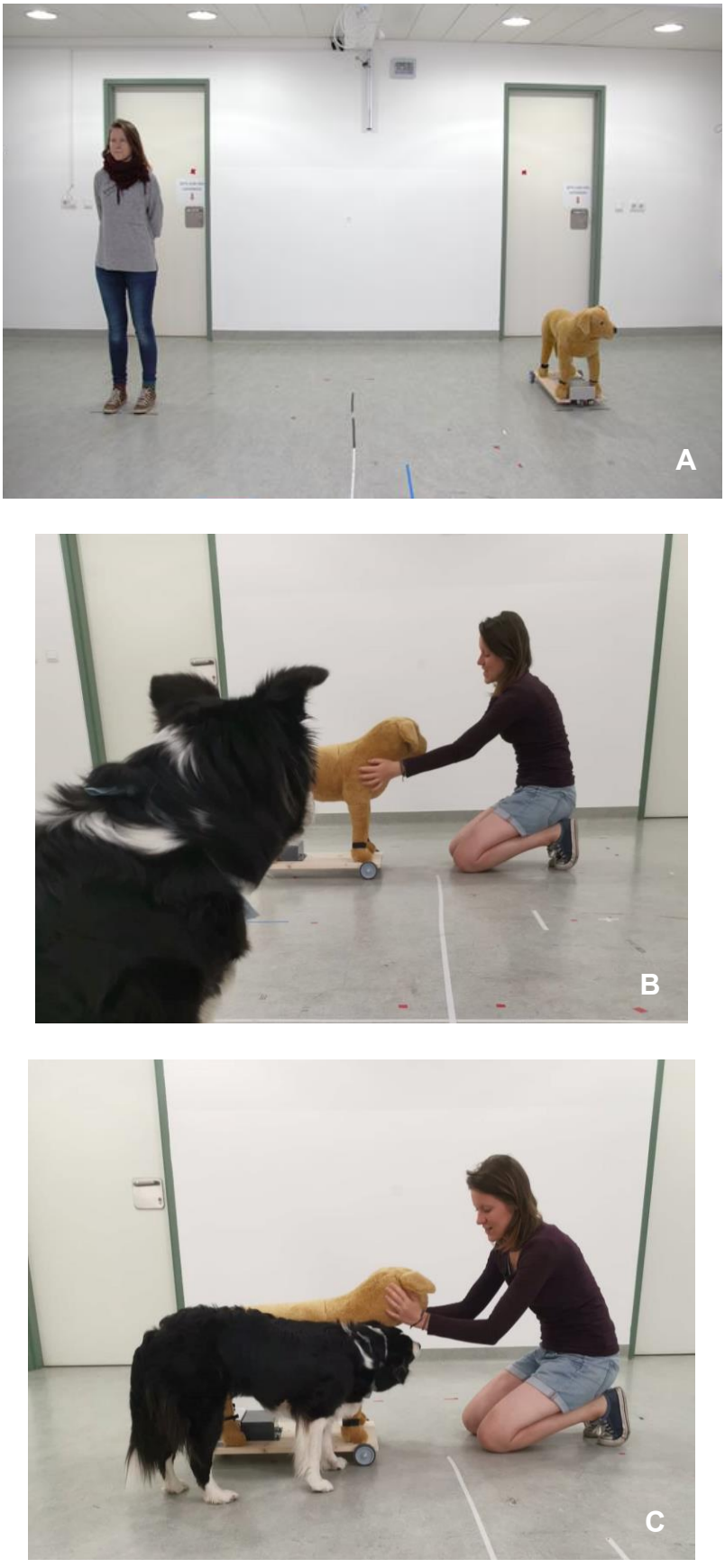

Figure 4. Introduction phase (A), interaction phase (B) and reaction phase (C)

2.5 Behavioural and statistical analyses

The behaviour of the dogs was video recorded and coded later on offline, using Loopy (LoopBio, on-site version). In the three test phases (introduction, interaction, reaction), the dogs' behaviours directed at the fake dog (all social behaviours, manipulation, blocking), directed at its human partner (friendly interaction with caregiver/stranger), and first approach (yes/no, if yes whether to the fake dog or to the caregiver/stranger) were coded (see ethogram and coding sheet *Table 10*). The overall behavioural reaction to the fake dog was coded and analysed according to 5 categories (Friendly, Neutral, Insecure, Insecure-Offensive, Offensive) in order to describe their behaviour throughout a phase. In the reaction phase, the first approach to the fake dog was used to demonstrate the dogs' attention and need of social closeness. The blocking response was analysed as one prominent indication of jealousy. We included friendly social behaviours to see the dogs' attitude and jealousy related displays towards the fake dog. Additionally, friendly behaviour towards the caregiver/stranger was chosen to show the dogs' behaviour towards the human demonstrator. The sniffing behaviour towards the fake dog was relevant as it indicates their general interest and specific social behaviours towards conspecifics (sniffing anal region).

The inter-observer reliability was measured by means of independent parallel coding of a random sample of 51 dogs. The resulting Spearman's rank correlation coefficient (r_s = 0.89) was good for the sniffing behaviour (count). Moreover, Cohen's Kappa was used and showed an agreement for the behavioural categories (κ = 0.79), fake dog interaction (κ = 0.52), blocking behaviour (κ = 0.86), and fake dog approach (κ = 0.79). As the agreement was too low for the non-offensive manipulation (κ = 0.38) and dominant behaviours (κ = 0.27), we had to exclude those variables from analyses.

The data were analysed using generalised linear models (GLM) using R package lme4. For the binary response variables (blocking, interaction with fake dog, and first approach of fake dog (present/absent) we used binomial GLMs. The sniffing response was analysed as a count variable (number of observed sniffing instances in the interaction phase: sniffing at fake dog and sniffing of anal region of fake dog) using a negative binomial GLM. In all these models, the predictor variables human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex of the dogs were included. Moreover, we included the interactions between human and treatment.

For the behavioural categories, the frequencies of these categories were modelled by fitting a mixed model ordinal regression using the R package ordinal. We included the predictor variables phase (introduction/interaction), human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex of the dogs. Also, all possible interactions between phase, human, and treatment were included.

For all models, in case of non-significant interactions, the interactions from the models were dropped in order to evaluate the main effects.

We assessed the model stability by excluding one subject at a time and refitting the models. Then, these models were compared to the original model. This procedure revealed the models to be stable with regard to the fixed effects. Moreover, we calculated Variance Inflation Factors (Field, 2005) to check for collinearity among the predictor variables, which revealed that there were no collinearity issues.

3 Results

3.1 Behavioural categories during first 2 phases (introduction and interaction)

Overall, the frequency of positive states increased from the introduction to the interaction phase ($\chi^2(1)=26.9513$, $p<0.001$; Figure 5), and positive behavioural reactions seemed to be particularly frequent when dogs saw their caregiver pet the fake dog (Treatment:Human interaction: $\chi^2(1)=4.5053$, $p=0.034$; Figure 6). Results indicated that negative reactions were more frequent in younger dogs when dogs saw the human partner and the fake dog entering and then interacting ($\chi^2(1)=8.5343$, $p=0.003$; Figure 7). The variable sex did not significantly affect the behaviour response.

Table 4

Results of the GLM with behaviour response as response variable and the predictor variables test phase (introduction/interaction), treatment (medical/petting condition), human (caregiver/stranger), sex, age (in months) and treatment (human).

	Estimate	**SE**	**χ^2**	**df**	**P**
Phase	-1.51498	0.32071	26.9513	1	<0.001
Treatment	-1.14244	0.52313			
Human	-0.03727	0.51304			
Sex	-0.23553	0.36496	0.4166	1	0.519
Age	-0.55924	0.20235	8.5343	1	0.003
Treatment: Human	1.55819	0.74176	4.5053	1	0.034

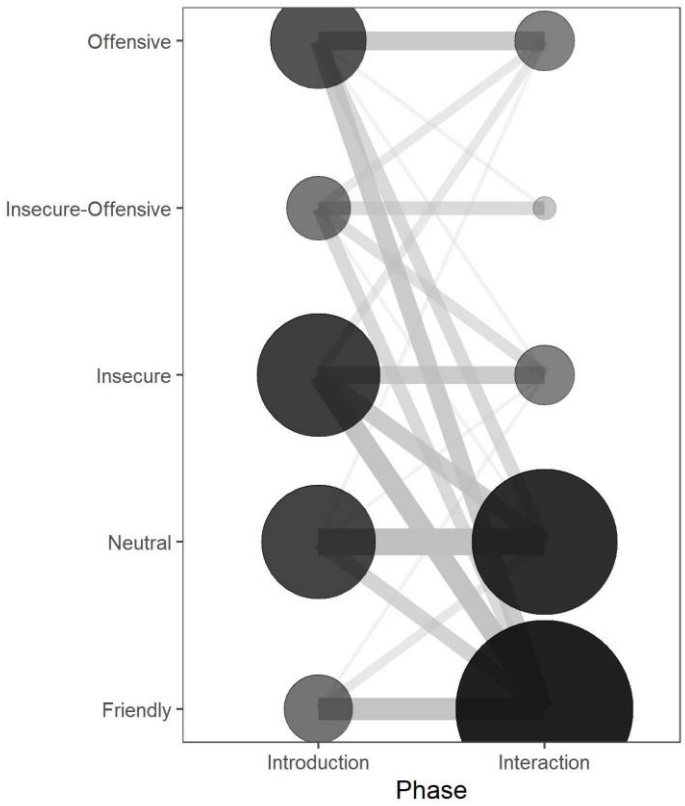

Figure 5. Effect of test phase on the behaviour response. The size of the dots and the lines is proportional to the number of represented individuals.

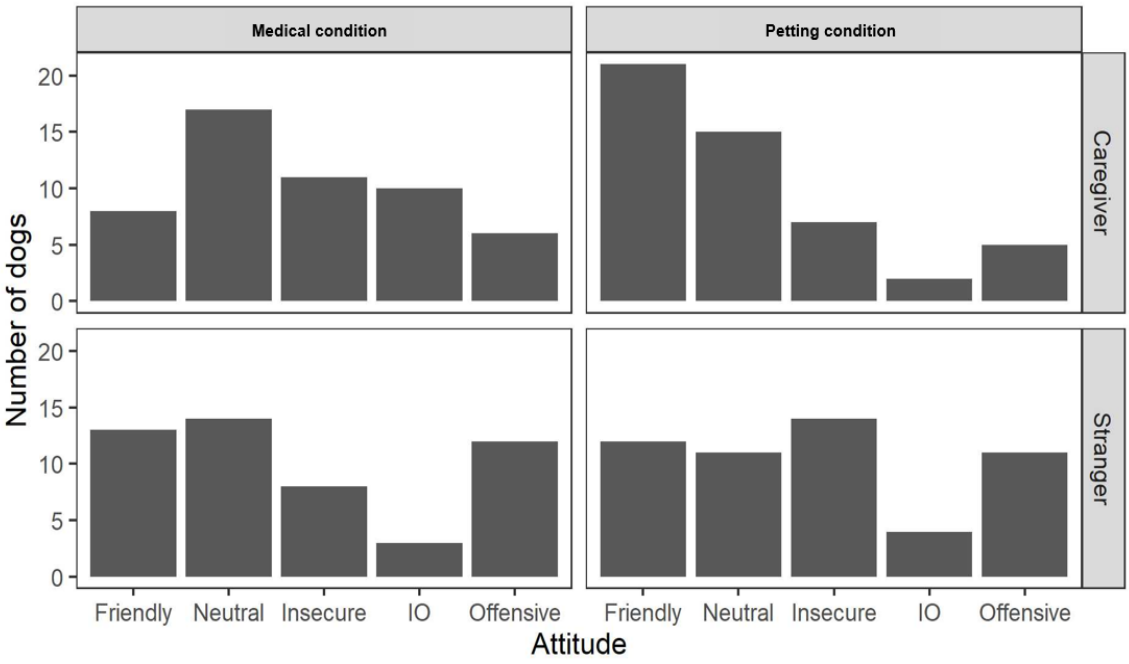

Figure 6. Effect of behaviour response (attitude) on human (caregiver/stranger) and treatment (medical/petting condition).

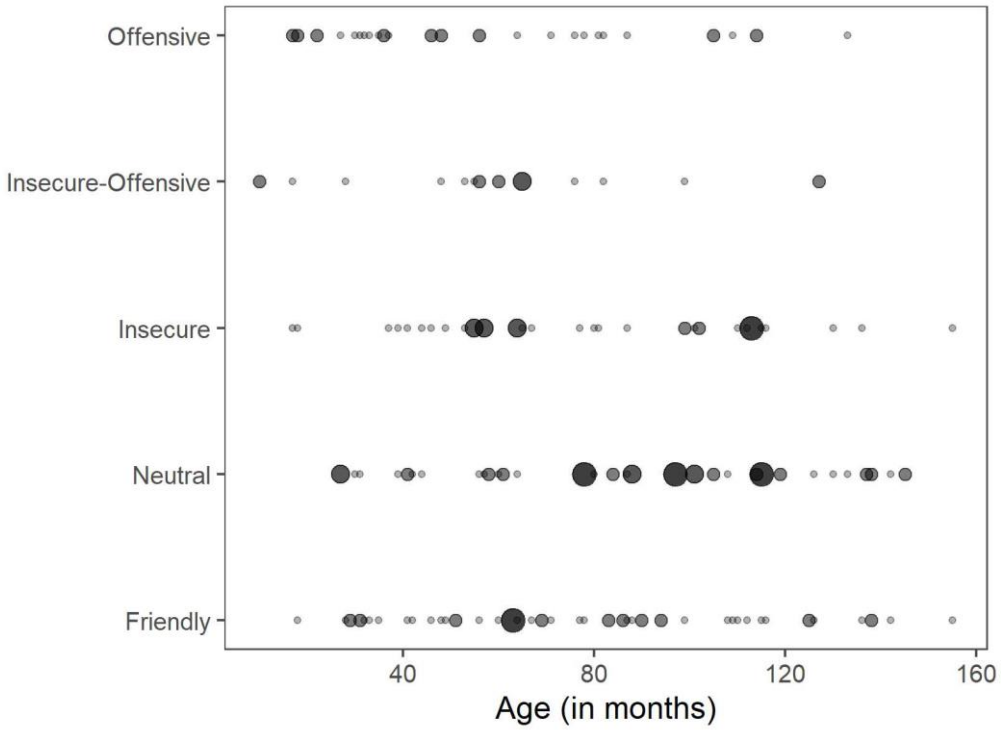

Figure 7. Effect of age on the behaviour response. The size of the dots is proportional to the number of represented individuals.

3.2 First approach of fake dog

For the first approach of the fake dog (after the dogs were released and the reaction phase started), a binominal GLM was used and the predictor variables human, treatment, age (in months), and sex were included. Dogs were significantly more likely to first approach the fake dog when the stranger acted as a demonstrator interacting with the fake dog ($\chi^2(1)=5.58$, $p=0.018$). Only thirteen out of all dogs did not approach the dyad but rather stayed next to the chair. The variables treatment, age and sex did not significantly affect the first approach response (Figure 8A).

Table 5

Results of the GLM with first approach of fake dog as response variable and the predictor variables human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex.

	Estimate	**SE**	**χ^2**	**df**	**P**
(Intercept)	-0.176	0.462			
Human	1.198	0.528	5.580	1	0.018
Treatment	0.834	0.508	2.771	1	0.096
Age	-0.034	0.264	0.016	1	0.898
Sex	0.477	0.509	0.889	1	0.346

3.3 Interaction with fake dog

For the response interaction with the fake dog, a binominal GLM was used and the predictor variables human, treatment, age, and sex were included. Results showed that the dogs interacted significantly more with the fake dog in the caregiver condition ($\chi^2(1)=4.301$, $p=0.038$) and when greeting was performed by the demonstrator ($\chi^2(1)= 7.545$, $p=0.006$).The variables age and sex did not significantly affect the interaction response (Figure 8B).

Table 6

Results of the GLM with interaction with fake dog as response variable and the predictor variables human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex.

	Estimate	SE	χ^2	df	P
(Intercept)	-1.581	0.531			
Human	-1.076	0.536	4.301	1	0.038
Treatment	1.459	0.564	7.545	1	0.006
Age	-0.383	0.273	2.054	1	0.152
Sex	-0.268	0.518	0.270	1	0.604

3.4 Sniffing of fake dog

The sniffing response was analysed as a count variable (number of observed sniffing instances in the reaction phase: sniffing at fake dog and sniffing of anal region of fake dog) using a negative binomial GLM. The predictor variables human, treatment, age (in months), and sex were included. As the results indicate, dogs were significantly more likely to sniff the fake dog when the caregiver acted as demonstrator interacting with the fake dog ($\chi^2(1)=4.154$, $p=0.042$) and younger dogs sniffed more than older ones ($\chi^2(1)=8.673$, $p=0.003$). The variables treatment and sex did not have a significant effect on the sniffing response (Figure 8C).

Table 7

Results of the GLM with sniffing of fake dog as response variable and the predictor variables human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex.

	Estimate	SE	χ^2	df	P
(Intercept)	2.029	0.170			
Human	-0.356	0.172	4.154	1	0.042
Treatment	0.286	0.174	2.727	1	0.099
Age	-0.276	0.089	8.673	1	0.003
Sex	0.060	0.173	0.120	1	0.729

3.5 Blocking behaviour

For the blocking response, we conducted a binomial GLM and included the predictor variables human, treatment, age, and sex. We found that the dogs were significantly more likely to show the blocking response when the caregiver acted as demonstrator compared to the stranger ($\chi^2(1)=6.111$, $p=0.013$). The treatment (medical/petting condition), age, or sex did not have a significant effect on the blocking response (Figure 8D).

Table 8

Results of the GLM with blocking behaviour as response variable and the predictor variables human (caregiver/stranger), treatment (medical/petting condition), age (in months, z-transformed), and sex.

	Estimate	SE	χ^2	df	P
(Intercept)	-0.305	0.414			
Human	-1.043	0.431	6.111	1	0.013
Treatment	0.325	0.434	0.567	1	0.451
Age	-0.407	0.225	3.456	1	0.063
Sex	0.525	0.429	1.514	1	0.219

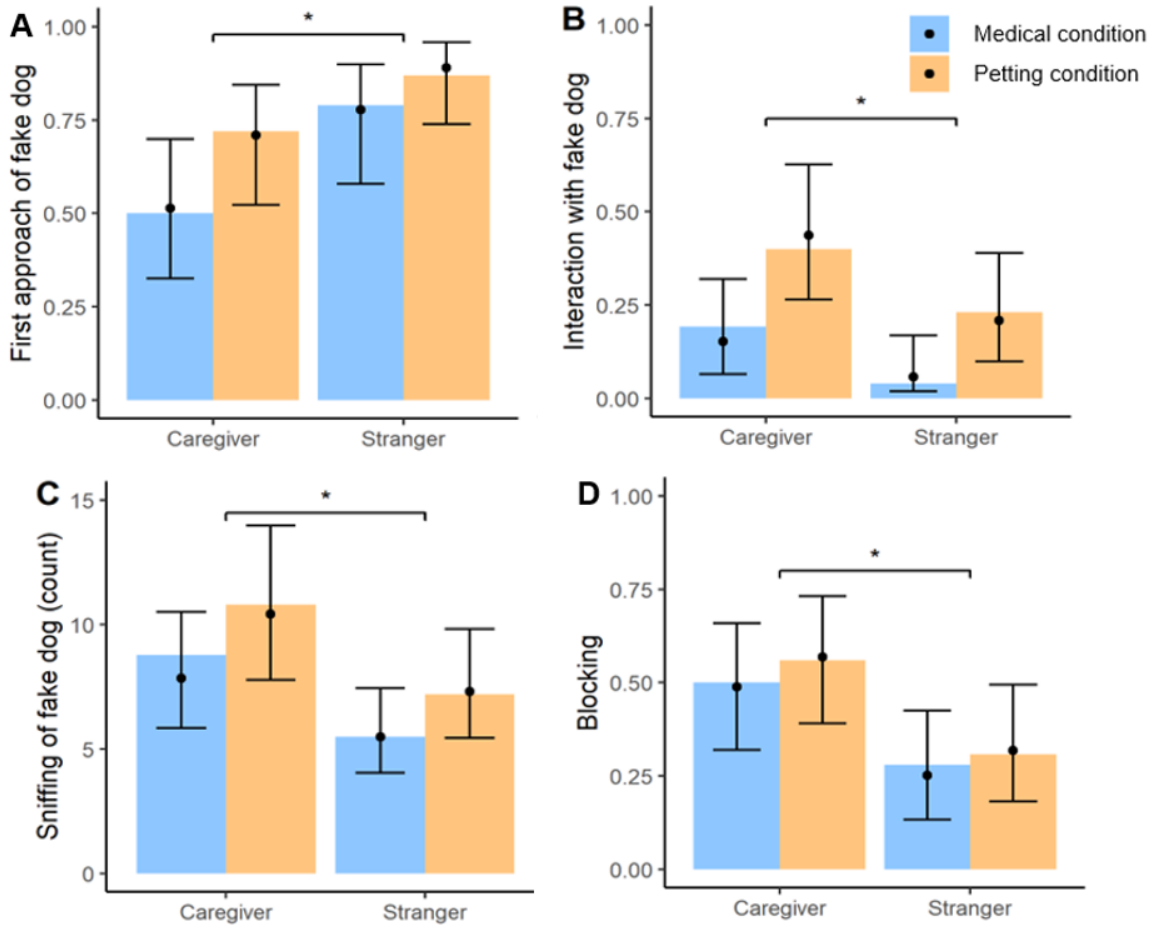

*Figure 8. Effect of conditions (human/treatment) on the different response variables: first approach of fake dog, interaction with fake dog, sniffing of fake dog, blocking behaviour. The black dots indicate the model estimates, and the whiskers show the 95% confidence intervals; *p<0.05.*

4 Discussion

The main objective of this study was to research companion dogs' reaction to observing their caregiver interact with another (fake) dog in a more or less affiliative manner. For this aim, we compared the dogs' reactions in four situations in which either their caregiver or a stranger interacted with a moving fake dog by petting and greeting (petting condition) or examining the fake dog's ears and teeth (medical condition). Accordingly, most of our results verified our expectations in respect of the "synchronization" hypothesis showing that dogs responded positively to seeing their caregiver interact with the fake dog. Moreover, findings indicated that jealousy may have also contributed to the behavioural reactions of dogs.

4.1 Introduction and interaction phase

In the introduction phase, results showed that dogs reacted negatively (insecure, offensive) or neutral towards the fake dog entering the room and approaching the dog. One explanation for the dogs' negative response could be that the fake dog's appearance, more precisely its stiff posture, and direct gaze, evoked an agonistic or insecure reaction in the dogs. Similarly, a former study stated that the subject dog tended to show more aggressive reactions towards a fake dog than a real dog (Shabelansky et al., 2014). According to Shabelansky et al. (2014), another explanation of the dogs' insecure attitude, when facing a fake dog, could be that it was perceived as a novel object. In experimental studies aiming at testing the fear reaction of dogs, technical tools such as remote-control cars are often used to evoke such a reaction (King et al., 2003; Ley et al., 2007). Stimuli with intensive physical features, such as high speed or loud noises are especially suited to evoke such reactions (Boissy, 1998), as "*these stimuli are not species-specific but rather are associated with the context of predation."* (Russel, 1979; King et al., 2003, p. 47). In the current study, the fake dog looked pretty much as a real dog, was not loud and did not move with a high speed. Nevertheless, it did make a mechanic noise caused by the remote-control construction, which the dogs might have perceived strange. Nevertheless, our findings demonstrated that the dogs sniffed at the fake dog's "body" and anal region in the reaction phase, which is an indication of perceiving it as a real dog at least initially. The first study investigating jealousy in dogs also used a fake dog, and, similar to our results, reported that 86% of the subject dogs sniffed the anal region of the fake dog when having the possibility to explore the third party (Harris & Prouvous, 2014). In the Harris & Prouvous (2014) study the animated dog also barked, whined and wagged its tale during the test, different to our fake dog. It remains an open question whether and how such unavoidably unnatural expressive behaviours on part of the fake dog may influence the subject dogs' perception.

Dogs' agonistic reactions, as for example the display of offensive behaviour, towards the fake dog, might be triggered by the fact that the fake dog did not express any de-escalating signals

("calming signals") e.g., turning its head aside or avoiding eye contact with the receiver (Shabelansky et al., 2014). Importantly, these behaviours may have a calming effect on other dogs and may help to avoid aggressive interactions between individuals (Rugaas, 2006; Shepherd, 2009; Landsberg et al., 2013; Kuhne et al., 2014). Another possible factor is the unnatural and controlled setting in which dogs were leashed to a hook on the wall. Thus, dogs might have felt constrained in their individual space, and might have showed more negative reactions (insecure, offensive behaviour) for this reason when being approached by the fake dog while entering the room.

However, the dogs' attitude switched as soon as the human demonstrator (caregiver or stranger) started to interact with the fake dog (interaction phase) so that positive reactions (friendly, neutral behaviour) became more frequent. This finding contradicts the "jealousy" hypothesis, as we would predict that jealous dogs react negatively (e.g., showing agonistic behaviours) when the human demonstrator, especially the caregiver, starts to interact with the fake dog. The dogs' actual reaction was rather in line with the "synchronization" hypothesis that predicts the adoption of the humans' behaviour by the subjects. Even more, again in agreement with the "synchronization" hypothesis, we found that in case of the caregiver, positive reactions were shown more in the petting than in the medical condition, whereas there was no treatment effect in case of the stranger. Based on these findings, I suggest that the dogs' reaction was mostly motivated by trying to synchronize with the humans' behaviour when seeing them interact with the fake dog in the introduction and interaction phase. Similarly, previous research by Duranton et al. (2016) demonstrated that pet dogs adjust their behaviour to their caregivers' movements (e.g., approaching, standing still or retreating) when being confronted with an unfamiliar human (stranger). That is, in this context behavioural regulation of the dogs seems to be driven by the social information received from the caregiver, which is one feature of social referencing (Russell et al., 1997). Generally, the paradigm of social referencing involves the subject observing a novel object/individuum and an informant, a social partner who reacts in different manners towards the novel stimulus (Merola et al., 2012). In the present study, the fake dog may have embodied the novel object/individuum to whom the informant (caregiver or stranger) showed controlled behaviours, as the inactivity of the human and the fake dog and the overall procedure of the dogs observing the human demonstrator's reaction towards an unknown third party throughout the two phases. Accordingly, it might well be that our setting in the introduction and interaction phase meets the experimental conditions of the social referencing paradigm. Indeed, dogs showed behavioural regulation based on the caregiver's behaviour, however, analyses of referential looking as further characteristic of social referencing are missing. Therefore, we cannot argue that dogs used their caregivers' behaviour as a referent to better assess the situation they were confronted with.

4.2 Reaction phase

As soon as dogs were unleashed by the experimenter/caregiver, the reaction phase started. We found that most dogs did indeed approach the dyad and most of them approached the fake dogs first. This is in contrast with the “direct response to human behaviours” hypothesis, as more dogs seem to have responded to the fake dog than to the person (especially to the stranger). However, this preferential approach to the fake dog was less expressed in the caregiver conditions: more dogs approached the caregiver first than the stranger, which may simply indicate the increased contact seeking with the caregiver than with the stranger or may support the “jealousy” hypothesis, as in the human infant literature, jealousy related behaviours include intense interest in the valuable social partner (Hart et al., 1998). In previous dog research, the first contact or approach to the valuable human partner has not been demonstrated yet (Prato-Previde et al., 2018).

Additionally, 25-50% of dogs showed blocking behaviour, that occurred more when the caregiver acted as a demonstrator, as compared to the stranger. Former studies have interpreted blocking as intervention attempt that serves to separate the valuable human partner from the social rival, and therefore, represents a main jealousy related feature (Abdai et al., 2018; Prato-Previde et al., 2018). Supporting this interpretation, we found more blocking in the caregiver groups showing that the humans’ familiarity mattered. However, we found no effect of treatment, which is in contrast with the “jealousy” hypothesis. Rather we found that dogs reacted to the same extent independent of the kind of interaction (positive/neutral) they had observed. One explanation could be that dogs were rather jealous of overall attention and physical contact, regardless of whether they saw their valuable human partner interacting with another dog in a positive or a more neutral manner.

Unfortunately, we are unable to report on other behaviours predicted by jealousy, such as agonistic behaviour (including offensive display, biting, and snaping) as the interobserver-reliability of this variable was too low (< 0.5), and therefore, we had to drop it. It is somewhat comforting that a previous study by Abdai et al. (2018) did not report such behaviours either, whereas, similarly to our results, intervening attempts and attention seeking occurred more often, especially in situations when the caregiver interacted with another dog (Abdai et al., 2018).

We could analyse however, whether the dogs showed friendly interactions with the fake dog, and we found that more dogs did so when the caregiver acted as a human demonstrator and when the fake dog was petted and greeted. These results again correlate with the “synchronization” hypothesis.

In contrast with the “synchronization” hypothesis, however, we found that treatment mattered also for the stranger, not only for the caregiver. These main effects of human partner as well as treatment (without a significant human partner * treatment interaction) rather support the

“jealousy” hypothesis. This finding, together with the rather prominent presence of blocking, suggests an interesting possibility. Even if jealousy is typically thought to manifest in negative behaviours, such as pushing against, vocalizations and general aggression, I suggest that several dogs in this study might have experienced jealousy but, instead of showing agonistic behaviours and interrupting the interaction offensively, they might have rather squeezed between the caregiver and the fake dog in a friendly manner.

The use of the fake dog was one key component in the current study aiming to investigate jealous behaviour in dogs. In order to find out, whether the subject dog is generally interested in the fake dog during the reaction phase, its sniffing behaviour, including sniffing at the fake dog’s “body” and sniffing of anal region, was analysed. Findings indicated that the dogs were significantly more likely to sniff the fake dog when the caregiver interacted with it. According to the “jealousy” hypothesis, one possibility is that the dogs sniffed at the fake dog more often when seeing the valuable human partner interact with it because they were more motivated to assess the situation and the fake dog’s intention by exploring the “potential threat” with their nose. Another explanation could be that the dogs rather synchronized their caregivers’ interaction by sniffing at the fake dog’s “body”. Moreover, the dogs were generally interested in the third party demonstrating by explorative sniffs regardless of their caregivers’ manner of interaction. Especially the occurrence of sniffing behaviour of the fake dog’s anal region, may indicate that the dogs perceived the fake dog as real at least in the beginning. As soon as they sniffed at the fake dog’s “body”, they might have recognized that it was not real, due to the missing dog specific body odour.

4.3 Age effects in all phases

Moreover, age had an effect on the sniffing response in the reaction phase, since younger dogs sniffed more at the fake dog than older ones. This seems to support previous results by Kubinyi et al. (2004), who investigated the use of dog-like robots by presenting four different test partners (remote control car, dog-like robot with and without fur and a puppy) to the dog in different contexts. Their findings showed that juveniles sniffed at the test partners longer than adult dogs did (Kubinyi et al., 2004). This might indicate that older dogs are in general more experienced, and therefore, can assess new situations sooner than younger, less experienced dogs. Alternatively, reduced curiosity and novelty seeking, and thereby, reduced exploration may reflect characteristic changes of dog personality due to age, as suggested by a recent study (Turcsán et al., 2020).

Kubinyi and colleagues (2004) also found that juveniles barked and growled more than adult dogs. Especially, the furry dog-like robot aroused the most barking responses in younger dogs (Kubinyi et al., 2004). In the present study, vocalizations (such as whining, barking, growling) were coded as part of categorizing the dogs’ overall behavioural reactions. In general, barking

indicates high arousal, whereas growling represents intense discomfort out of different reasons. Together both vocalizations stand for an overall negative attitude, which is why these preceding findings again support the present results showing that negative reactions (insecure, insecure-offensive, offensive) were more frequent in younger dogs during introduction and interaction phase. Again, the age effect might have been an outcome of the less experience of the younger dogs reacting rather insecure and offensive towards new situations, individuals or objects they have never seen before.

5 Conclusion

The present study attempted to extend research on dogs' reaction when observing either their caregiver, as a valuable human partner, or a stranger interact positively or neutrally with a moving fake dog. Our findings revealed that the reaction of dogs did not indicate jealousy and responsiveness to human behaviour in the introduction and interaction phase. However, results demonstrated that dogs rather synchronized with the human demonstrators', particularly their caregivers' behaviour. For me, it seems that the first phase of introduction resembles the paradigm of social referencing due to the use of a fake dog and the controlled behaviour of the human demonstrator interacting with a third party. In the reaction phase, dogs displayed social behaviours towards the fake dog, nevertheless, results and correlations showed that both synchronization and jealousy might have contributed to their behavioural reactions, especially if we assume that jealousy may occur without agonistic behaviours. It is very probable that using a fake dog largely contributed to the unclarity of these results. Indeed, the fake dog's unnatural body language and the noises it made could have influenced the subject dogs to some extent. Nevertheless, we found a number of behavioural indications that the dogs perceived the fake dog as a real social partner at least until the first contact in the reaction phase. Still, I suggest our results warrant further studies that should use a fake dog behaving in a more realistic manner or a real dog in more naturalistic settings to thwart possible limitations. Overall, even if jealousy as secondary emotion has not been proved in dogs, the present study should contribute to further extend the field of research on jealousy and social behaviour in interspecific contexts to better understand dogs' reactions. Given that dogs seem to synchronize especially with their familiar human partners, caregivers should know that their actions provide an essential behavioural and emotional reference to their pet dogs when interacting with a third party. That could be seen as basic prerequisite to prevent potential problems in everyday life with dogs.

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7 Appendix

Table 9

Data of all dogs included in the analyses: The four conditions were stranger petting (SP), stranger medical (SM), caregiver petting (CP), and caregiver medical condition (CM) (see below for details). In parentheses three variables are described that were counterbalanced across dogs: the identity of the stranger (K for student 1, T for student 2), the side of the door where the fake dog entered (L for left, R for right), and the location of the caregiver's or E1's chair (L for on the left side of the dog, R for on the right side of the dog).

No.	**Dog**	**Breed**	**Age** (in years)	**Sex**	**Castration**	**Lab experiences**	**Condition**
1	Hailey	Golden Retriever	7	female	no	yes	SP (K L/L)
2	Hanya	German Shepherd	5	female	no	yes	SP (T R/R)
3	Nanouk2	Australian Shepherd	7	female	yes	no	SP (K R/L)
4	Poppy2	Miniature Poodle-Spaniel-Mix	5	female	yes	no	SP (T L/R)
5	Charly5	Spanish Water Dog	3	male	yes	no	SP (K L/L)
6	Butzi	Welsh Corgi Pembroke	9	male	yes	no	SP (T R/R)
7	Milow	Labrador Retriever Mix	8	male	no	yes	SP (K R/L)
8	Batman	Jack Russel Terrier	11	male	yes	no	SP (T L/R)
9	Bailey2	Staffordshire Bull Terrier	5	female	yes	no	SP (T L/L)
10	Freya	Husky-Malamute-Mix	5	female	no	yes	SP (K R/R)
11	Cindy7	Mix	12	female	yes	no	SP (T R/L)
12	Emily7	Collie-Mix	10	female	yes	no	SP (K L/R)
13	Laiki	Dobermann-Mix	8	male	yes	yes	SP (T L/L)

14	Maylo	Border Collie-Mix	3	male	yes	yes	SP (K R/R)
15	Sammy8	Labradoodle	2	male	yes	no	SP (T R/L)
16	Spin	Shetland Sheepdog	3	male	no	yes	SP (K L/R)
17	Suka-Sevilla	Galgo	9	female	yes	no	SP (T L/R)
18	Anouk3	Labrador Retriever	3	female	yes	no	SP (K L/R)
19	Levi	Mix	4	male	yes	yes	SP (T L/L)
20	Eisbär	Maltese	1	male	yes	no	SP (K R/R)
21	Balian	Border Collie	9	male	yes	yes	SP (K L/L)
22	Linus	Australian Shepherd	5	male	no	yes	SP (T R/R)
23	Müsli	Border Collie	6	male	yes	yes	SP (K R/L)
24	Maeva	Border Collie	8	female	no	yes	SP (T R/L)
25	Arielle	Border Collie	4	female	no	yes	SP (T L/R)
26	Mulan	Labrador-Drahthaar-Mix	9	female	yes	yes	SP (T L/L)
27	Emma7	German Shepherd	6	female	yes	yes	SM (K L/L)
28	Sambesi	Rhodesian Ridgeback	3	female	yes	no	SM (T R/R)
29	Sheila	Border Collie-Mix	6	female	yes	yes	SM (K R/L)
30	Sophie	Papillon	5	female	yes	yes	SM (T L/R)
31	Flamme	Pyrenean Sheep dog-smooth faced	11	male	no	yes	SM (K L/L)
32	Sixtus	Griffon Bruxellois	3	male	no	yes	SM (T R/R)
33	Finn7	Iceland Dog	1	male	no	no	SM (K R/L)
34	Marlboro	Whippet	3	male	yes	no	SM (T L/R)
35	Bella5	Kangal	7	female	yes	no	SM (T L/L)
36	Sunny10	Miniature Poodle	2	female	yes	no	SM (K R/R)

37	Cassy3	Dackel-Shi Tzu-Mix	6	female	yes	no	SM (T R/L)
38	Bärbel	Dackel-Terrier-Mix	5	female	no	no	SM (K L/R)
39	Guinness3	Labrador-Mix	7	male	yes	yes	SM (T L/L)
40	Sepp	Beagle	7	male	yes	yes	SM (K R/R)
41	Luca2	Scotia Duck Trolling Retriever	3	male	yes	no	SM (T R/L)
42	Zeus3	Mix	4	male	no	no	SM (K L/R)
43	Ronja4	Jack Russell Terrier-Mix	8	male	yes	yes	SM (T L/R)
44	Dada	Shepherd-Mix	3	female	yes	no	SM (K L/R)
45	Paul2	Jack Russell Terrier-Mix	2	male	no	no	SM (T L/L)
46	Campino	Romanian Mioritic Shepherd dog	2	male	yes	no	SM (K R/R)
47	Aeden	Border Collie	11	male	yes	yes	SM (K L/L)
48	Gatsby	Border Collie	9	male	no	yes	SM (T R/R)
49	Schoko2	Magyar Vizsla	9	female	yes	yes	SM (T R/L)
50	Chasie	Border Collie	10	female	yes	yes	SM (T L/R)
51	Akina	Akita Inu	11	female	yes	yes	SM (T L/L)
52	Dottie	Mix Breed	9	female	no	no	CP (K L/L)
53	Miss Face	Alaska Husky	12	female	yes	yes	CP (T R/R)
54	Riu	Australian Shepherd	1	female	no	no	CP (K R/L)
55	Pepina	Boxer	6	female	yes	yes	CP (T L/R)
56	Emil6	Jack Russel Terrier-Mix	7	male	yes	no	CP (K L/L)
57	Gismo4	Border Collie-Mix	4	male	no	yes	CP (T R/R)
58	Nils2	Golden Retriever	5	male	no	no	CP (K R/L)

59	Jo-Jo3	Kangal	5	male	yes	yes	CP (T L/R)
60	Leia	Beagle	7	female	yes	yes	CP (T L/L)
61	Amie	German Shepherd-Mix	1	female	yes	no	CP (K R/R)
62	Yuki4	Mix	4	female	no	no	CP (T R/L)
63	Zoe4	German Spitz	11	female	yes	no	CP (K L/R)
64	Dante	Galgo	4	male	yes	yes	CP (T L/L)
65	Orlando	Long-Haired Collie	9	male	no	yes	CP (K R/R)
66	Monty2	Border Collie	9	male	yes	yes	CP (T R/L)
67	Ame	Akita Inu	3	male	no	no	CP (K L/R)
68	Nana3	Mix	5	female	no	no	CP (T L/R)
69	Mia7	Golden Retriever	2	female	no	no	CP (K L/R)
70	Maroni	Miniature Pinscher	7	male	yes	no	CP (T L/L)
71	Scampi	Labrador-Mix	5	male	yes	no	CP (K R/R)
72	Carlisle	Border Collie	8	male	no	yes	CP (K L/L)
73	Hagrid	Drahthaar-Mix	9	male	yes	yes	CP (T R/R)
74	Zuri	Rhodesian Ridgeback	10	female	yes	yes	CP (K R/L)
75	Kayleigh	Border Collie	8	female	no	yes	CP (T R/L)
76	Emily2	Border Collie	11	female	yes	yes	CP (T L/R)
77	Mädi	Mix	8	female	yes	no	CM (K L/L)
78	Eowyn	Terrier-Mix	2	female	yes	no	CM (T R/R)
79	Pamina2	American Staffordshire Terrier Mix	4	female	yes	yes	CM (K R/L)
80	Jolie	Pinscher-Whippet-Mix	9	female	yes	yes	CM (T L/R)
81	Thor	Husky	2	male	yes	yes	CM (K L/L)
82	Snoopy6	Beagle	7	male	yes	no	CM (T R/R)

83	Barbarix2	Bearded Collie	6	male	yes	no	CM (K R/L)
84	Grisu2	Magyar Vizla	1	male	no	no	CM (T L/R)
85	Dusty	Border Collie	2	female	yes	no	CM (T L/L)
86	Jia	Labrador Retriever	2	female	no	no	CM (K R/R)
87	Runa	Czechoslovakian Wolfdog-Mix	4	female	yes	no	CM (T R/L)
88	Helena	Standard Poodle	8	female	no	yes	CM (K L/R)
89	Arkani2	Belgian Tervuren	5	male	no	yes	CM (T L/L)
90	Lenni	Greyhound-Magyar agár Mix	6	male	yes	yes	CM (K R/R)
91	Blacky4	Mix	8	male	yes	no	CM (T R/L)
92	Emil7	Parson Russel Terrier	4	male	yes	no	CM (K L/R)
93	Fiby2	French Bulldog	4	female	yes	no	CM (T L/R)
94	Finja2	Labrador Shepherd-Mix	2	female	no	no	CM (K L/R)
95	Lumpi	Dackel-Mix	4	male	no	no	CM (T L/L)
96	Maylo2	Golden Retriever	5	male	yes	no	CM (K R/R)
97	Akin	Rhodesian Ridgeback	10	male	yes	yes	CM (K L/L)
98	Cameron	Border Collie	7	male	no	yes	CM (T R/R)
99	Cliff	Border Collie	5	male	no	yes	CM (K R/L)
100	Amy8	Border Collie	9	female	no	yes	CM (T R/L)
101	Apryl	Border Collie	10	female	yes	yes	CM (T L/L)
102	Kiki2	Mix	4	female	no	yes	CM (K R/R)

Table 10

Ethogram and coding sheet

Name of phase	Name of coded event	Definition
Definition of phases		
Introduction phase (Fake dog enters the room.)	Start point (Point event)	The first frame the fake dog is visible.
	End point (Point event)	The last frame before stranger/caregiver touches fake dog.
Interaction phase (The caregiver/stranger interacts with the fake dog, while the test dog is tied.)	Start point (Point event)	The first frame when stranger/caregiver touches fake dog.
	End point (Point event)	The last frame before the leash is visibly away from the dog at the releasing moment.
Reaction phase Sub-phase 1. First approach (The test dog is free to interact.) (Only coded separate for categorization, not included in configuration.)	Start point (Point event)	The first frame when the leash is visibly away from the dog at the releasing moment.
	End point (Point event)	After first approach within 10 cm, the last frame before dog's nose is further away again than 10 cm. If dog does not reach the distance within 10 cm, then sub-phase ends with last frame before real dog actively changes directions for the first time. If dog does not move at all first sub-phase is not coded.
Reaction phase Sub-phase 2. The rest of phase 3. (The test dog is free to interact.) (Only coded separate for categorization, not included in configuration.)	Start point (Point event)	After first approach within 10 cm, the first frame before dog's nose is further away again than 10 cm. If dog does not reach the distance within 10 cm, then sub-phase starts with first frame after real dog actively changes directions for the first time. If dog does not move at all, start point is the first frame when the leash is visibly away from dog (because no first sub-phase is coded).
	End point (Point event)	The last frame before caregiver or stranger starts to stand up/stops interacting with the fake dog or after 180 seconds.

Coded events			
Category of coded event	**Name of the event**	**Phase(s) the event is coded**	**Definition of coded event**
Behavioural categories (The category is to describe the dog's behaviour throughout a phase. If dog exhibits behaviours that fall into different categories, the more aggressive category gets coded (neutral < friendly < insecure < insecure-offensive < offensive). Behavioural categories get coded only towards the fake dog (not towards stranger/caregiver).	Friendly (Point event)	Phase 1. Phase 2. Phase 3.	The body posture of the dog is relaxed, fur is not standing, ears are loose or slightly pointing forward, tail is around the level of the back of the dog and is wagging or is relaxed, hanging. Can be accompanied by barking, jumping, and running.
	Neutral (Point event)		The dog does not show any interest towards the fake dog or caregiver/stranger, does not look intensively (longer than 3 seconds with stiff body) or go into the direction of the above. Body language is calm and body parts/ muscles are loose, tail is low and relaxed. It can be standing, sitting, lying and/or sleeping, gaze direction is often changing between stuffed dog and caregiver/stranger.
	Insecure (Point event)		The dog tends to – in Phase 1 and 2 attempts - step or move away or duck away from the fake dog. The body posture can be slightly crouched back, ears pointing backwards, tail is lower than the level of the dog's back, can be even between the legs. It can be combined with avoiding to look

			into the direction, attention/support seeking from caregiver/stranger, showing stress signals, and/or barking. If the dog approaches the fake dog, it moves towards the fake dog following a curve with slightly crouched body (not straight).
	Insecure – Offensive (Point event)		Dog faces/intensively stares (longer than 3 seconds) towards the fake dog – in Phase 1 and 2 attempts -, can even move towards or away from it a few steps, body slightly crouched, tail is lower than the level of the dog's back. It can be combined with ears pointing backwards, growling or barking.
	Offensive (Point event)		Dog actively moves – or in phase 1 and 2 attempts to move - towards the fake dog or leaning into the leash/harness or intensively stares towards it (longer than 3 seconds). Body language is stiff, ears erected, tail level is above the back, erected, slightly wagging. Can be combined with growling or barking, or rushing up to the fake dog, snapping, biting.
Friendly behaviours (The dog engages in social interactions with the fake dog.)	Friendly interactions with fake dog (State event)	Phase 3.	The dog initiates friendly interactions with fake dog with relaxed body, ears and tail (which can be wagging around the middle level). Friendly

			interactions can be leaning towards, licking, grooming fake dog, or initiation play with a play bow (stretching of the body, front legs on the floor, tail wagging, can be combined with barking).
	Friendly interactions with caregiver/stranger (State event)		Dog initiates interactions with caregiver/stranger with relaxed body, ears and tail (which can be wagging around the middle level). Friendly interactions can be leaning towards, licking or initiation play with a play bow (stretching of the body, front legs on the floor, tail wagging, can be combined with barking). (Please note, that small dogs can use human as “step” to reach fake dog – this is not initiating interaction.)
	Sniffing “body” of fake dog (State event)		The nose of the dog is a few centimetres away from the body of the fake dog exclusive the anal region (few centimetres around the tail), either with acoustically hearable sniffing sounds or with small, fast head movements to initiate sniffing.
	Sniffing anal region of fake dog (State event)		The nose of the dog is a few centimetres away from the anal region of the fake dog (a few centimetres around the tail), either with acoustically hearable sniffing sounds or

			with small, fast head movements to initiate sniffing.
Jealousy related behaviours	Blocking (Point event)	Phase 3.	Any part of the dog is positioned in-between the fake dog and the caregiver/stranger.
Manipulation	Non-offensive manipulation (Point event)	Phase 3.	Dog manipulates fake dog in relaxed or maybe in insecure body posture (tail lower than back level, body stiff, can be slightly crouched, head low) with its mouth (biting or grabbing), paws (puts paw on it) or body (leaning towards it) – exclusive the positive social interactions (see above under the category of "Friendly interactions"). These manipulations will not be included in categorization of test subject as insecure-offensive or offensive.
Agonistic behaviours	Offensive manipulation (Point event)	Phase 3.	Dog manipulates the fake dog with its mouth (biting or grabbing), paws (puts paw on it) or body (leaning towards it) with stiff body, head held high, tail position is above back level. This can be combined with growling.
	Dominant behaviours (Point event) These appeared in the videos.	Phase 3.	<u>Stand tall:</u> dog straightens up to full height, with a rigid posture and tail, may include raised hackles, ears erect and tail perpendicular or above the back. <u>Dominant approach:</u> to approach fake dog within one

			meter for at least 5 seconds, with the tail perpendicular or above the plane of the back and the ears erect and pointed forward. Paw on: to place one or both front paws on the fake dog's back. Head on: dog approaches fake dog with a rigid posture another's shoulder/back and puts its head on it. Most of times formation looks like a capital "T". The tail is usually held up or perpendicular to the body.
Locomotion	First approach to caregiver/stranger (Point event)	Phase 3.	The first attempt of approaching caregiver/stranger within 10 centimetres.
	First approach to fake dog (Point event)		The first attempt of approaching the fake dog within 10 centimetres.