Universidade de Évora - Escola de Ciências e Tecnologia

Mestrado Integrado em Medicina Veterinária

Dissertação

Dog Behaviour and Ethology

Fábio Faustino Agostinho

Orientador(es) | A. M. F. Pereira
Ana Sofia Arroube
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A dissertação foi objeto de apreciação e discussão pública pelo seguinte júri nomeado pelo Diretor da Escola de Ciências e Tecnologia:

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1. Abstract

Dogs engage in various interactions with artificial agents (UMOs) but it is not clear whether they recognize UMOs as *social* agents. Jealous behaviour emerges when an important relationship is threatened by another individual, but only when the intruder is a social agent. We investigated whether UMOs elicit jealous behaviour in dogs. We tested three groups of 15 dogs, each group observed different behaviour of the UMO: mechanistic movement, non-social or social behaviour. Then, the owner interacted with another dog, the UMO and a magazine while ignoring the subject. Dogs displayed more rival-oriented behaviour and attempt to interrupt the owner-rival interaction in case of the other dog and UMO compared to the magazine (the latter mainly occurred in the Social UMO group). However, they showed less owner- and interaction-oriented behaviour in case of the UMO. Thus, although some elements of jealous behaviour emerged toward the UMO, the results are not conclusive.

Keywords: dog, dog-robot interaction, jealous behaviour, social partner, social behaviour

2. Resumo

Comportamento e Etologia Canina

Os cães interagem com agentes artificiais (UMOs), mas não sabemos se os reconhecem como agentes *sociais*. O comportamento de ciúme surge quando uma relação importante é ameaçada por outro indivíduo, mas apenas quando o rival é social. Investigámos se os UMOs geram comportamento de ciúme nos cães. Testámos três grupos de 15 cães, cada grupo observou diferentes comportamentos do UMO: comportamento mecânico, não-social ou social. Posteriormente, o dono interagiu com o outro cão, o UMO e uma revista, enquanto ignorava a cobaia. Os cães demonstraram mais comportamento orientado ao rival e tentaram interromper a interação dono-rival mais vezes no caso do outro cão e do UMO comparado com a revista (principalmente no grupo do UMO Social). Porém, os cães mostraram menos comportamento dirigido ao dono e à interação no caso do UMO. Portanto, apesar de alguns elementos de comportamento de ciúme surgirem com o UMO, os resultados não são conclusivos.

Palavras-chave: cão, interação cão-robô, comportamento de ciúme, parceiro social, comportamento social

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5. List of symbols and abbreviations

CI – Confidence Intervals. Intervalos de Confiança.

E1 – Experimenter 1. Investigador 1.

E2 – Experimenter 2. Investigador 2.

GLMM – Generalized Linear Mixed Model. Modelo Linear Generalizado Misto.

ID – Identification. Identificação.

LMM – Linear Mixed Model. Modelo Linear Misto.

LRT – Likelihood Ratio Test. Teste De Razão De Verossimilhança.

PC – Principal Component. Componente Principal.

PCA – Principal Component Analysis. Análise de Componente Principal.

UMO – Unidentified Moving Object. Objecto Móvel Não Identificado.

6. Introduction

6.1. Artificial models in ethological research

The social behaviour of animals depends largely on the behaviour of its social partners[1]. Social behaviour of animals can only be studied in the presence of a partner, but there can be a large variability in their behaviour, even when the same, trained individual is used. The partner may display undesired behaviours, making it difficult to know which of these elicited the observed behaviour of the studied individual. Also, some characteristics can be difficult to control properly, which hinders the assessment of the effect of specific cues, further hindering the interpretation of subjects' behaviour. The use of artificial models as social partners may provide a solution to these issues, because they provide repeatability and reproducibility of experiments and facilitate to establish more controlled experimental methods[2,3]. By using simple artificial models, experimenters provide a single stimulus to test animals to observe their response, which allows to identify specific triggers for a behaviour[1–4]. However, the use of these simple models does not allow to test more complex interactions, e.g., cooperation, courtship or collective behaviour[1]. The advancement of technology facilitates the development of more sophisticated artificial models, capable of carrying out complex behaviour, including the simultaneous display of several behaviours or chain events (e.g., collective behaviour of cockroaches (*Periplaneta americana*)[5], male courtship of bowerbirds (*Ptilonorhynchus violaceus*)[6], or the alarm behaviour of eastern grey squirrels (*Sciurus carolinensis*)[7]). This facilitates discovering the specific aspects of complex interactions, and the underlying cognitive mechanisms[1,3,4].

Robots are defined as mechanical devices capable of interacting physically with their environment and performing a behaviour, or behaviour sequence, either autonomously or by remote control. These artificial agents allow for the introduction of a con- or a heterospecific-like agent that interacts with the test subject[1,2]. Interactive robots have three main aspects that should be considered in ethological research: embodiment, autonomy and behavioural skills[3].

Embodiment depends largely on the research question, thus robots can be perfect matches to conspecifics, they can mimic specific features of the species studied, or they can look different than a usual social partner[3]. Humans mainly use visual stimuli to interact with the social and ecological environment, but other animals may rely on other cues, which can lead to difficulties in the design of interactive robots[2]. Thus, the robot being similar to the test animal, from the viewpoint of the experimenter, does not guarantee that the animal acknowledges the robot as a conspecific[3]. For instance, to make a robot "look like" a cockroach, the physical appearance is less important, since cockroaches primarily rely on olfactory cues to identify conspecifics[5]. Hence, care must be taken in choosing the proper characteristics of the robot, so the studied species perceive it as a conspecific (morphologically and behaviourally)[1,4]. But there are virtually no limits as for how many combinations of morphological and behavioural characteristics can be created[1]. Separation of embodiment from behaviour is one of the greatest advantages of using robots, because it allows for the systematic manipulation of the morphological and behavioural traits of the partner, facilitating the study of how specific stimuli, or combination of stimuli influence the behaviour of the subjects[1–3]. Despite all, robots have their own issues, e.g., visual information and movement can be difficult to manipulate; its own noise from the motor or moving parts may disturb the animal[2].

In some situations, it is preferable to use a robot that does not resemble neither a con- nor a heterospecific agent that the individual encountered before. This type of robot has been referred to as Unidentified Moving Object (UMO), because the subject has no past experience with this interactive agent, and it displays (at least seemingly) self-propelled motion.[3,4]

Regarding autonomy, we can differentiate three types of robots. In case of remote-controlled robots, the experimenter controls the motion of the artificial agent. It enables researchers to study more complex interactions, but has several limitations, including the length of the observation period and subjectivity introduced by the experimenter controlling the robot[1,3]. Semi-autonomous robots are a transition between remote-controlled and autonomous robots. The experimenter only needs to start and stop a sequence of behaviours that was pre-programmed[1,3]. However, the fixed sequence cannot be changed during the experiment, regardless of how the test subject reacts. Autonomous robots increase the objectivity of the interaction, and allow longer test periods[1,3], although such robots are difficult to program because they need to properly function in the physical and social environment. The control system can be externalized to enable human intervention in case it is necessary to change the course of the interaction[1,3], but, naturally, this raises other concerns (e.g. subjectivity).

Behavioural skills are as important as embodiment, in some cases maybe even more. A functional ("meaningful") interaction can only be established between animals and robots if the latter displays proper behaviour, otherwise the animal may end the interaction prematurely. In order to keep a functional interaction, the robot must not only be able to identify the test subject as the social partner (in case of autonomous robots), but it also must be perceived as a social partner by the test subject[3].

6.2. Dog-Robot Interaction

Dogs (*Canis familiaris*) are social animals, and their social behaviour originates from the social behaviour of dogs' closest common ancestor with wolves (*Canis lupus*). Dogs and humans share the same environment for more than 15.000 years[8,9], which makes dogs particularly competent in interactions with humans. It has been suggested that due to dogs' interspecific social competence, they may be able to generalize their heterospecific interactive skills to other social agents as well[3,10,11]. This allows the study of dogs' behaviour using robots (UMOs) that do not resemble to their heterospecific social partner, humans, thus dogs have to rely solely on behaviour cues when engaging in interaction with the robot[10]. These studies generally used the same conditions regarding the interactive agent: a human partner and/or a UMO with interactive or non-interactive (mechanistic) behavioural characteristics.

Lakatos et al.[12] used a human sized and pre-programmed robot to study dog-robot interaction. The robot had a chest high table on which a touch screen was mounted, and had two arms, one able to point. First, the test partner, either a human or the robot, engaged with the owner. The robot was either interactive or non-interactive, whereas the human was always interactive. Thus, dogs could only rely on third-party information about the test partner. The two-way choice test consisted of the test partner pointing at a previously baited bowl (the dog did not know which was baited) and dogs had to choose a bowl, after the pointing of the test partner. Dogs in the interactive group were more successful in finding the hidden food than dogs in the non-interactive group. However, dogs were more successful in choosing the bowl with the human than with the robot. Considering the experimental arrangement, the results also indicate that dogs can learn from triadic interactions and may use the obtained information by generalizing it in future interactions with the robot[12].

Gergely et al[10] applied a method widely used in dog-human communicative interactions[13] to study whether dogs engage in similar interactions with UMOs as with humans. The UMOs used were remote controlled cars that have apparent self-propelled motion and can display other relatively complex behaviours. Dogs were presented with a problem-solving task, in which they had to obtain an unreachable reward. In this case, Gergely et al[10] used eye spots on the interactive UMO and it also showed variations in movement (direction) and agency (goal directedness). The mechanistic UMO moved always on the same path and the mechanistic human moved as similar as possible to the mechanistic UMO, with sunglasses on. Results showed that dogs looked more at the interactive UMO than the mechanistic counterpart, or the mechanistic human. They found that in the first trial, dogs behaved similarly towards all test partners, but in the last trial their behaviour changed depending on the test partner. In the last trials, dogs gazed longer towards the interactive UMO and displayed more frequent gaze alternation between the place of the hidden reward and the interactive UMO[10]. These results indicate that physical traits of the UMO are less important than its behavioural skills, which play a very important part in enabling interactions[10].

In another study, Gergely et al[14] also introduced a remote controlled car as a UMO that behaved either in an interactive (helping the dog in a problem solving situation) or non-interactive way (moving around the room mechanistically). They also used an interactive and non-interactive human partner showing similar behaviour as the UMOs (respectively). Following the introduction of one of the partners, dogs were tested in a two-way choice test in which a piece of food was hidden in one of two pots without the dog seeing it. The test partner called the dog's attention, but instead of pointing, as in Lakatos et al[12], the UMO/human approached the baited pot, pushed it a bit and then returned to the initial position. The dog could choose between the pots. Gergely et al[14] found that dogs chose the baited pot above chance level in all conditions except in case of the non-interactive UMO. Importantly, dogs did not readily follow the indication of the interactive UMO, but rapidly learnt that the interactive UMO indicates the place of the hidden food. The choice was at chance level in the non-interactive UMO, which further supports the need for previous interactive experience with the artificial agent in order to understand its movements as signals.

Researchers also found that when the interactive UMO helped dogs obtain unreachable food, the same UMO was able to elicit counterproductive choices in dogs when they were presented with smaller vs larger amounts of food, similarly to human partners[11]. Authors suggested that dogs may be able to generalize their experiences with humans to the UMO based on behavioural similarities, which facilitates the recognition of the UMO as an interactive partner.

The UMO elicited a bias in dogs in another context as well. The A-not-B error was first found in human infants in a hide-and-seek game. The error occurred in social situations in which an adult human hid a toy in the same place (hiding place A) repeatedly and, after some 'A' trials, hid the toy in another place (hiding place B). After successfully finding the toy under hiding place A several times, infants continued to look for it in this place, even in 'B' trials. The error occurred only when the toy was hidden by an adult using ostensive communication[15]. Topál et al[15] suggested that the error is induced in infants because they misinterpret the situation. Infants consider the interaction as a learning situation instead of a hide-and-seek game. Dogs also commit the same error when a human using communicative signals is the partner[11]. A similar study[16] using UMOs found that dogs do not commit this error when the non-interactive UMO carries out the hiding, but the interactive UMO was able to elicit the A-not-B error.

One finding that was common in most studies was that dogs required a short previous interactive experience with the UMO to engage in various interactions with the artificial agent. Authors suggested that this experience facilitated the generalization of dog's past experience with humans to the present situation, regardless of the embodiment of the interacting partner[10,11,14,16,17]. However, there are several remaining questions regarding dog-robot interactions. One of the most intriguing and important question is how dogs recognize the UMO, that is, whether dogs consider the artificial agent as a true *social* partner, or whether similarities in their behaviour displayed towards a human and a UMO rely on different mental mechanisms.

6.3. Jealous behaviour as a tool

Despite a general agreement about the presence of some primary emotions in vertebrate animals (e.g., fear, happiness, anger, etc.), there is not enough evidence to support the presence or absence of more complex, secondary emotions, like jealousy[18].

Jealousy is a complex emotion triggered in social triangles when a potential rival threatens an important relationship with a social partner. It appears in different relationships, for example, in sexual relationships, sibling-parent relationships and among friends, and it is mainly investigated in humans[19–28]. This emotion usually triggers behaviours that facilitate the maintenance of the relationship: 1) calling the attention of the partner to themselves, 2) stopping the interaction between the rival and the partner, and/or 3) removing the rival[29,30]. Although studies often aim to reveal the presence of jealousy as an emotion controlling a specific set of behaviour, first jealous behaviour should be studied in order to understand the purpose of these behaviours[30].

Jealous behaviour was found to be present in six-month-old human infants when their mother attended to a realistic fake baby, as opposed to when another unknown woman showed the same behaviour[18,29–32]. As social relationships are essential to maintain both social and basic needs, there is a possibility for jealousy to evolve as a survival strategy, highly adaptive, at least in some social nonhuman species, like dogs. Dogs not only rely on humans for basic needs (e.g., food and shelter), but they also form an attachment with their owner that is functionally similar to that of a mother-infant attachment. Based on the above, it has been suggested that dogs may also display jealous behaviours[18,29,31,32]. Owners frequently describe a similar set of behaviours that they consider to be part of jealous behaviour[33]. These are most often attention seeking behaviours, such as touching the owner, vocalizations (barking, whining, growling), attempts to separate the owner and the rival (e.g., getting in between the owner and the rival, pushing one of them away), and/or removing the rival (e.g., snapping/biting the rival)[31,32].

Findings on dogs' jealous behaviour are controversial, different researchers have encountered different results. The general methodology involves attempting to provoke jealous behaviour by letting the test subject watch the owner interact with a third party. Harris & Prouvost[31] used a fake dog to avoid aggressive conflicts between real dogs, a jack-o-lantern pail and a book (control) as test partners. They found that dogs reacted to the fake dog in a way that resembled jealous behaviour, that is, they pushed and touched more the stuffed dog than the other objects and showed increased aggression towards it, despite only inviting dogs that were reported by the owners as not showing aggressive behaviour in such situations. But some behaviours were observed in both the stuffed dog and the jack-o-lantern pail conditions, for example, the attempt to separate the owner and test partner, whining, looking at the owner and orienting away from the owner, indicating that the displayed behaviour might not (only) be related to jealous behaviour. Also, it was not clear whether dogs recognized the fake dog as a real one, despite it being an important factor to claim jealous behaviour[18]. The fake dog barked and wagged its tail, which could be recognized as social interaction cues at first, but if demonstrated out of context, they might be confusing or even prove to the dog that the 'rival' is not real[29]. Although most dogs sniffed the fake dog's anal region, the experimenters did not use olfactory cues, which are crucial in dogs' social communication. This small interaction would suffice for the dog to understand the fake dog as not real, hence recognizing it as an object or perhaps a toy, since some dogs have experience with stuffed dogs as toys[18,29,30]. On another note, the experiment was conducted at the owners' homes, thus behaviours displayed by the subject dog might be related to territoriality rather than jealous behaviour[29].

Prato-Previde et al[18] used two fake dogs to test whether jealous behaviour in dogs can be tested by using these as potential rivals. Either the owner or an unfamiliar human engaged with the fake dogs. They found that the subject dogs' behaviour did not fulfil the criteria of jealous behaviour. In contrast to the previous study[31], here they did not find aggression towards the fake dogs, other than negligible chewing. However, absence of aggression does not necessarily mean that dogs do not show jealous behaviour. Dogs might opt for other approaches before showing aggression in jealous behaviour. But the fact that some test subjects still chewed on the fake dogs might also suggest they considered these as toys. Importantly, dogs paid similar attention to the fake dog regardless of who manipulated it (the owner or a stranger). Additionally, they did not find proof that the fake dogs were viewed as real. In contrast to Harris & Prouvost[31], this study was conducted in a lab, excluding that territoriality plays a role in dogs' behaviour, and also used a stranger to see whether the behaviours are displayed only when the owner engages with the 'rival' (which is an important criterion in jealous behaviour). Nonetheless, dogs were still curious towards fake dogs, which can be explained either by fake dogs being perceived as toys (as mentioned above), or due to the unfamiliarity of the object[18].

In another study about jealous behaviour, Prato-Previde et al[32] found great individual variability and no evidence of jealous behaviour, other than the test dog sustaining the gazing towards the owner for long periods of time when the owner was paying attention to the other dog from the same household. Since they live together, it is possible that the dogs already established a set of behaviours that are displayed in such situations instead of using more overt behaviours. Authors suggested that this should be controlled for by using unfamiliar conspecifics as test partners[32]. Although the study of Prato-Previde et al[32] controlled for several potential confounding factors, some aspects of the method might have influenced the results. The first dog was ignored for two minutes before the trial, and the second dog, despite being petted during the trial of the first dog and having a one-minute break to reduce any carryover, still was ignored the same time (two minutes at the beginning), plus two more minutes afterwards, before the test trial. Thus, these dogs were ignored longer, which could have skewed the results.

Lastly, Abdai et al[29] used familiar and unfamiliar dogs as potential rivals, and familiar and unfamiliar objects as control. They found that dogs displayed different behaviour in the social and non-social situations. Dogs displayed jealous behaviour when the owner gave attention to a familiar or unfamiliar dog, but not when he/she gave attention to an unfamiliar object, suggesting that dogs did not react solely to the loss of the owner's attention. Importantly, they found that test dogs' behaviour towards the unfamiliar dog might indicate general interest in the test partner. Not only the studies above[18,32], but also Abdai et al[29] did not find aggression, which might be due to owners not letting their dogs be aggressive in general (see other potential explanations above).

Although the above studies reached somewhat contradictory results, this may have been because of the different methods and rivals used in the studies. Still, in some situations, dogs seemed to show jealous behaviour when their owner engaged in interactions with a potential rival. Putting this tool to use in other social interaction studies with dogs, specifically in studies with UMOs, may help us understand how dogs perceive these robots. Considering the different results and the capacity of dogs interacting with UMOs, it would be interesting to see whether UMOs can elicit jealous behaviour in dogs, and if so, what does it take regarding on the level of interaction (interactive, non-interactive, or mechanistic).

7. Scientific Aim

In the present study, we aimed to investigate whether dogs consider an artificial interactive agent (UMO) as a *social* agent and to identify the complexity of the behaviour that the agent needs to display to be recognized as a social agent. Thus, we tested dogs in a jealousy evoking situation (similar method as applied by Abdai et al [29]) after introducing them to the different UMOs (inanimate, non-interactive and interactive). We hypothesized that an animate and a socially behaving UMOs elicit jealous behaviour in the dog when the owner interacts with it, that is, dogs consider the UMOs as social agents that can threaten their relationship with the owner, whereas an inanimate UMO as a non-social test partner cannot threaten the relationship. Alternatively, a) the animate and social UMOs do not elicit jealous behaviour, because UMOs are not considered social agents by the dog, regardless of their behavioural complexity. b) Dogs only show jealous behaviour if the UMO previously engaged in a social-like interaction with a human, but animateness alone is not sufficient to consider the UMO as rival. c) Dogs may show jealous behaviour even in case of a mechanistically moving (inanimate) UMO, because its self-propelled motion (start from rest and turning) is enough for dogs to perceive de UMO as an animate agent.

8. Materials and Methods

8.1. Materials

The UMO was a remote-control car (#32710 RTR Switch Abarth 500; with a novel white plastic cover 37 cm x 18.5 cm x 12 cm) with magnets attached to the front, to enable it to pick up the unfamiliar object. The Observation phase was recorded by two wide-angle lens cameras (Zoom Q2n) attached to the ceiling. The UMO was controlled by Experimenter 1 (E1) from the adjacent room via the live image of the cameras. The Test phase was recorded by three cameras. As test partners, we used the other dog from the same household, a magazine and the UMO.

During the Observation phase, the UMO fetched an object unfamiliar to the dog. The object was a red dome shaped object on a plastic plate. The plate had metal sheets on all sides, the magnets in the front of the UMO attached to these metal sheets. We placed two wooden blocks in the opposite sides of the room and fixed them to the floor with reusable adhesive (three meters away from the dog and 3.6 m from each other). The blocks allowed the UMO to remove the plate from the magnets by gently hitting them with it (Figure 1).

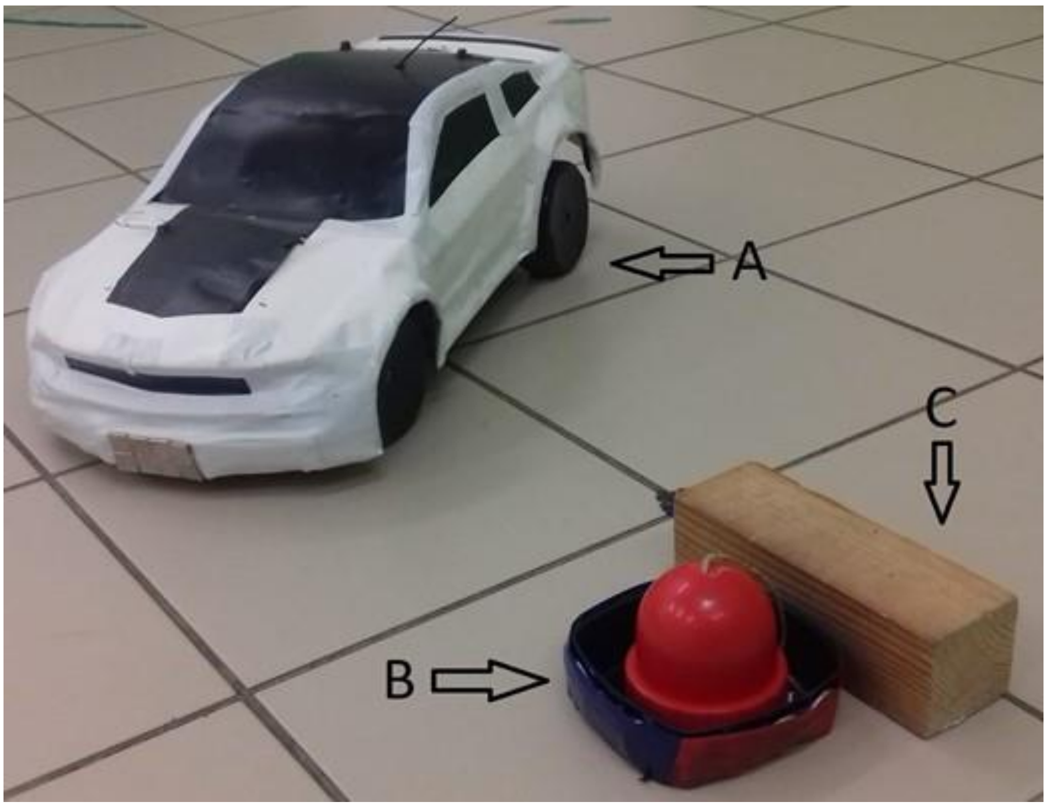

Figure 1 A) the UMO with the magnets attached to the front; B) the unfamiliar object on a plate; and C) one of the wooden blocks.

8.2. Subjects

The National Animal Experimentation Ethics Committee, Hungary, provided ethical approval (PE/EA/3741-4/2016). The experiment was carried out following relevant guidelines and regulations and was performed in accordance with the EU Directive 2010/63/EU. Owners provided written consent indicating voluntarily allowing their dogs to participate in the study.

We recruited 52 dogs from the database of the Department of Ethology, Eötvös Loránd University (Budapest, Hungary) and via social media (Facebook). Data on both subject and rival dogs can be found on appendix A. We excluded seven dogs for various reasons: recording error due to which we cannot analyse the entire test (N = 1); loud noise in the university building during testing which might influence subject's behaviour (N = 1); the dog did not approach the UMO possibly due to distress (N = 2); the owner displayed different behaviour at the three potential rivals (N = 2); and the other dog from the household (used as rival) vocalized during the test from outside, which distracted the test dog (N = 1).

The remaining subjects (N = 45) were randomly divided into three groups: Interactive UMO (N = 15, 6 males, mean age ± SD = 4.7 ± 2.7 years), Non-Interactive UMO (N = 15, 7 males, mean age ± SD = 4.4 ± 2.4 years) and Mechanistic UMO (N = 15, 7 males, mean age ± SD = 4.8 ± 2.6 years).

Subjects were required to be unexperienced with the UMO and to come from multiple-dog households. We tested dogs whose owners reported jealous behaviour between their dogs. If more than one dog from the same household was reported to show jealous behaviour, all dogs were tested but on different days (in case of two dogs, the second dog was tested after a one-hour break), and the dogs were assigned to different groups.

8.3. Groups and conditions

Dogs were divided into three groups based on the behaviour demonstrated by the UMO in the Observation phase. In the Interactive UMO group, dogs observed the UMO interacting with Experimenter 2 (E2). E2 gave commands to the UMO ("*Come here*", "*Stay*", "*Look*", "*Fetch*"), and praised and petted the UMO when it obeyed. Dogs in the Non-Interactive UMO group observed E2 and the UMO carrying out the same behaviour as in the previous group, but not in an interaction. E2 repeated the same commands/praise/petting in the same order, whereas the UMO displayed the behaviours in reverse order, so they would not interact with each other. For example, the UMO fetched the object while E2 was giving the "*Come here*" and "*Stay*" commands while turning away from the UMO. Lastly, in the Mechanistic UMO group, the UMO only moved around the room for two and a half minutes, while E2 moved around the room, repeating the commands and praises she used in the other groups.

The Test phase was the same for all dogs. Dogs encountered three different test partners: 1) the other dog from the household; 2) the previously mentioned UMO; and 3) a magazine (conditions are labelled as "Dog", "UMO" and "Reading", respectively). In this phase, the behaviour of the UMO was identical in all groups.

8.4. Procedure

The experiments were carried out in two adjacent test rooms at the Department of Ethology, Eötvös Loránd University, Budapest, Hungary. The larger room (6.27 m x 5.40 m) was used for the Observation phase and the smaller room (3 m x 5.40 m) for the Test phase.

In the Observation phase, dogs observed the behaviour of the UMO (see above). Before the owner and the dog entered the room, we placed a chair to the middle of one of the walls, the two wooden blocks to their predetermined location, and the plate with the object on it next to one of the wooden blocks (side is counterbalanced between subjects). The UMO was also placed in front of the chair, next to the opposite wall of the room (Figure 2).

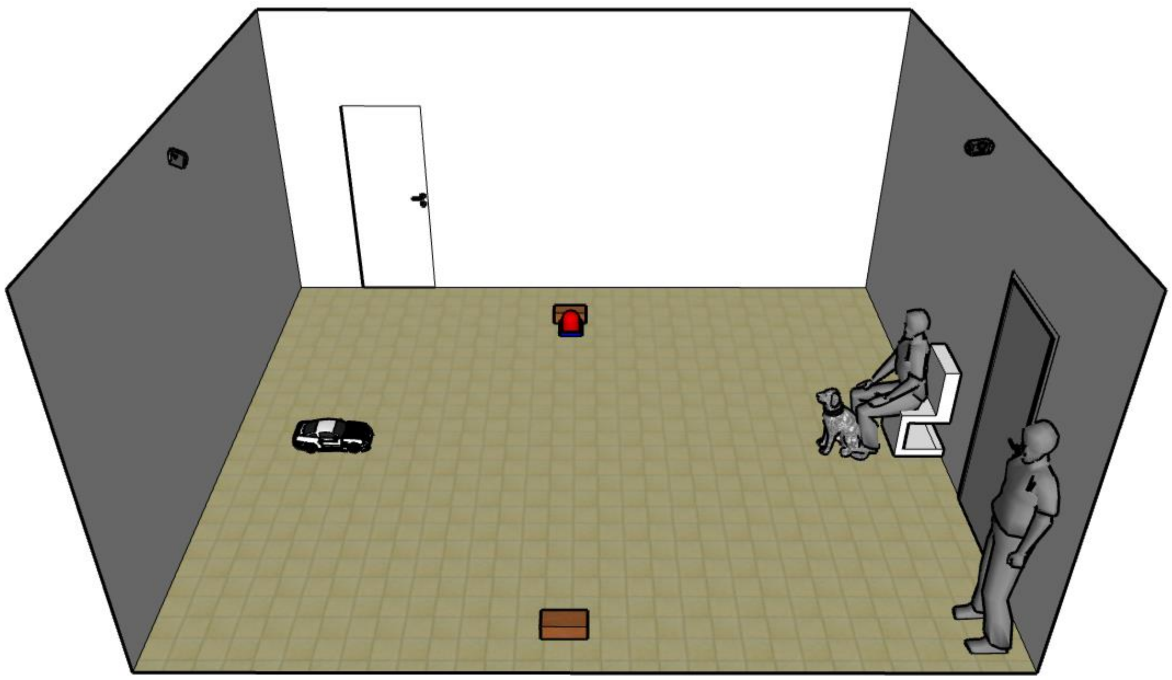

Figure 2 Experimental setup of the Observation Phase. Objects are not to scale.

In the Test Phase, the owner interacted with three different test partners, one at a time, while ignoring the subject dog. The UMO and the magazine were placed in the room before the owner and the dog entered, whilst the other dog entered the room with the owner and the subject dog. We counterbalanced the order of the test partners between subjects.

8.4.1. Observation Phase

The owner and the dog entered the room with E2. E2 informed the owner while the dog explored the room. After the exploration, the owner sat on the chair and held the dog in front of him/her. E2 stood in the corner of the room, on the left side of the dog. The UMO started to move around the room, either in a circle (mean (s) ± SD = 33.0 ± 4.4) or in a winding trajectory (mean (s) ± SD = 51.1 ± 8.5) (counterbalanced between subjects), and then returned to its starting position. After the UMO stopped, the owner released the dog that was allowed to explore the UMO. If the dog did not approach the UMO, E2 and the owner went to the UMO and encouraged the dog to get close to it. We excluded dogs that did not approach the UMO at all because these dogs were likely to avoid the UMO later in the Test phase as well, thus their behaviour would not have been comparable across conditions.

Then, the owner sat back on the chair, and held the dog in front of him/her. E2 stood back in the corner. The dog observed the behaviour of the UMO, according to the group they were assigned to. This part was about the same length in all groups (mean (s) ± SD = 227.4 ± 24.9; Interactive group, 229.5 ± 15.5; Non-Interactive group, 242.6 ± 31.4; Mechanistic group, 209.5 ± 8.6).

In the Observation phase, we measured dogs' looking duration at the UMO, E2 or the interaction of E2 and the UMO, from the moment the UMO started to move until it left the room. As total time varied between subjects, we used the percentage of the looking duration (looking duration divided by total time, and then multiplied by 100). We excluded dogs that looked at the demonstration overall less than 20% of the time.

8.4.1.1. Interactive UMO Group

The UMO started to move in the room in various routes for about 20 seconds (measured from when the UMO started to move until E2 started moving) (mean (s) ± SD = 19.42 ± 4.5), after which E2 walked to the other side of the room opposite to the plate. Then, E2 oriented towards the UMO and called it by saying "Come here". As soon as the UMO arrived, E2 petted and praised it for about five seconds. In the next step, E2 gave the command "Stay" to the UMO and moved to the opposite side of the room and then E2 called the UMO again by saying "Come here", while orienting towards the UMO. When it arrived to E2, she petted the UMO and praised it for five seconds and repeated the steps ('Stay' and 'Come here' commands) once more.

After petting and praising the UMO, E2 gave the command "Stay" again, and went to the plastic plate with the object on it. She lifted it up and showed the object to the UMO while saying "Look". She placed the plastic plate back on the floor and went back to the UMO. Here, E2 gave the command "Fetch it" while pointing towards the plate. The UMO went to the plate, picked it up with the magnets on its front and took it to E2. E2 took the plate from the UMO and rewarded the UMO by petting and praising it. E2 and the UMO moved to the opposite side of the room together (E2 continuously encouraged the UMO to go with her, saying "Come"). The showing of the object and the fetch command were repeated once more. After the UMO took the object to E2, who praised and petted the UMO, E2 and the UMO left the room together (E2 kept encouraging the UMO with the command "Come"). The UMO always obeyed to the commands immediately.

8.4.1.2. Non-Interactive UMO Group

In this group, the behaviour of the UMO and E2 were the same as in the Interactive UMO group; however, the UMO carried out the actions in a reverse order (started by fetching the plate) while E2 did the same routine as before but did not address the commands to the UMO (started by giving the commands ‘Stay’ and ‘Come’). Thus, the behaviours of both were complex, but there was no interaction between E2 and the UMO.

The UMO started to move in the room in various routes (mean (s) ± SD = 20.2 ± 3.3). E2 walked to the opposite side of the room (while the UMO was still in motion) where she pretended to call the UMO by saying “Come here”, but she was turned away from the UMO. After about five seconds, E2 bent down, praised and petted the air/ground as if the UMO would be there, for five seconds. E2 gave the command “Stay”, while turning away from the UMO and then moved to the other side of the room. There, E2 said “Come here”, while turning away from the UMO. After five seconds, E2 bent and talked for five seconds, as if the UMO was there. This was repeated once more.

While E2 was carrying out the ‘Stay’ and ‘Come here’ routine, as in the Interactive UMO group, the UMO carried out the “Look” and “Fetch it” routine. The UMO went to the plate placed on the floor, grabbed it, took it to the wooden block on the opposite side of the room and took it off by hitting it gently on the wooden block. In case the UMO was unable to grab the plate, it stayed there for five seconds and then tried to grab it again. In case the UMO was unable to take the plate off, it continued to move with the plate on, to the other side. After finishing this routine, the UMO continued its own route by going to the corner on the opposite side of the room as the dog was, while E2 went to pick up the plate with the object (after saying “Stay” to the imaginary UMO). If the plate was still on the UMO, then during the switch of the routines, E2 bent down and detached the plate while walking, without looking at the UMO.

Both the UMO and E2 continued their own routine. E2 went to the plastic plate, lifted it up and showed up the object, away from the UMO, by saying “Look”. Then, E2 placed the plastic plate back on the floor and went back to her original position and said the command “Fetch it”. After about 10 seconds, E2 praised and petted the air/floor for five seconds, as if the UMO was there. This was repeated once more, on the other side of the room. During these steps, the UMO kept moving as if it was replying to the commands “Stay” and “Come here” (without going to the plate or E2).

At the end, E2 opened the door and left the room, continuously encouraging as if the UMO was leaving with her, saying “Come”. The UMO either waited in its place for five seconds or went to the other side of the room and waited there for five seconds, leaving the room afterwards.

There was no interaction between E2 and the UMO, but there was no avoidance either. In this group, E2 and the UMO pretended they had someone to interact with but were always independent from each other.

8.4.1.3. *Mechanistic UMO group*

In this group, the UMO moved around the room, along the walls, but without getting close to the dog, with constant speed for two and a half minutes. After about 20 seconds (mean (s) ± SD = 22.11 ± 3.31), E2 started walking around the room, in a winding route, and repeated the same commands with the same tone of voice as in the other groups, but did not look at nor interacted with the UMO. After the time elapsed, E2 left the room. The UMO left the room when it reached the door on its route.

At the end of the Observation Phase, E2 went back to the room and the owner and the dog left the room with her. The UMO was removed from the hallway by E1.

8.4.2. Test Phase

As mentioned before, the subjects encountered three test partners. Before encountering the first test partner, E2 instructed the owner to behave the same way as if the test partner would be the other dog from the household (e.g. using similar words, tone of voice, and touch), even if the first test partner was the UMO or the magazine. The owner was allowed to pet the test partner and talk to it, but we asked the owner not to play with the test partner nor give commands to it (including calling the test partner). After the first condition, E2 instructed the owner to behave the same way in the next two conditions as well (e.g., use the same tone of voice and repeat similar words).

Before the owner and the dog entered, E1 placed the UMO/magazine in the room; the dog test partner entered the room with the owner and the subject dog. After the owner and the subject entered the room along with E2, the owner took the dog(s) off leash. After E2 left the room, the owner waited for 10 s, before starting to interact with the test partner. During this time, the owner ignored both the subject dog and the test partner (did not look at, touch or talk to them); the owner measured the time by counting. After the 10 s elapsed, the owner started to pet and talk to the test partner for 90 s (or other behaviours that may have elicited jealous behaviour in the subject dog; except playing, commands/tasks, or calling), while continued to ignore the subject dog. When the test partner was the UMO, it moved every 20th second, for a total of four times. When the test partner was the magazine, the owner was instructed to move with the magazine as they moved with the other test partners, or would move if it were a dog, and put it down on the ground or hold it close to the ground. When the 90 seconds elapsed, E2 entered the room and accompanied the owner and the dog out of the room for about 60 seconds. During this break, E2 informed the owner about the next condition. If the test partner was the other dog, it left the room with the owner and was led back to the waiting room. E1 changed the test partner in the room while the owner and the dog waited outside. After the last condition, the test ended.

8.5. Behavioural variables and data analysis

All tests were recorded, and dogs' behaviour was analysed in Solomon Coder 19.08.02 (András Péter: https://solomon.andraspeter.com/). Coding was carried out by two coders, both analysed the behaviour of half of the subjects with a 20% overlap of subjects to carry out inter-coder agreement analysis. However, this analysis has not been carried out yet, thus the data analysis and results described here are only preliminary. Statistical analysis was carried out using R software version 4.1.1 (R Development Core Team (2021)) in RStudio version 1.4.1717.

The behaviours analysed in the Test phase are provided in Table 1. Behaviours were measured from the owner's first contact with the test partner until 90 seconds elapsed.

Table 1 Definitions of behaviours analysed in the Test Phase.

Measurement	Behaviour	Description
Frequency	Interruption	Moving in between the owner and test partner
Duration (s)	Looking at Owner	Head turned to owner
	Looking at Test Partner	Head turned to test partner
	Looking at Interaction	Head turned to the interaction between owner and test partner
	Touching Owner	Less than 2cm away from owner
	Touching Test Partner	Less than 2cm away from test partner
	Touching Interaction	Less than 2cm away from the interaction between owner and test partner
	Orienting to Owner	The body itself is turned towards the owner
	Orienting to Test Partner	The body itself is turned towards the test partner
	Orienting to Interaction	The body itself is turned towards the interaction between owner and test partner
	Moving to/Parallel with Owner	Moving towards the owner or in parallel with him/her
	Moving to/Parallel with Test Partner	Moving towards the test partner or in parallel with it
	Moving to/Parallel with Interaction	Moving towards or in parallel with both
	Stay near owner	The dog is within 0.5 m near the owner
	Standing still	The dog is not moving, its paws are still
	Moving	The dog is in motion
	Laying	The dog is laying down
	Sitting	The dog is sitting

Principal Component Analysis (PCA) (with oblique rotation), Eigenvalue > 1 was used for data reduction. Based on the Horn's Parallel Analysis for component retention, we retained five Principal Components (PC) (Eigenvalues: PC1 = 2.453, PC2 = 2.397, PC3 = 1.510, PC4 = 1.444 and PC5 = 1.095).

Principal components were analysed using linear mixed models (LMM; 'lme4' package) (except PC5, see Results). Residuals of the model analysing PC3 and PC4 were normally distributed (Kolmogorov-Smirnov test: PC3, $D = 0,057$, $p = 0.781$; PC4, $D = 0.068$, $p = 0.569$). Residuals of the model analysing PC1 and PC2 were normally distributed after Box-Cox transformation ('MASS' library; PC1: lambda = 0.05; PC2: lambda = 0.15) (Kolmogorov-Smirnov test: PC1, $D = 0.064$, $p = 0.643$; PC2, $D = 0.057$, $p = 0.779$). We estimated the fixed effects of group (Dog vs UMO vs Reading) and condition (Social vs Non-Social vs Inanimate) (two-way interaction). We also tested whether the trial number (Trial), the Order of conditions, and whether the UMO moving in a round or winding route at the beginning of the Observation phase (Introduction) had an effect on the principal components. The ID number assigned to the dogs was included as random intercept to control for the within-subject comparison. Backward model selection was carried out using drop1 function; selection was based on likelihood ratio test (LRT). LRT of non-significant variables are reported before their exclusion from the model. For significant explanatory variables in the final models, we carried out pairwise comparisons ('emmeans' package; Tukey correction) and we report contrast estimates ($\beta \pm SD$).

We counted the frequency of the Interruption behaviour. Based on the AIC values (model comparison with ANOVA), negative binomial distribution fit the data best (AIC = 363.69; model with the lowest AIC value was kept and a model was considered better whenever ΔAIC was ≥ 2). We carried out generalized linear mixed model (GLMM; 'lme4' package) with negative binomial distribution to analyse the data. We estimated the fixed effects of group (Dog vs UMO vs Reading) and condition (Social vs Non-Social vs Inanimate) (two-way interaction). We also tested whether the Introduction, Trial and Order of conditions had an effect on the Interruption behaviour. Data analysis was carried out similarly as in case of the principal components.

9. Results

All behaviours measured by duration (see Table 1) were included in the PCA. These behaviours were grouped into five principal components (see above), except for the sitting behaviour, the loading of which was below 0.50. We labelled the PCs as "Test partner-oriented behaviour" (PC1), "Owner-oriented behaviour" (PC2), "Activity" (PC3), "Interaction-oriented behaviour" (PC4) and "Interaction-oriented activity" (PC5) (Table 2). Reliability analysis showed that all PCs but PC5 had acceptable reliability (see Table 2 for the alpha values). PC5 was excluded from further analysis.

Table 2 Loadings of behaviours of the five factors (PCA), and the result of the reliability analysis (alpha values).

Principal Component	Alpha Values (95% CI)	Behaviour	Loadings
Test partner-oriented behaviour (PC1)	0.67 (0.60; 0.74)	Look Test Partner	0.807
		Orient Test Partner	0.846
		Touch Test Partner	0.615
		Stand Near Owner	0.806
		Move to/Parallel with Test Partner	0.439
Owner-oriented behaviour (PC2)	0.69 (0.62; 0.76)	Look Owner	0.907
		Orient Owner	0.633
		Touch Owner	0.654
		Move to/Parallel to Owner	0.789
Activity (PC3)	0.85 (0.81; 0.90)	Standing Still	0.932
		Moving	0.938
Interaction-oriented behaviour (PC4)	0.50 (0.37; 0.63)	Look Interaction	0.809
		Orient Interaction	0.799
		Touch Interaction	0.477
Interaction-oriented activity (PC5)	0.19 (0.04; 0.35)	Move to/Parallel to Interaction	0.459
		Laying	0.957

The group by condition interaction did not have an effect on dogs' Test partner-oriented behaviour (LMM, χ^2_4 = 3.352, p = 0.501), but condition had a significant effect on this behaviour (χ^2_2 = 22.690, p < 0.001). Subjects displayed more Test partner-oriented behaviour in both the Dog and the UMO conditions than in the Reading condition (Dog vs Reading: β ± SE = 0.012 ± 0.004, p = 0.011; Reading vs UMO: β ± SE = -0.021 ± 0.004, p < 0.001), but there was no difference between the Dog and the UMO conditions (Dog vs UMO: β ± SE = -0.009 ± 0.004, p = 0.105) (Figure 3).

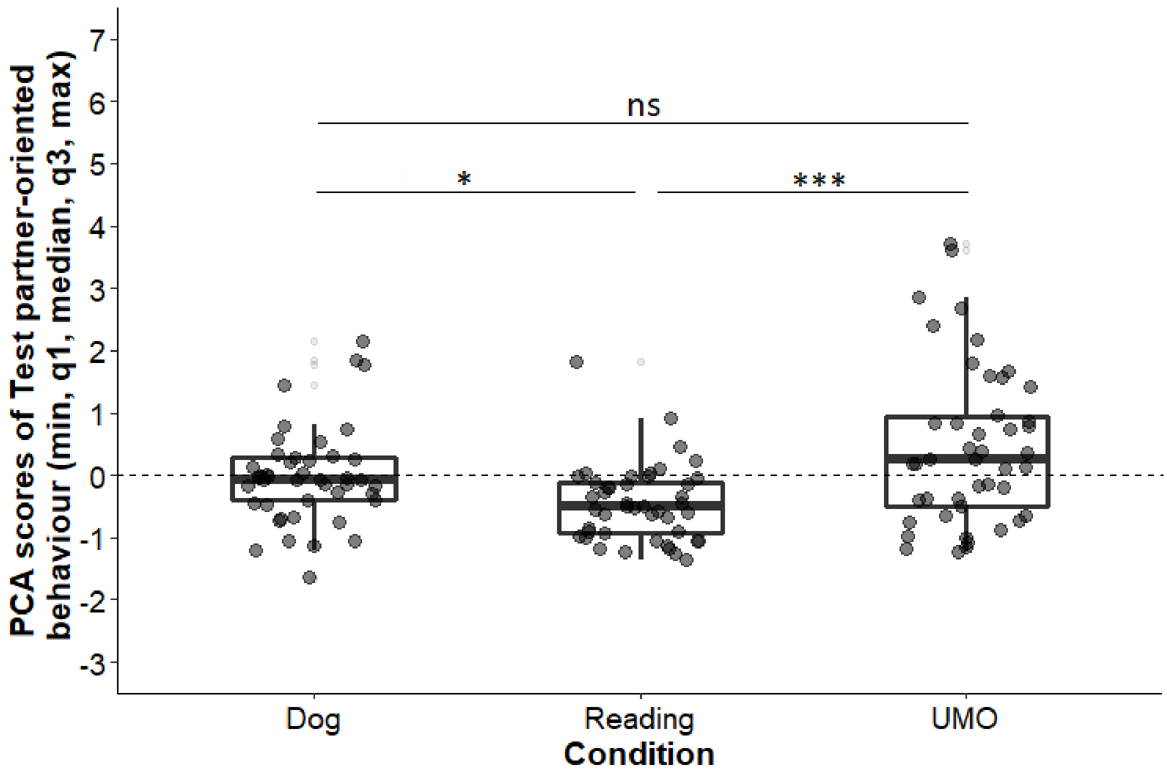

Figure 3 Influence of Condition on Test partner-oriented behaviour. * p<0.05; *** p < 0.001 ns: non-significant effect

However, the UMO's distinct behaviours observed by the test subject did not influence the Test partner-oriented behaviour (Group: χ^2_2 = 3.292, p = 0.193).

The interaction of group and condition did not have an effect on dogs' Owner-oriented behaviour either (LMM, χ^2_4 = 5.147, p = 0.273), but condition did (χ^2_2 = 9.678, p = 0.008). Behaviour towards the owner was similar in the Dog and the Reading conditions (Dog vs Reading: β ± SE = 0.015 ± 0.011, p = 0.396), and in the UMO and the Reading conditions (Reading vs UMO: β ± SE = 0.021 ± 0.012, p = 0.162), but subjects showed more Owner-oriented behaviour in the Dog condition than in the UMO condition (Dog vs UMO: β ± SE = 0.035 ± 0.011, p = 0.006) (Figure 4). However, the UMO's distinct behaviours observed by the subject did not influence Owner-oriented behaviour (Group: χ^2_2 = 1.919, p = 0.383).

The interaction between group and condition had no effect on Interaction-oriented behaviour (LMM, χ^2_4 = 8.049, p = 0.090), but there was a significant difference between conditions (χ^2_2 = 32.577, p < 0.001). Subjects displayed more Interaction-oriented behaviour when the other dog was the test partner, than when it was the UMO or the owner had to read the magazine (Dog vs UMO: β ± SE = 0.850 ± 0.137, p < 0.001; Dog vs Reading: β ± SE = 0.460 ± 0.137, p = 0.003), and they also showed more Interaction-oriented behaviour when the test partner was the magazine than when it

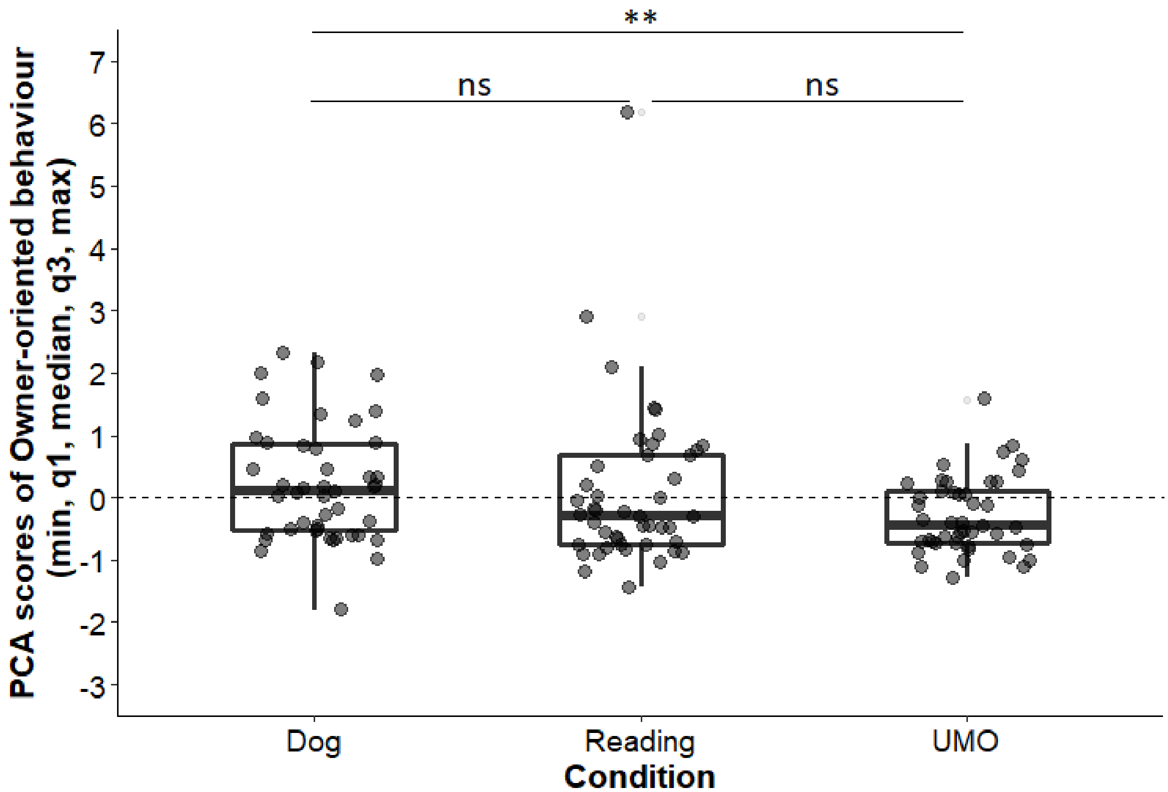

Figure 4 Influence of Condition on Owner-oriented behaviour. ** p < 0.01; ns: non-significant effect

was the UMO (Reading vs UMO: β ± SE = 0.390 ± 0.137, p = 0.015) (Figure 5). However, the UMO's animateness did not influence Interaction-oriented behaviour (Group: χ^2_2 = 1.005, p = 0.605).

The group by condition interaction did not influence dogs' Activity (LMM, χ^2_4 = 6.937, p = 0.139), but it was influenced by condition (χ^2_2 = 26.397, p <0.001). Dogs were more active when the owner was interacting with the Dog than in the UMO or Reading conditions (Dog vs Reading: β ± SE = 0.662 ± 0.150, p < 0.001; Dog vs UMO: β ± SE = 0.740 ± 0.150, p < 0.001), but there was no difference in Activity between the Reading and the UMO conditions (Reading vs UMO: β ± SE = 0.078 ± 0.150, p = 0.864). Trial also significantly affected subjects' Activity (χ^2_2 = 13.432, p = 0.001). Dogs showed more activity in the first Trial than in the other trials (Trial 1 vs 2: β ± SE = 0.549 ± 0.150, p = 0.01; Trial 1 vs 3: β ± SE = 0.364 ± 0.150, p =0.045), but showed a similar level of activity in trials two and three (Trial 2 vs 3: β ± SE = -0.185 ± 0.150, p =0.438). However, Activity was not influenced by the behaviour of the UMO (Group: χ^2_2 = 1.809, p = 0.405).

Trial, trial order and introduction did not have significant effects on the behaviour towards the Test partner (Trial χ^2_2 = 1.490, p = 0.475; Trial Order χ^2_5 = 3.874, p = 0.568; Introduction χ^2_1 = 0.979, p = 0.322), nor towards the Owner (Trial χ^2_2 = 0.523, p = 0.770; Trial Order χ^2_5 = 6.813, p = 0.235; Introduction χ^2_1 = 1.63, p = 0.202), or the Interaction (Trial χ^2_2 = 1.744, p = 0.418; Trial Order χ^2_5 =

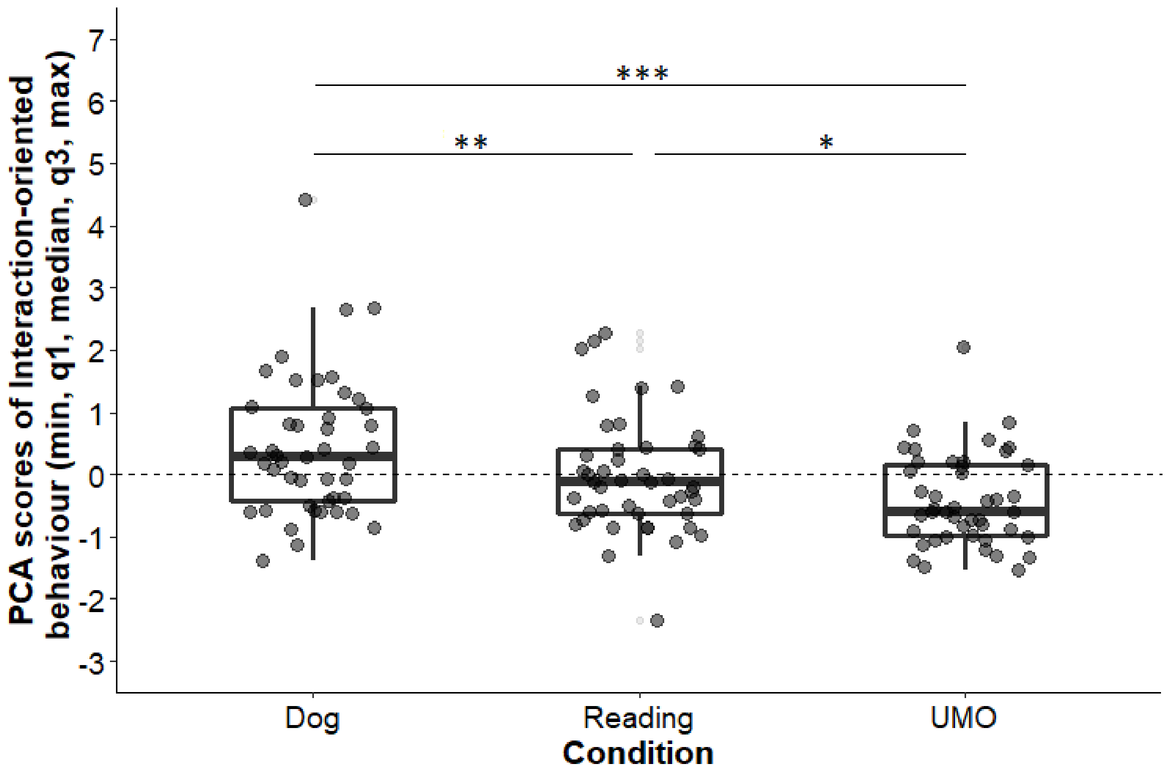

Figure 5 Influence of Condition on Interaction-oriented behaviour. * p<0.05; ** p < 0.01; *** p < 0.001

5.213, p = 0.390; Introduction χ^2_1 = 0.703, p = 0.402). Trial order and Introduction also did not influence dogs' Activity (Trial Order χ^2_5 = 6.118, p = 0.295; Introduction χ^2_1 = 0.035, p = 0.853).

The Group by Condition interaction had significant effect on interruption behaviour (GLMM, χ^2_4 = 10.909, p = 0.028) (for the results of the pairwise comparison, see table 3). In both the Inanimate and Non-social groups, dogs attempted to interrupt the interaction between the other dog and the owner more often than the interaction between the owner and the UMO or the magazine. However, there was no difference in the frequency of interruption between the UMO and the Reading conditions. In the Social group, dogs interrupted the dog-owner interaction more often than the owner-magazine interaction, but there was no difference between the UMO and Reading conditions, and between the Dog and the UMO conditions. Regarding the UMO's animateness/sociality, there was no difference between any of the groups in the Dog and Reading conditions. However, dogs attempted to interrupt the interaction between the owner and the UMO in the Social group more often than in the Inanimate group. No difference was found between the Inanimate and the Non-Social groups, nor between the Social and Non-Social groups (Figure 6). Introduction, Trial and Trial Order did not have significant effects on the interruption behaviour (Introduction χ^2_1 = 0.112, p = 0.738, Trial Order χ^2_5 = 3.958, p = 0.555; Trial χ^2_2 = 5.767, p = 0.056).

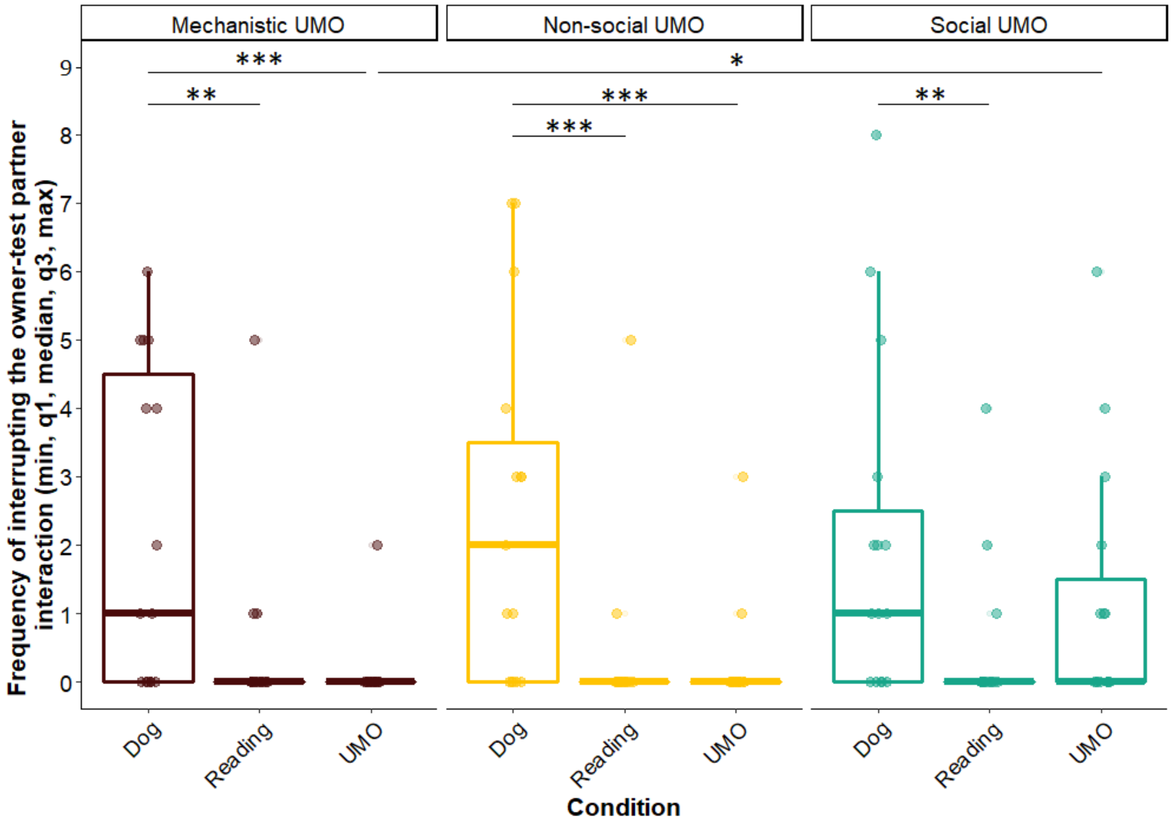

Figure 6 Influence of Group by Condition interaction on Interruption behaviour. * p<0.05; ** p < 0.01; *** p < 0.001

Table 3 Effect of Group by Condition interaction on subjects' attempt to interrupt the owner-test partner interaction (GLMM with negative binomial distribution based on LRT; pairwise comparison using 'emmeans' package). We provide contrast estimates (β ± SE). Orange highlight indicates significant variables.

Group	Condition	β ± SE	p-value
Between Conditions			
Mechanistic	Dog vs UMO	2.947 ± 0.795	< 0.001
	Dog vs Reading	1.742 ± 0.520	0.002
	Reading vs UMO	1.206 ± 0.858	0.338
Non-Social	Dog vs UMO	2.207 ± 0.593	< 0.001
	Dog vs Reading	1.971 ± 0.526	< 0.001
	Reading vs UMO	0.236 ± 0.708	0.941
Social	Dog vs Reading	1.593 ± 0.503	0.004
	Reading vs UMO	-0.941 ± 0.518	0.164
	Dog vs UMO	0.653 ± 0.400	0.232

Between Groups			
Mechanistic vs Non-Social	Dog	-0.151 ± 0.489	0.949
Mechanistic vs Social		-0.078 ± 0.495	0.986
Non-Social vs Social		0.073 ± 0.487	0.988
Mechanistic vs Non-Social	Reading	0.078 ± 0.737	0.994
Mechanistic vs Social		-0.227 ± 0.714	0.946
Non-Social vs Social		-0.305 ± 0.722	0.907
Mechanistic vs Non-Social	UMO	-0.892 ± 0.989	0.639
Mechanistic vs Social		-2.373 ± 0.884	0.020
Non-Social vs Social		-1.481 ± 0.706	0.090

10. Discussion

Attempts to interrupt an interaction between an important social relationship partner and a third-party individual is one of the most important elements of jealous behaviour. Dogs showed this behaviour not only when their owner attended to another dog, but also when they engaged in an interaction with the social UMO. Considering that the behaviour occurred less often when the UMO previously behaved mechanistically or displayed animate and non-social goal-directed motion only, it seems that relatively complex, socially interactive behaviour is needed for dogs to categorize the UMO as a social agent, at least in this specific context. However, displaying only one of the elements does not necessarily indicate the presence of jealous behaviour *per se*.

Dogs' behaviour towards the owner, the test partner, or their interaction was not influenced by the behaviour of the UMO observed before. Although dogs displayed more behaviour related to the test partner in case of the dog and UMO, compared to when the owner was reading, these behaviours more likely indicate interest in or calling the attention of the partner rather than attempt to remove it. Thus, we suggest that the test partner-oriented behaviour displayed here might not be related to jealous behaviour (see also [18]). Moreover, dogs showed more behaviour oriented to the owner when either the other dog or the magazine was present. Abdai et al[29] also used the other dog from the household and a magazine as potential rivals, but they found that dogs displayed less behaviour towards the owner, the interaction, and the test partner when the owner was reading from the magazine. This difference in owner-oriented behaviour between studies might be because in Abdai et al[29] dogs only participated in a jealousy-evoking test (without an observation phase) and the unfamiliar object used did not move during the test. This difference between the methods might influence dogs' behaviour; for example, distress elicited by the novel agent at an unfamiliar place might influence dogs to try to maintain close proximity to their owner in general.

Thus, our results do not allow drawing firm conclusions about whether dogs displayed jealous behaviour toward the UMO. We have to note that there can be large individual variability in dogs' jealous behaviour[32], and dog-owner relationships vary, for example, depending on how owners allow dogs to behave around them, and the way owners interact with the dogs. Both of these could have an effect on our findings. Also, as mentioned above, jealous behaviour comprises several behaviours, only some of which were found in the present study. Here we only report preliminary results and we plan to analyse further behaviours described as related to jealous behaviour[29,30], such as jumping on the owner or the rival, pushing away or snapping at the rival, different vocalizations (barking, growling and whining) and signs of stress. Analysing these behaviours can provide further details.

In the present study, dogs had limited interaction with the UMO, which cannot be compared to their daily experiences with humans or other dogs. Thus, we cannot exclude that dogs need more experience with an unfamiliar partner to display jealous behaviour when it interacts with their owner. In previous studies[10-12,14,16,29], dogs were allowed to engage in direct interaction with the UMO, but here, dogs could only observe the UMO's behaviour during the observation phase, before having a chance to interact with it. Thus, it is possible that (1) the novel partner was too interesting, and dogs were more focused on exploring it instead of showing jealous behaviour (as supported by high test partner-oriented behaviour), or (2) direct experience with the UMO is required for dogs to display jealous behaviour when the owner interacts with it. Future research may use this methodological approach to analyse differences in dogs' behaviour between only observing an interaction and dogs interacting with the UMO. It may also be interesting to see how the behaviour of dogs varies by changing their interaction with the UMO in duration, frequency, and the specific situation.

Decreased activity of dogs after the first trial suggests some weariness during the test. However, this could not have an effect on our results regarding differences in the behaviour toward the dog, UMO or magazine, because the order in which dogs encountered the test partners was counterbalanced. It has been suggested that dogs' behaviour displayed towards test subjects in similar situations might be due to territoriality[18,29,32]; however here, the study was carried out in a neutral place.

Since jealous behaviour is displayed only when a rival is interacting with someone whose relationship one fears to lose, Prato-Previde et al[18] used a stranger-test partner interaction as a control. Although their method included fake dogs, it would be interesting to use a stranger in the present experimental setup as well. The use of stranger-test partner interaction allows to study whether dogs' behaviour is displayed due to general interest in the interaction/test partner (same behaviour occurs in the presence of the stranger and the owner) or elicited only when they lose the attention of the owner.

Nowadays more and more companies aim to develop social robots capable of interacting with pets (e.g., Varram, https://varram.com/). Artificial agents developed to interact with dogs when they are left alone already exist. These artificial interactive agents may be used for increasing dogs' well-being in everyday scenarios and may also serve as a social partner in the absence of the owner thus decreasing behavioural issues, such as showed in case of separation-related stress. But there are no studies indicating whether dogs consider these robots as social partners, or whether they have a positive effect on dogs' welfare. Further research using our method would allow to see how artificial interactive technology can be used for increasing dogs' well-being. The demonstration of jealous behaviour suggests that dogs consider the test partner as a rival, and thus probably as a social agent. If so, the same social agent may be used to interact with the dog in other situations, as the ones mentioned above and become a long-term social partner for dogs.

10.1. Conclusion

Although some elements of jealous behaviour appeared when the owner was interacting with the UMO, we cannot conclude that dogs' behaviour displayed in the present study was related (entirely) to jealous behaviour. Similarly, as dogs' behaviour was only influenced by the UMO's sociality in one case, it is difficult to identify the complexity of behaviour required to display by the UMO in order to be recognized as a social agent. However, these are only preliminary results, and the analysis of inter-observer agreement is required to allow correct interpretation of results.

These studies enable us to better understand how dogs interact and interpret social situations, not only in the human-dog relationship, but also with other social partners, especially with artificial agents that may be part of their lives in the (close) future. These novel directions in the research of dogs' behaviour and cognition can help humans understand better dogs' needs, and provide better care improving their well-being.

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12. Appendix A

Table A1. Data of subject and rival dogs.

ID	Subject Breed	Age (year)	Sex	Rival Breed	Rival Age (year)	Rival Sex
Interactive Group						
1	Border Collie	1.0	Male	Border Collie	7.0	Female
2	Miniature Dachshund	6.0	Female	Shih-Tzu	7.0	Female
3	Hungarian Vizsla	5.0	Male	Wirehaired Dachshund	5.0	Male
4	Australian Shepherd	4.0	Female	Border Collie	5.0	Male
5	Papillon	2.5	Female	Mongrel	9.0	Female
6	English Cocker Spaniel	1.0	Male	English Cocker Spaniel	3.0	Female
7	Labrador Retriever	2.0	Male	Labrador Retriever	6.0	Male
8	Miniature Pinscher	5.0	Female	Miniature Pinscher	4.0	Female
9	Pekingese	5.0	Male	Moscow Watchdog	3.0	Male
10	Mongrel	4.0	Female	Mixed (Labrador Retriever X Hungarian Vizsla)	1.5	Female
11	Border Collie	1.5	Male	Mongrel	10.0	Female
12	English Cocker Spaniel	9.0	Female	English Cocker Spaniel	6.0	Female
13	Labrador Retriever	8.0	Female	Dachshund	8.0	Male
14	German Vizsla	8.0	Female	Mixed (Irish Terrier)	5.0	Male
15	Weimaraner	8.0	Male	Hungarian Vizsla	7.0	Female
Non-Interactive Group						
16	Mudi	1.5	Male	Border Collie	10.0	Male
17	Labrador Retriever	5.0	Female	Labrador Retriever	5.0	Male
18	Mongrel	2.5	Female	American Stafforshire Terrier	1.5	Male
19	Yakutian Laika	2.5	Male	Mongrel	3.5	Male
20	Border Collie	1.5	Female	Mongrel	5.5	Female
21	Labrador Retriever	6.0	Male	Labrador Retriever	2.0	Male

22	Jack Russell	4.0	Female	Jack Russell	3.0	Male
23	Australian Shepherd	1.6	Male	Border Collie	5.0	Male
24	Mixed (Mudi)	9.0	Female	Mixed (Chihuahua X Dachshund)	3.0	Female
25	Mixed (Irish Terrier)	5.0	Male	German Vizsla	8.0	Female
26	Cocker Spaniel	7.0	Male	Rhodesian Ridgeback	9.0	Female
27	Portuguese Water Dog	4.0	Female	Portuguese Water Dog	1.5	Male
28	Hungarian Vizsla	7.0	Female	Mixed (Hungarian Vizsla X Irish Setter)	6.0	Female
29	Dalmatian	2.0	Male	Dalmatian	4.0	Male
30	Yorkshire Terrier	7.0	Female	Yorkshire Terrier	7.0	Female
Mechanistic Group						
31	Mongrel	3.5	Male	Yakutian Laika	2.5	Male
32	Jack Russell	11.0	Male	Jack Russell	15.0	Male
33	Cocker Spaniel	1.0	Male	Cocker Spaniel	2.5	Male
34	Miniature Schnauzer	3.0	Male	Miniature Schnauzer	1.0	Male
35	American Staffordshire Terrier	3.5	Female	Border Collie	5.5	Male
36	Transylvanian Hound	5.0	Female	Transylvanian Hound	7.0	Female
37	Dutch Shepherd Dog	4.0	Male	Labrador Retriever	5.0	Female
38	Mixed (Hungarian Vizsla)	7.0	Female	Mixed (Dachshund)	11.0	Female
39	German Shepherd	7.0	Female	Jack Russell	13.0	Male
40	Portuguese Water Dog	1.5	Male	Portuguese Water Dog	4.0	Female
41	Mixed (Hungarian Vizsla x Irish Setter)	6.0	Female	Hungarian Vizsla	7.0	Female
42	Border Collie	5.0	Male	Australian Shepherd	4.0	Female
43	Mongrel	5.0	Female	Cane Corso	5.0	Male
44	Yorkshire Terrier	7.0	Female	Yorkshire Terrier	7.0	Female
45	Mongrel	2.0	Male	Chinese Crested	4.0	Female