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Dog (*Canis familiaris*) – robot interaction

Experimental research on dogs' socio-communicative behaviour

Doctoral thesis

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„At bottom, robotics is about us. It is the discipline of emulating our lives,
of wondering how we work.”

Rod Grupen (2008)

1. Introduction

1.1. *Social interaction*

Behaviour ecology defines social behaviour as interactions between individuals of the same species that has fitness consequences (Székely et al 2010), and which, at the functional level, is organised for achieving different goals such as finding a suitable mate, evading predators, cooperating in the acquisition of food etc. In contrast to many traits that are passively selected by the environment, social behaviour relies complex mechanisms where animals create a selective environment for themselves by interacting with each other. Accordingly, features of social behaviour and social traits have evolved specifically to contribute to the survival of the individual if group living provides some selective advantage (Székely et al 2010).

In general, social interactions between individuals can be categorised as competitive or cooperative. Competition refers to interactions among two or more individuals in which the fitness of one is lowered by the presence of another (Begon et al 2006). Individuals compete for resources, territory, mate etc. required for growth, survival and reproduction in order to increase their fitness. In contrast, cooperation is defined as interactions with benefit for all participants involved (i.e. which increase the reproductive success of the participants) (Noë 2006).

The so-called kin-selection theory provides a solution to the problem of cooperative behaviour between relatives and helps to understand the evolution of social behaviour (e.g. West et al 2002). Individuals predicted to behave less competitively and more cooperatively toward their relatives, because they share a relatively high proportion of their genes. Consequently, by helping kin (i.e. relative), individuals are helping copies of their own genes (Hamilton 1964).

At the same time, this theory did not solve the riddle of cooperation among unrelated individuals from the same or from different species. The latter issue referred to as the central theoretical problem of sociobiology (Wilson 1975) and has been studied by a large number of researchers.

1.2. *Cooperative interactions between members of different species*

Because of the functional similarities in the life of different species one may expect that a range of social behaviours reflect some commonalities (matching competencies) based on

ancient homologies or convergent evolutionary processes. Given that group living or limited co-existence may also confer some advantages in the case of different species social behaviour could also emerge in heterospecific contexts, both developmentally and on an evolutionary time scale (e.g. interspecific communication, see also Kostan 2002, Miklósi & Gácsi 2012). One well known example for this is the collaboration between honey guide birds (*Indicator indicator*) and African tribal people in order to find honey by locating beehives in the forest (Isack & Reyer 1989). In another case Bshary et al (2006) show that the grouper (*Plectropomus pessuliferus*) and the giant moray eel (*Gymnothorax javanicus*) hunt cooperatively, probably, because they have complementary behavioural skills, and the two partners, belonging to different species, are able to coordinate their actions at the behavioural level, that is, the grouper uses a specific visual signal to lure the moray eel on a hunting trip (Bshary et al 2006).

The evolution of such interspecific social interaction has long been a topic in the field of behavioural ecology, evolutionary biology and ethology, as well as different cognitive prerequisites required for various forms of social behaviour to take place in humans and non-humans alike. Three paths have been reviewed in the study of cooperation between non-related individuals from the same or from different species (for a review see Dugatkin 2002). Trivers (1971) argued that one path to cooperative behaviour, among humans and non-human animals, is reciprocity which most likely evolves when the minor cost paid by the helper individual is made up for when the other individual restores the favour in the future. Another possibility is mutualism which occurs in “harsh” environment where the cost of not being cooperative is immediate and the benefit of cooperation outweighs cheating (i.e. by-product mutualism, e.g. Dugatkin 2002). The third and probably the most controversial one is trait-group selection where natural selection operates at two levels: within groups and between groups. Group selection models showed that cooperation is favoured when the response to between-group selection outweighs the response to within-group selection (see Sober & Wilson 1998 for a review).

In addition to examine fitness consequences, the study of cognitive abilities involved in social interactions is also essential. For example effective cooperative hunting requires skills of communication (e.g. initializing the hunt) and behavioural synchronisation (e.g. Clutton-Brock 1977, 1996) that relies on cognitive abilities like role differentiation and coordinated movements (Boesch & Boesch 1989). Effective communication for initializing the joint hunt via signals appears more difficult to achieve between heterospecific interactants of sharply different behavioural patterns. Based on an observational study Pryor and co-workers (1990)

described cooperative fishing between fisherman and bottlenose dolphins (*Tursiops truncatus*) in Brazil where the water is extremely turbid with limited visibility of fish. Authors observed that the cooperative fishing is initiated by the dolphins' rolling movements at the surface and followed by casting the nets by the fisherman. They also found evidence that the direction of dolphins' movements indicated the location of the fish and the intensity of the movement carried information about the school size.

In case of joint hunting between groupers (*Plectropomus pessuliferus*) and giant moray eels (*Gymnothorax javanicus*) researchers observed that groupers actively visited moray eels and performed head-shaking movements (Bshary et al 2006). Morays usually responded to head shaking by leaving their crevices. Authors suggested that "groupers use visual signals to engage morays in a joint hunt". Thus similar head-shaking behaviour have never observed in moray eels, researchers argued that groupers' signalling is unlikely to represent a generalization of the morays' natural intraspecific repertoire to an interspecific context.

Although observational studies provide some notable insights for animal social interaction, results of these monitoring are difficult to interpret. For instance the simplest explanation of dolphins' behaviour through joint fishing with humans is that the observed rolling behaviour is an element of dolphins' natural behavioural repertoire which occurs also in the absence of the fisherman. In this case rolling was probably due to increased motivation by larger prey density and the intensity of the rolling behaviour conveys no information for humans about the school size. Although authors claimed that fishing is "highly ritualized and involved learned behaviour in both men and dolphins" (Pryor et al 1990), these observations did not allow to draw conclusions about the underlying mechanisms. Well designed and controlled experimental paradigm is needed to examine mechanism, function, developmental and evolutionary aspects of social interactions.

1.3. Animal-robot interaction as a special case of social interaction

Investigating social behaviour of animals living in groups by the means of controlled experiments is essential in the study of animal behaviour. However, the nature of social interactions makes experimental investigations very difficult due to many different reasons. First, the behaviour of the individuals is dependent on their interaction partners. Second, it is nearly impossible to manipulate and control behaviour of a living individual for longer duration, and third the interaction is always influenced by prior experiences related to participating individuals (see also Krause et al 2011).

One solution to these problems has been to use artificial stimuli or stimulus objects that resembled to different degree conspecific companions. For example, in the early years of ethology Tinbergen (1951) used this method to evoke social behaviour (e.g. courtship or territorial behaviour) in different animal species (e.g. sticklebacks – *Gasterosteus aculeatus*). The use of more or less schematic models in a systematic way allowed researchers to determine which properties of the stimulus act as behavioural releasers (cf. sign stimulus) and have the potential to evoke particular behaviour (cf. modular action patterns) which are comparable to that observed under natural conditions (e.g. Lack 1943, Kramer 1937). Nowadays behaviour biologists and engineers are developing more complex models, autonomous or remote controlled devices, which are able to stimulate subject animals. This trend has become even more popular with the possibility to construct more sophisticated stimuli, “robots” (Mitri et al 2013). Krause et al (2011) argued that using such artificial agents (robots) as social partners could enhance controllability and reproducibility in the experimental techniques.

In the past 10 years many robots have been used to investigate social-communicative behaviour in wide-range of animals. Most of these studies examined intraspecific interactions and used life-like ‘conspecific robots’ aimed to mimic the morphology and particular behaviour of the species studied. Although none of the following studies controlled for the importance of life-likeness they seemingly assumed that the bodily appearance (embodiment) must be as similar as possible to the species studied for evoking animals’ social responsiveness.

1.3.1. Analysis of the honeybee dance communication system

One of the first examples the “mechanical” bee, was designed for investigating various components of honeybees’ (*Apis mellifera*) wagging dance (Michelsen et al 1992). The model carried a scent and was controlled by a computer, thus selected components of the dance could be manipulated independently from each other. Some cases it gave conflicting information about the food location. Results of the experiments showed that the wagging run and sound convey altogether the essential information about the distance and direction of the food source, while the eight-form of the dance seemed to be less important. The accuracy of transferred directional information was similar to that obtained in experiments with live dancers, however live dancing bees recruited 5-10 times more bees than did the model. Authors suggested that the crude nature of the mechanical bee effected bees’ willingness to

follow the model. In order to examine the latter hypothesis researchers developed the biomimetic dancing bee (Landgraf et al 2010, 2012) which was extended with camera sensors and precise motion data obtained from high-speed dance recordings. They hypothesised that camera sensors that enable the robot to react on the environment (i.e. interactive behaviour/contingent reactivity) might be the key to the recruitment of followers. Results showed that the biomimetic bee was able to collect more recruits than the mechanical bee. Authors suggested that this difference might be due to the fact that the biomimetic bee was able to continuously dance for many hours while the previous model had limited time ability for dancing. It has been previously shown that bees following more than 20 waggle runs most likely fly to the communicated place, thus repeated runs of the robot seemed to be crucial for the outcome. However in the absence of control trials in Landgraf et al's studies it remains unclear whether the life-like embodiment and/or the interactive behaviour of the biomimetic bee will eventuate more effective bee-robot interaction.

1.3.2. Analysis of different channels of animal communication by means of robots

In a playback experiment Narins et al (2005) used an electromechanical model frog in order to investigate which stimulus (visual and/or acoustic) is essential for evoking aggressive behaviour in male dart-poison frog (*Epipedobates femoralis*). In the bimodal trials the presence of the frog model accompanied by playback calls, while only one of the stimulus (model frog or playback calls) was presented in unimodal control trials. They found that only bimodal signals were effective to elicit physical attacks by a territorial male. Partan and co-workers (2009) studied alarm behaviour of the eastern grey squirrel (*Sciurus carolinensis*) with a squirrel robot (Figure 1/A) and used the same method as in the previous experiment (Narins et al 2005). In five conditions they separated and combined audio (recorded grey squirrel alarm calls) and visual stimuli (presence of the robot and tail motion). They found that wild squirrels showed enhanced responses to multisensory, audio/visual signals of alarm compared to unisensory (either audio or visual) signals. Results of the two experiments are in line with the law of heterogeneous summation which states that “the independent and heterogeneous features of a stimulus situation are additive in their effects upon behaviour” (McFarland 2006). Experiments mentioned above are good examples for how naturally complex, multimodal signals can be investigated by robots as they allow researchers to examine one channel at a time.

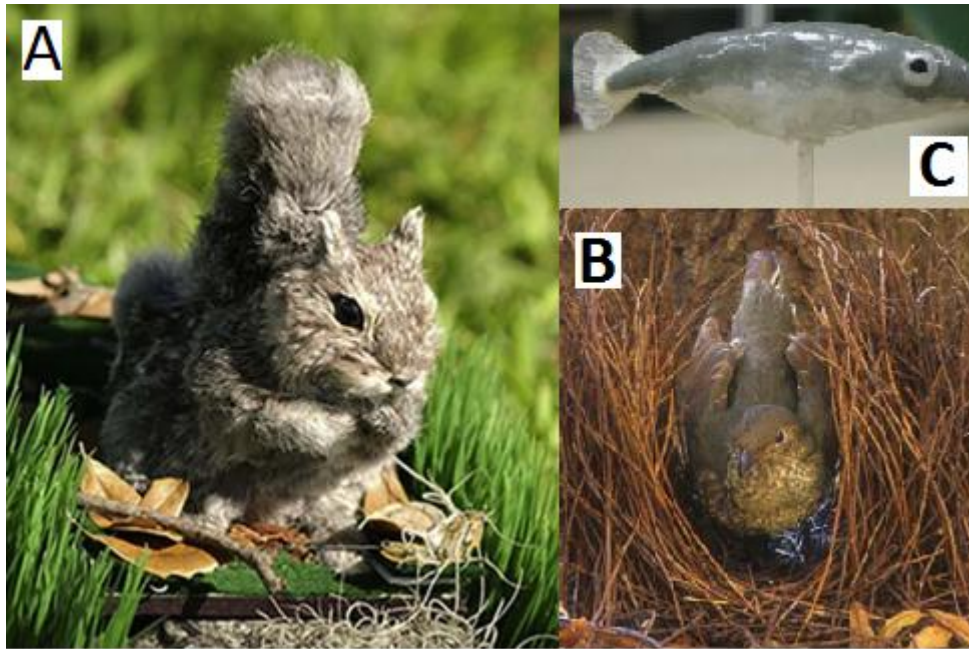


Figure 1. A: The squirrel robot (from Partan et al 2009); B: The robotic bowerbird (from Patricelli et al 2006); C: The “robofish” (from Faria et al 2010)

1.3.3. Analysis of mating behaviour in birds

It has been raised that during courtship males from several different species adjust their displays according to not only external factors (e.g. presence of predators, for example see Godin 1995) but to cues and signals used by females (e.g. Patricelli et al 2002). Patricelli et al (2006) used robotic female bowerbirds (*Chlamydera maculata*) that mimicked female startling (i.e. rapidly moving back into the upright position from crouched position and then remained there until the end of courtship) (Figure 1/B) in order to test the hypothesis that males reduce the intensity of their courtship displays after startling females. With this standardised method they found that males did not always display at maximum intensity, but rather reduced their intensity in response to female startling during courtship. At the same time they found no evidence that males’ courtship success is related to this flexible mating behaviour.

1.3.4. Analysis of collective behaviour

Another research field which utilize robots for more controlled experimental design is the examination of collective behaviour of animals (i.e. animals moving in groups). These studies focused on group dynamics, interactions between individuals and potential leadership of a particular individual. Results of previous theoretical studies in fish suggested that individual

attributes (behaviour, nutritional and information quality, body size etc.), shoal size and relative spatial position of the individuals may affect leadership (for details see Krause et al 2000, Reefs 2001). However, more empirical and theoretical work is necessary to determine key factors of leadership especially in larger shoals (Krause et al 2000). Faria et al (2010) examined collective behaviour in three-spined sticklebacks (*Gasterosteus aculeatus*) and utilized the ‘Robofish’ (Figure 1/C) to define different aspects of leadership and recruitment. This study revealed that the robot was able to act as a leader: it could recruit a single fish from the refuge and initiate a turn in groups of ten. Although Robofish was no larger than the other individuals these result suggest that body size may not as important as previously thought (Reefs 2001). This study also provided first evidence that interactions between individuals in the shoal are mediated by topological, rather than metrical distances.

1.3.5. Dog-robot interaction experiments

In the last decade there has been a growing interest in building robots which are able to interact in a socially meaningful way with humans (Miklósi & Gácsi 2012). It turned out quickly that this new direction of research needs collaboration from different scientific fields. Whereas the design, construction and operation are mainly engineering tasks, integration of “social robots” into human society requires contribution of social sciences, psychology, sociology, philosophy or ethics. However detailed investigation of human-robot interaction is also essential and gives behavioural sciences an important role. It has been suggested that closer look at human-animal interaction, especially research on social relationship between humans and dogs, may provide important insights for social robotics (Miklósi & Gácsi 2012). This statement based on the idea that any social behaviour of other species which are recognisable for humans could be incorporated into these robots. This interdisciplinary research area at the interface of ethology and robotics is often referred to as “ethorobotics” (e.g. Partan 2009).

Due to the reasons mentioned above and further advantages of using robots (see Krause et al 2011), several recent studies have been focused on dog-robot interaction. For example, Kubinyi and her colleagues (2004) investigated adult and juvenile dogs’ social behaviour in a neutral and in a feeding situation toward different partners: a dog-like robot (AIBO) with or without puppy-scented fur, a 2-month-old puppy and a remote control car (see Figure 2/A). Results showed that the dogs’ age, the experimental context and external features of the AIBO had an effect on dogs’ behaviour. Order of the partners based on their attractiveness was the following: puppy, furry AIBO, AIBO, remote control car. Authors concluded that the AIBO

had limited ability to act as social partner for dogs, however in adult dogs, the approach and the orientation evoked by the puppy and the furry robot did not differ in any situations. In another study (Leaver & Reimchen 2007), which focused on intraspecific communication, dogs encountered a life sized dog model which had either a short or a long, wagging or not wagging tail (Figure 2/B). Researchers hypothesised that dogs (especially small sized dogs) would approach the short-tailed and non-wagging tail model with increased caution than a wagging long-tailed one due to the reduced availability of social cues. Results supported the expectation on body size and tail movements as smaller dogs behaved more cautiously towards the model while the wagging long-tailed replica triggered faster and continuous approach.

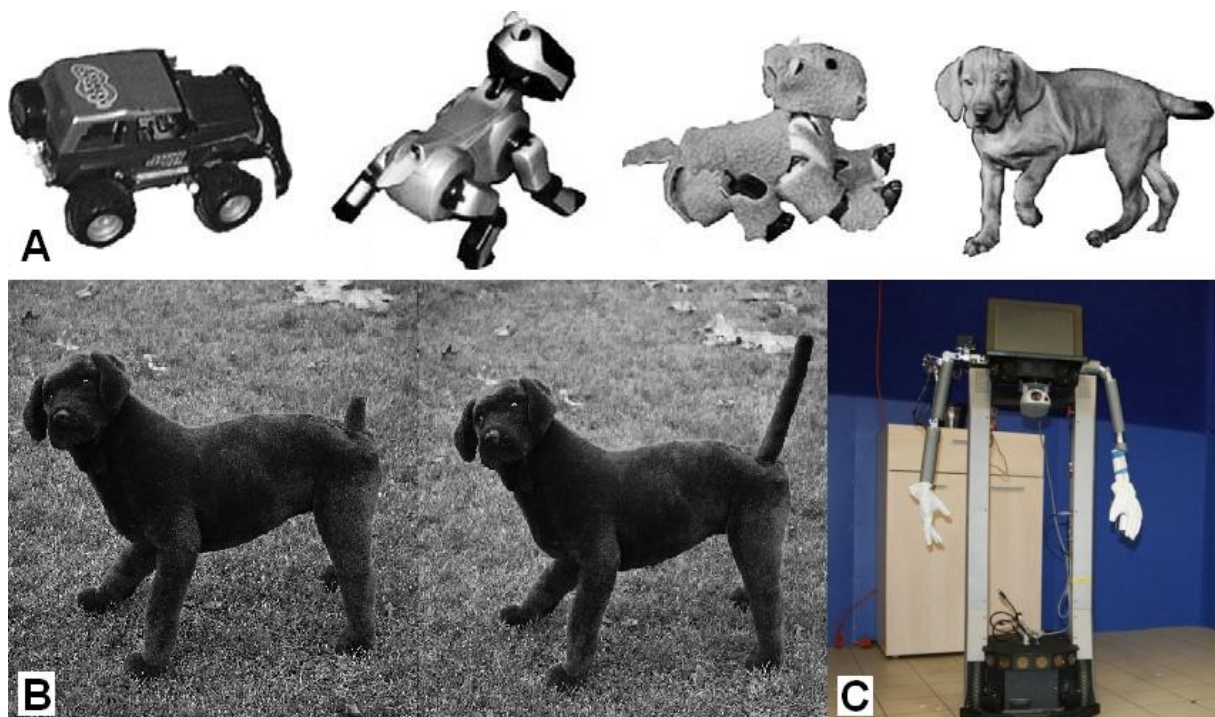


Figure 2. A: The remote control car, the AIBO, the AIBO with fur and the puppy (from Kubinyi et al 2004); B: the short and long-tailed life sized dog model (from Leaver & Reimchen 2007); C: the PeopleBot (from Lakatos et al 2014)

In line with similar investigations with other species these two experiments used a mechanical partner resembled to the studied species. However, special social relationship between humans and dogs would allow the utilization of humanoid robots as partners in such experiments. As far as I know, only one published study by Lakatos and co-workers (2014) used a human-like robot (PeopleBot, see Figure 2/C) with one moveable arm in order to examine whether the level of sociality shown by the robot affects dogs' comprehension on its

pointing gestures. In the beginning of the test dogs' had the opportunity to observe the encounter of the robot and the owner. This interaction was social-interactive (i.e. the owner and the robot shook each other's hand, conversed with one another and walked around the room together etc.) or non-interactive (i.e. instead of shaking hands and talking to the robot, the owner typed on the keyboard of the robot, walked around the room in opposite directions etc.). This interaction phase was followed by a pointing phase where the robot stood between two identical plastic pots (potential hiding places), gained the attention of the dog and turned its body towards the baited pot while displaying the pointing gesture. In the social condition the robot called the dog by its name before the pointing while in the nonsocial condition the robot emitted a beeping sound when pulling up its arm in front of its body. Results showed that dogs looked longer at the head of the robot during the interaction phase in the social-compared to the nonsocial condition. During the pointing phase dogs' performed at chance level in both groups, i.e. they choose the indicated and non-indicated pot randomly, however they gazed at the indicated pot longer in the social condition than in the nonsocial one. Authors concluded that the contingent reactivity shown by the robot (in the social-interactive condition) was not enough to evoke the same set of social behaviours from the dog as with humans in a similar situation. At the same time dogs' gazing behaviour suggested that sociality had a positive effect on dog-robot interaction.

Experiments described above utilized robots designed to resemble conspecific individuals or familiar social partners from different species (Lakatos et al 2014) in order to examine different aspects of social behaviours. In this case subjects' social behaviour was evoked by the behaviour displayed by the artificial partner (e.g. tail movements, Leaver & Reimchen 2007) and/or induced by the artificial partners' familiar bodily appearance (embodiment). However, this method did not allow researchers to separate the effect of the partners' behaviour and embodiment on animals' social responsiveness.

1.4. The separation of behaviour from the body

The conceptual separation of behaviour and cognition (mind) from the body has a long history in the cognitive sciences (e.g. Ziemke & Lowe 2009) with the assumption that cognition and behaviour is embodied (i.e. strongly dependent upon features of the agent's body) (Pfeifer & Scheier 1999). This issue could be put to test in several forms, given the advance in technology. One important question could be whether animals or humans are able to recognise and react to behaviour patterns independently from the embodiment.

This approach opens ways for experimenting, in which researchers look at the extent and limitation (both on the part of the observer and the agent) to engage in social interaction. Such data would be important to reveal the flexibilities of animal and human mind, including evolutionary and developmental factors.

In his classic study Meltzoff (1995) reported that 18-month-old infants imitated the movements of a human hand but failed to replicate the same movement when it was executed by a robotic “hand”. He argued that the infants at this age are attributing intentions to humans but not to non-human agents. Results of the inanimate control had the potential to confirm the hypothesis that infants not responding exclusively to the physics of the situation (arm movements) but they had psychological understanding on the human actors’ action. In a later study Meltzoff and co-workers (2010) demonstrated that 18-month-old infants follow more likely human-like robot’s gaze if they saw it act in social-communicative interaction with the human experimenter. Authors concluded that the emergence of social interaction between infant and robot depends also on their prior experience. Human-like physical features of the robot alone (e.g. presence of the eyes) was not sufficient to generalise from human experience in infants.

In a series of experiments Gy. Gergely et al (1995) and Csibra et al (1999) examined 6- to 12-month-olds’ understanding on goal-directed action of geometrical figures. During habituation events they repeatedly presented infants with a simple animation in which a small circle approaches and contacts another (bigger) circle by jumping over an obstacle. This ‘rational’ action can be interpreted as an action to achieve the goal. In the test phase the same jumping action became unnecessary to achieving the goal in the absence of the obstacle (‘nonrational’ action). The other test event presented a straight-line approach to the same position and considered as ‘rational’ action. Results showed that 9- and 12-month-olds but not 6-month-old infants looked at the ‘nonrational’ action longer in the test phase than the ‘rational’ action. Authors concluded that 9- and 12-month-old infants applied the rationality principle to the observed action and attributed goals to an agent had no human-like features while 6-month-olds did not.

Several years later Kamewari and his colleagues (2005) raised that human-like features of the agent might affect 6-month-olds’ psychological reasoning and they probably regard the action as goal-directed if it is displayed by a human or a humanoid robot. They used the same paradigm as Gy. Gergely et al (1995) and Csibra et al (1999) and demonstrated that infants of this age attributed goals to both human action and humanoid motion but not to a moving box.

Experiments mentioned above provided important findings on early human cognitive abilities by using non-living unfamiliar agents as partners and therefore separating the effects of the partners' behaviour and body. Results revealed some developmental progress of psychological reasoning and goal-attribution which can be affected by human-like features at particular age (Gy. Gergely et al 1995, Csibra et al 1999, Kamewari et al 2005). At the same time human-likeness itself seemed to be less effective in eliciting social behaviours from infants (e.g. gaze following) while previous social experience in this case proved to be essential (Meltzoff et al 2010).

1.4.1. The general concept of the Unidentified Moving Object (UMO)

Using artificial agents in a social context may also reveal the animals' ability to recognise some aspects of the other's behaviour and the quality and quantity of experience needed for such recognition to emerge and/or to get improved. In this way, the effects of behaviour and embodiment can be investigated separately allowing us to identify those external and behavioural features (i.e. key stimulus) of the partner that are important for the animal to engage in social interactions. As far as we know, however, such approach, in which the embodiment and the behaviour of the agent are varied in a systematic way, has not yet been utilized in animals. One interesting question would be whether animals are able to generalise their previous experience with natural partners in such situations independently from the artificial partners' embodiment. Previous studies used animal models resembling the species studied and expected that subjects considered the robot as a conspecific (e.g. Partan et al 2009). In this case we cannot exclude the possibility that subjects' willingness to interact with the robot caused solely by the contextual information of its embodiment and not its behaviour. One feasible solution would be the utilization of an unfamiliar artificial partner that is able to execute actions with the same function in different manners. In this case the embodiment should be as distinct as possible from the range of objects and living animal species with which the subject interacts in a social way under habitual (natural) conditions. In principle this agent can take any form and shape, so we introduce the general term of an unidentified moving object (UMO) which emphasises that at the time of the first encounter the animal subject has no previous experience with that particular artificial agent. The overall goal of such experiments is to find out under which conditions is the subject able and willing to interact with the UMO given the possibility that both the embodiment and the behaviour can be modified, and interactions can be repeated both in space and time.

From an ethological point of view, using a non-living non-human like agent as a social partner has further advantages in studying dogs' social behaviour. It has been suggested that the presence of a human experimenter, especially in a social context is particularly effective in influencing the behaviour of dogs and often leads to mistaken or counterproductive behaviour (e.g. Kupán et al 2011). For example, Erdőhegyi et al (2007) showed that dogs were not able to solve a reasoning task in a social context (i.e. when the human experimenter used gazing cues and directional gestures), while the elimination of these signals resulted in better performance. Several studies revealed that socio-communicative context exerts strong effects on dogs' social and physical cognitive abilities. For example the so-called A not B perseverative search error (search for a hidden object at its initial hiding place even after observing it being hidden at another location) occurs exclusively in social context in which the hiding procedure is associated with eye contact, addressing signals and gaze shifts between the hiding location and the dog (e.g. Topál et al 2009a). Due to these findings we believe that eliminating human influence as much as possible from the experiment has the potential to reveal different aspects of dogs' cognitive abilities.

1.5. Aims and questions

Our studies aimed to provide supporting evidence for the above concept of using UMOs with different embodiments and behaviours. We decided to use dogs as subjects, especially because they are becoming very popular in studying complex social behaviours. Dogs may also be favourable subjects for these studies because they have shared a common environment with humans (a heterospecific agent) for a long time, and they live also in human families at present. Thus dogs may be especially skilful at interacting with non-dog-type agents (UMOs) if they can recognise some aspects of the behaviour of those unfamiliar agents. We designed our experiments by adopting recently used methods in human-dog interaction studies to see whether dogs display similar social behaviour toward a human and an UMO.

As a first step in Experiment 1 we investigated whether different behaviour of the UMO has an effect on dogs' social behaviour in a problem situation. We endowed the 'social' UMO with different properties that are general characteristics of entities with minds (people or animals) to which infants may be sensitive (for a review see Rakison & Poulin-Dubois 2001). We also used a 'mechanical' UMO which differed only in behavioural properties from the 'social' UMO and a human partner who acted as similar as possible to the 'mechanical' UMO in order to control for the embodiment of the partner.

We hypothesised that dogs' would increase their social behaviour toward the 'social' UMO compared to the 'mechanical' UMO if they recognised some social aspects of the UMO's behaviour. We also assumed that dogs would utilize similar amount of behaviours toward the human and the 'mechanical' UMO partners. This would indicate that the behaviour of the partner might play more important role for evoking subjects' social responsiveness than the embodiment.

As a next step in Experiment 2 we were curious about whether dogs are able to flexibly adjust their social behaviour to fit their UMO partners' different capabilities. We utilized the same problem situation as in Experiment 1 except that the problem could be solved in two different ways by the two UMOs. According to the results of a previous study with human partners in a similar situation (Horn et al 2012), we hypothesised that dogs are able to discriminate between different roles of their inanimate partners and they would prefer the appropriate partner, who is able to help in that particular situation. We also assumed that dogs would display similar amount of behaviours toward the two UMOs.

In Experiment 3 we focused more on communicative interaction between dogs and different animate and inanimate partners. Ample evidence suggests that dogs comprehend the human pointing gestures (for a review see Miklósi & Soproni 2006), however, the underlying mechanism is still unclear. It has been recently shown that both evolutionary and ontogenetic factors might have a role (Miklósi & Topál 2013, Udell et al 2014), at the same time, the relative contribution of these factors is difficult to determine with previously used methods. In this experiment dogs in one group had opportunity to interact socially with the UMO or the human partner in a similar problem situation as in Experiment 1 (Context 1), while dogs in the other group had no interaction with the UMO or the human partner during this phase. After, all of the subjects faced with a two-way choice task in which the partner approached one of the hiding places and then they were allowed to make a choice (Context 2). During this phase the UMOs and the human partners acted in a very similar way. We assumed that dogs experience human directional signals in everyday life (Context 1), thus previous interaction with the human partner is not necessary for dogs to rely on this signal in the test situation (Context 2). We also hypothesised that after previous social interaction dogs would be able to generalise the social behaviour of the UMO to the test situation i.e. they would consider the UMO's movement as an indication. We emphasised that results of this experiment might have useful insight on how do communicative signals between dogs and humans achieve their function.

The aim of Experiment 4 was to investigate whether dogs' behaviour can be influenced by a human or an UMO partner in a food-choice task. Previous studies demonstrated that dogs had a tendency to change their food preference in accordance with their human partner's choice and suggested social influencing/learning as an underlying mechanism (Prato-Previde et al 2008, Marshall-Pescini et al 2012). In line with these findings we hypothesised that dogs would change their 'original' preference for options between small and large amount of food after having witnessed a human's explicit preference for the other. However they would 'follow' an inanimate UMO's preference exclusively after previous social interaction with it. In Experiment 5 we focused more on practical applications of dog-robot interaction and designed an experiment in order to provide useful information to the SWARMIX Project (for details see *Practical applications* paragraph below). Our questions were whether dogs are able to generalise different acoustic signals to novel contexts. Few experimental studies have so far investigated stimulus generalisation in dogs. One study demonstrated that frequency of correct responses to learnt verbal commands decreases in novel context (Braem & Mills 2010), but no such study exists about the generalisation of previously learnt acoustic signals. In the present experiment dogs were trained to perform oriented movement (go left/right) in response to different acoustic signals, then they were exposed to novel test situations where they had to rely on the same acoustic signals to solve a series of new spatial tests. We hypothesised that dogs are able to generalise learnt acoustic signals to novel contexts.

1.5.1. Practical applications

The Swiss SWARMIX (Synergistic Interactions in Swarms of Heterogeneous Agents) project (2011-2014) is about developing a flying robot (Swinglet) working in cooperation with humans and rescue dogs to solve distributed tasks that require a wide diversity of sensory-motor and cognitive skills. The aim is to provide high level of autonomy to each participant, and at the same time to set up efficient interaction and information flow between all system components. To reach this goal it is essential to examine different aspects of dog-robot interaction more precisely dogs' socio-communicative behaviour toward non-living partners. Our studies have been designed also to provide useful information for the SWARMIX project and support the effective development of the Swinglet aimed to cooperating with rescue dogs and human handlers.

2. Experiments

2.1. *Experiment 1¹: The emergence of social interaction between dog and an Unidentified Moving Object (UMO)*

The method of the present study originates from the well-documented observations on communicative interactions between dogs and humans in problem solving situations (for details see Miklósi et al 2000, Miklósi et al 2003, Gaunet 2010). In these scenarios a human hides a piece of food in the presence of a dog at an inaccessible location. After the departure of the hider the dog has the opportunity to interact with a naive human (owner) entering the room for a short time. The original experiment (Miklósi et al 2000) involved also two control conditions in which dogs were left alone after the hiding or no food was hidden. Dogs seemed to utilize both gazing and gaze alternations between the place of food and the owner (cf. “showing behaviour”) during the interaction and these behaviours were more frequent in the presence of the owner and hidden food than in the absence of a human or when no food had been hidden. In most cases dogs were also successful to direct the naive human to the place of the hidden food (see also Lakatos et al 2012).

Based on these findings, we aimed to compare how adult pet dogs perform in an analogous problem solving task with different partners. There are three different partners: ‘mechanical’ or ‘social’ UMOs and a ‘mechanical’ human (see below). Using a between-subject design we compare the emergence of dogs’ social and communicative behaviours toward the different partners. We endowed the social UMO with different external (eye spots) and internal (goal directedness, interactive responsiveness, varied movements) properties that are general characteristics of entities with minds (people or animals) to which infants may be sensitive (for a review see Rakison & Poulin-Dubois 2001).

We have hypothesised that dogs would display similar behaviour toward the mechanical partners (UMO and human). At the same time they are expected to increase their social behaviours toward the social UMO after repeated encounters, which would indicate that they are able to recognise some aspects of the UMOs’ social behaviour.

¹ Based on: **Gergely, A., Petró, E., Topál, J., & Miklósi, Á.** 2013. What are you or who are you? The emergence of social interaction between dog and an Unidentified Moving Object (UMO). *PLoS ONE*, 8, e72727. doi:10.1371/journal.pone.0072727.

2.1.1. *Materials and Methods*

Subjects

Fifty adult pet dogs were recruited from the Family Dog database of the Department of Ethology, Eötvös Loránd University. We excluded 3 dogs because they displayed high level of anxiety-related behaviours in the experimental room (N=2) or upon encountering the UMO (N=1). The remaining 47 dogs were assigned to one of three experimental conditions: *Mechanical UMO* (N= 15, 5 males, 10 females, mean age±SD: 3.6±2.3 years), *Social UMO* (N=17, 9 males, 8 females, mean age±SD: 4.6±3.2 years) and *Mechanical Human* (N=15, 7 males, 8 females, mean age±SD: 3.7±3.2 years) (for details see Appendix, Table 8). Only dogs older than 1 year were recruited, and there was no upper age limit to participate. Therefore some old dogs (older than 10) were also included and this increased the age range. Importantly, however, our analysis of the dogs' mean age did not show significant differences between the 3 groups (One-way ANOVA $F_{2,44}=0.504$, $p=0.607$). Subjects were allowed to participate only if they could be motivated with dry dog food. Each subject participated only in one condition.

Apparatus

Dogs were tested at the Department of Ethology, Eötvös Loránd University in a 4.5m x 3.5m test room. In this experiment we used a remote control (RC) car (#32710 RTR SWITCH, 28 cm x 16 cm x 13 cm) as UMO which was supplemented with two magnets on its back and front. The car was controlled by Experimenter 2 (E2), who was standing in the corner of the lab (see Figure 3). Throughout the experiment she avoided carefully getting engaged with the dog.

A metal wire mesh box (61 cm x 46 cm x 54 cm) was used as a hiding location, with a fixed magnet inside, and three transparent plastic bowls (10 cm x 10 cm) were used as potential food sources, one was equipped with two metal sheets. We recorded each trial with four cameras in the test room (see Figure 3).

Three magnets with different strength were used in the experiment. The weakest magnet was placed on the front of the car (UMO) which was supposed to connect to one of the metal sheets on the bowl with the food. Hence the UMO carried the food into the box that was now inaccessible for the dog. The moderately strong magnet was placed inside the box. It was supposed to attach to the other metal sheet on the bowl when the UMO transported the bowl

into the box. Thus the UMO was “able to” leave the food inside the box. The most powerful magnet was placed on the back of the UMO. This was used when the UMO reversed into the box in order to carry the food to the dog.

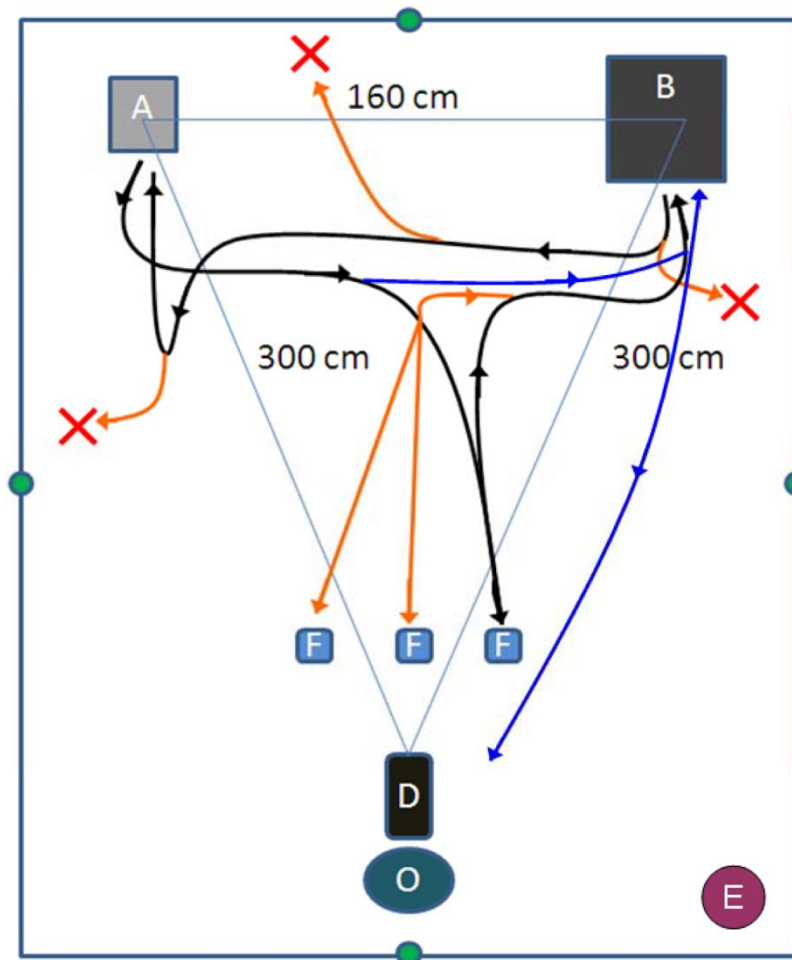


Figure 3: Experimental room and paths of partners’ move. O=place of the owner, D=place of the dog, E= position of Experimenter 2, F=place of the three plates (i.e. potential food sources), A=start point of the partner (UMO or Human), B=place of the box. Green circles indicate the location of the cameras. The triangle presents distance between the dog the partner and the place of the inaccessible food (box). Black lines show the paths of the partner to the plate (location of the food), to the box and back to the start point. Orange lines show the different path of the *Social UMO* compared to the *Mechanical* partners (UMO or Human) to each plates, box and different start points during the 2nd to 6th trials (red X). Blue lines show the path which in the partner goes back to the box from the start point and bring the food to the dog.

Test-partners

In the *Mechanical UMO* and *Social UMO* groups we used the same RC car as a partner. However, the *Mechanical UMO*, moved always along the same path during the experiment, and approached the plastic bowl always from the same location.

In contrast, the *Social UMO* had two eye spots (2 cm in diameter, placed on the engine hood) (see Figure 4), and it moved along varied paths in the room during the experiments, it went to different start points in the lab, approached both empty and baited bowls (“made a choice” see below), and started to move when the dog looked at it in particular situations (responded to dog’s behaviour) (for details see Procedure). In order to control for the embodiment we included a *Mechanical Human* group in which a female human was the partner. We wanted to make her behaviour highly similar to that displayed by the *Mechanical UMO*. She was wearing sun glasses to avoid any kind of eye contact with the dog, she was wearing blue T-shirt and brown trousers, she did not display any social cues during the test and she did not speak at all. She was moving along the same route as the RC car in the *Mechanical UMO* group with constant speed (see Figure 3).



Figure 4: The three test partners: a; *Mechanical UMO* b; *Social UMO* c; *Mechanical Human* (for more details see text).

Procedure

Familiarization

1. The owner and the dog (on leash) entered the room and walked around. There were three empty bowls, the UMO (at the start point), in the *Mechanical* and *Social UMO* groups, or female human in the *Mechanical Human* group, and the metal box placed at a fixed location; E2 stood in the corner of the lab. The dog could sniff and explore the room on leash for 1 minute. Then the owner sat down at a predetermined location and held the dog in front of him/herself.

2. Experimenter 1 (E1) entered the room and put three pieces of dry food into one of the tree bowls and left the room.
3. The owner took off the leash and encouraged the dog to eat the food (e.g. „It’s yours”; „Come on take it” etc.). After having eaten the food the owner called the dog back. This procedure (Steps 2 and 3) was repeated two times.
4. The UMO or the female human started to move around the room (for 30 seconds) in full view of the dog. In the *Mechanical UMO* and *Mechanical Human* groups they were circling around the bowls travelling on the same path. In contrast, the *Social UMO* moved along varied routes in the room. All partners moved in the same amount of time.
5. Steps 2 and 3 were repeated two times, except that the *Mechanical* and *Social UMO* or the *Mechanical Human* were moving always in the same way as in Step 4. After the second feeding the partner returned to the start point.

Test trials

In *Mechanical UMO* and *Mechanical Human* groups the experiment consisted of 6 trials. One trial consisted of the following steps:

1. E1 entered the room put three pieces of food into one bowl (she baited always the same bowl during the trials), and then left.
2. The *Mechanical UMO* or the *Mechanical Human* approached the baited bowl, carried it into the box, left it inside, and returned to the predetermined start point. The bowl was inaccessible for the dogs but they could see it and smell the food.
3. Owner released the dog from the leash, and it was allowed to move freely for 30 seconds. By knocking at the door E1 informs the owner to call the dog back.
4. The *Mechanical UMO* or the *Mechanical Human* returned to the box and brought/took out the bowl, and stopped with it in front of the dog.
5. The owner let the dog eat the food, and the partner returned to the start point.

The *Social UMO* group consisted of 7 trials. The 1st and the 7th trials were exactly the same as test trials in the *Mechanical UMO* and *Mechanical Human* groups; including the position of the start point of the partner (see Figure 3).

The 2nd to 6th trials were similar to the 1st and 7th one, except that during Step 1 the experimenter varied the position of the baited bowl, at the end of Step 2 the car stops at various points in the lab (potential start points, see Figure 3) and finally during Step 3 E2

started to move the car toward the box after the dog displayed the first, short (approximately 1 s long) glance at it.

Behavioural variables and data analysis

All trials were videotaped and dogs' behaviour (Table 1) during the 30 s of free movement was analysed later with Solomon Coder 060612 (András Péter <http://solomoncoder.com>).

Name of behaviour element	Definition
Looking at the partner	Looking duration (s) at the partner (UMO or human)
Latency of looking at the partner	Time span (s) from owner releasing the dog until the dog looks first at the partner (UMO or human)
Latency of touching the partner	Time span (s) from owner releasing the dog until the dog touches first the partner (UMO or human) with its muzzle
Frequency of gaze alternation	Number of looks from the partner (UMO or human) to the box (place of food) directly or vice versa regardless of order

Table 1. The definitions of coded behavioural elements

Inter-observer agreement (between two coders) was assessed by recoding a randomly selected 25% of the subjects (Cohen's Kappa, 0.98).

For statistical analysis we used IBM SPSS Statistics 21. For the Binary GLMM (for Binomial distribution) we calculated the *Ratio of looking* (number of dogs who looked or did not look) at the partner (UMO or Human) in each trial, and the *Ratio of touching* (number of dogs who touched or did not touch the partner (UMO or Human) with muzzle in each trial.

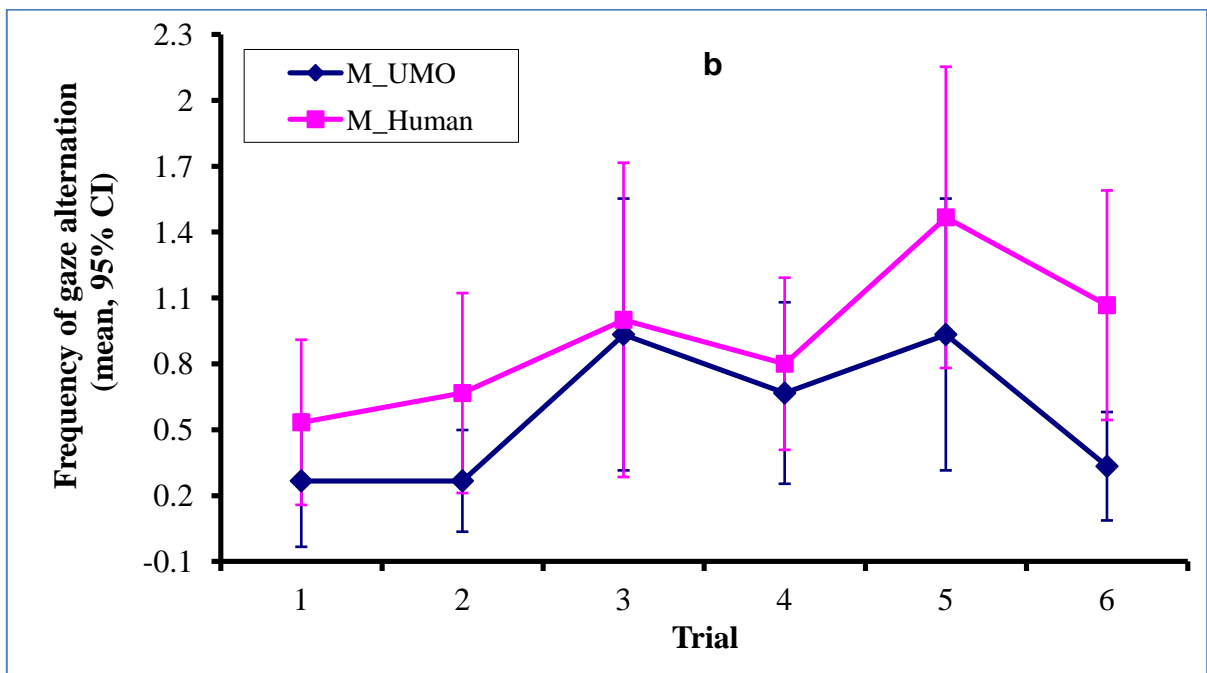
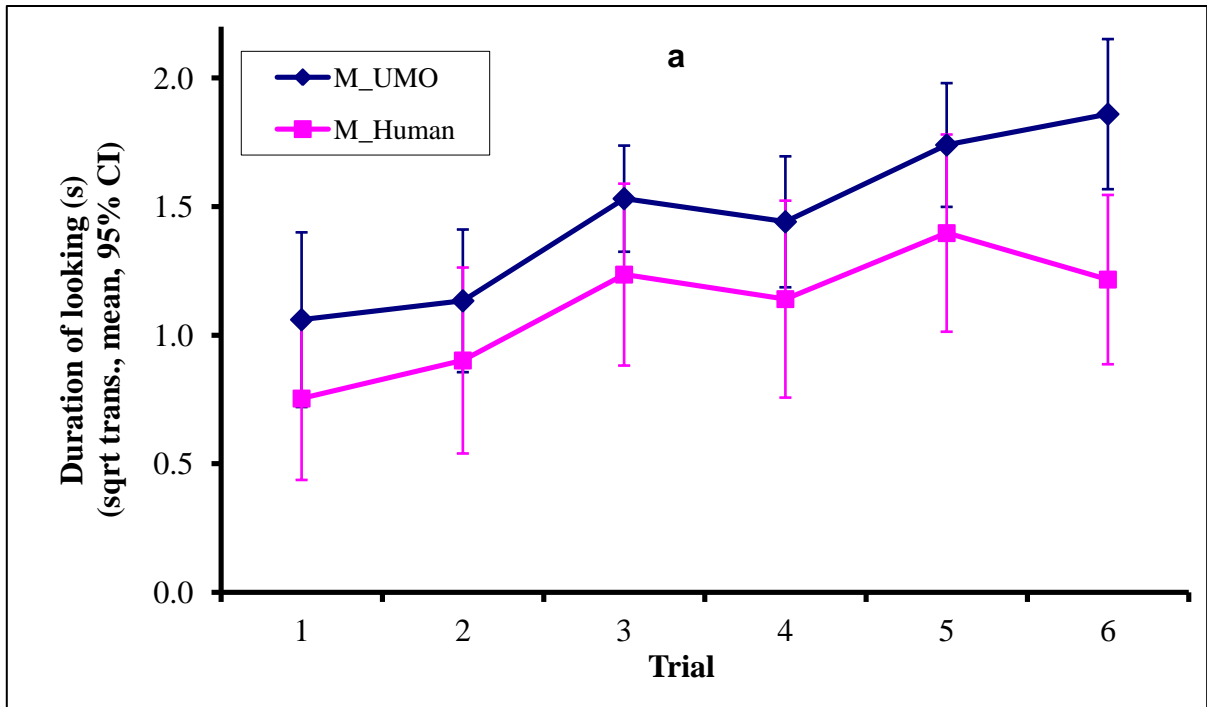
In the first series of analyses we studied the effect of the repetition, and difference in embodiment and behaviour by comparing the *Mechanical UMO* and *Mechanical Human* groups. The square-transformed *Looking at the partner* was analysed by the means of a GLMM (Generalized Linear Mixed Model) for Normal distribution. We analysed *Ratio of looking* and *touching dogs* variables with Binary GLMM (for Binomial distribution) to examine whether the subjects looked or did not look at or touched or did not touch the partner (UMO or Human) during the 30 s. Next we analysed whether there was a difference in the

Latency of touching the partner between the *Mechanical UMO* and *Mechanical Human* groups (GLMM for Normal distribution). We also analysed the *Frequency of gaze alternation* between the partner and the place of food in the two *Mechanical* groups (GLMM for Poisson distribution). We compared the *Ratio of looking dogs* (with Binary GLMM), and *Latency of looking at the partner* (GLMM for Normal distribution) variables among all the 3 groups. Finally, we compared all first trials and last trials among all three groups for all observed behavioural variables (Kruskal-Wallis test with Dunn post-hoc test).

2.1.2. Results

Comparison of *Mechanical UMO* and *Mechanical Human* groups

First we compared the two mechanical groups (*Mechanical UMO* and *Mechanical Human*) to see whether dogs showed comparable behaviour toward the *Mechanical UMO* and the *Mechanical Human*. Dogs in both groups were looking longer at the partner over repeated trials ($F_{5,136}=7.59$, $p<0.0001$). At the same time dogs looked longer toward the *Mechanical UMO* than toward the *Mechanical Human* ($F_{1,12}=5.37$, $p=0.039$) (Figure 5/a). Gaze alternations between the partner and the place of food became more frequent with repeated trials in both groups ($F_{5,55}=3.35$, $p=0.01$), and on the whole dogs in the *Mechanical Human* group displayed more gaze alternations than dogs in the *Mechanical UMO* group ($F_{1,47}=4.5$, $p=0.038$) (Figure 5/b). More dogs touched the partner in the *Mechanical UMO* group ($F_{1,46}=10.38$, $p=0.002$), however this behaviour did not change with the trials ($F_{5,95}=1.02$, $p=0.4$) (Figure 5/c). Dogs also touched the partner sooner in the *Mechanical UMO* group than dogs in the *Mechanical Human* group ($F_{1,22}=4.37$, $p=0.048$), but this latency did not change with the trials ($F_{5,17}=1.98$, $p=0.134$) (Figure 5/d).



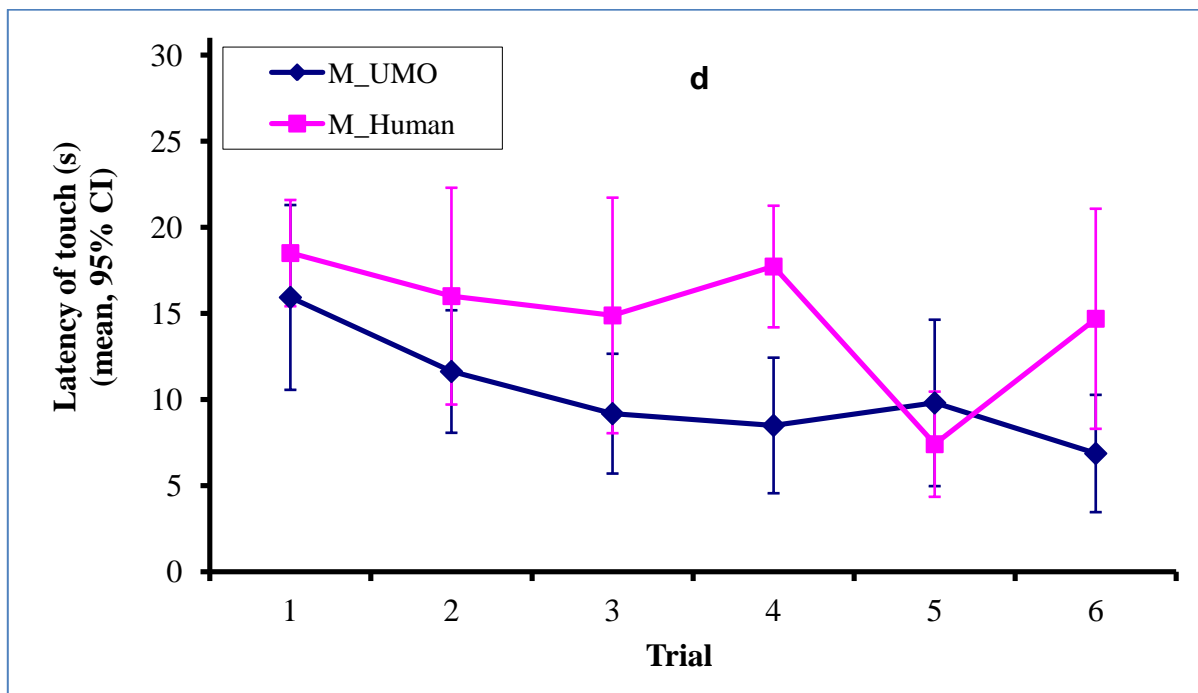
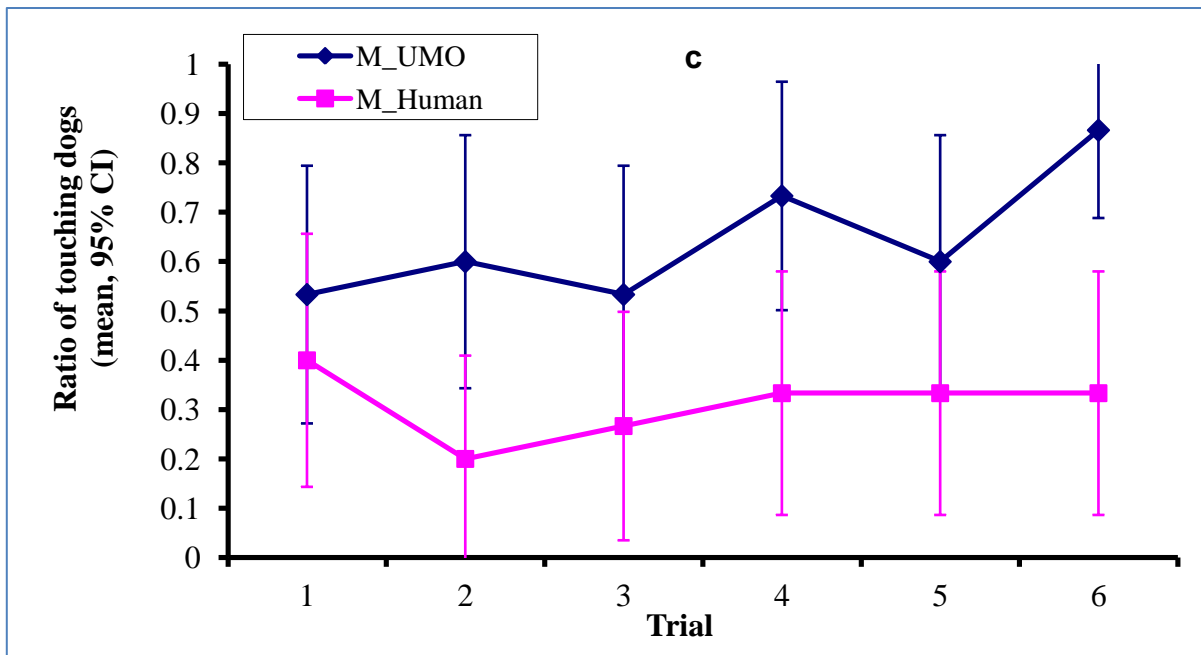
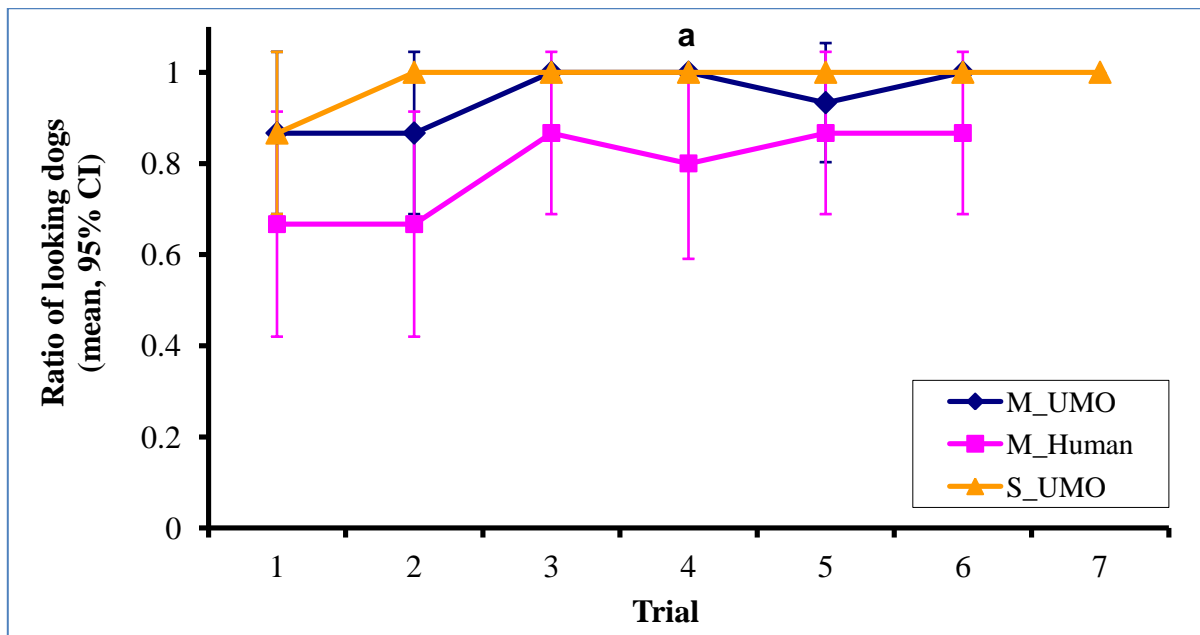


Figure 5a-d: Comparison of different behavioural measures between the Mechanical UMO (M_UMO) and Mechanical Human (M_Human) group during a 30 sec period in each trial when dogs were allowed to move freely. a; mean duration of looking at the partner (UMO or Human) b; mean frequency of gaze alternations between the partner (UMO or Human) and the place of food c; ratio of dogs who touched the partner with its muzzle (UMO or Human) d; mean latency of touching the partner with muzzle (UMO or Human).

Analysis of the *Ratio of looking dogs* and *Latency of looking at the partner* variables

Interactivity of the Social UMO did not allow us to compare most behavioural variables during trials 2th to 6th because the partner started to move when the dog looked at it (see Methods). However, we could analyse how many dogs looked at the partner (*Ratio of looking dogs*) and the latency of this action (*Latency of looking at the partner*). We found that trials had an effect on how many dogs looked at the partner at all ($F_{6,39}=36.7$, $p<0.0001$) (Figure 6/a). Groups also differed in the *Ratio of looking dogs* ($F_{2,8}=10.3$, $p=0.005$). More dogs looked at the partner in the *Social UMO* group than in the *Mechanical UMO* ($p=0.001$) or in the *Mechanical Human* group ($p=0.033$). At the same time fewer dogs looked at the *Mechanical Human* than the *Mechanical UMO* ($p=0.035$). In general, dogs looked sooner at the partner as trials went by ($F_{6,67}=10.9$, $p<0.0001$), and group also had an effect ($F_{2,46}=11.15$, $p<0.0001$). Dogs in the *Social UMO* group looked first to the partner sooner than dogs in the *Mechanical Human* group ($p=0.0001$), but there were no differences between the two types of UMOs ($p=0.069$) or between the two mechanical partners ($p=0.18$) (Figure 6/b).



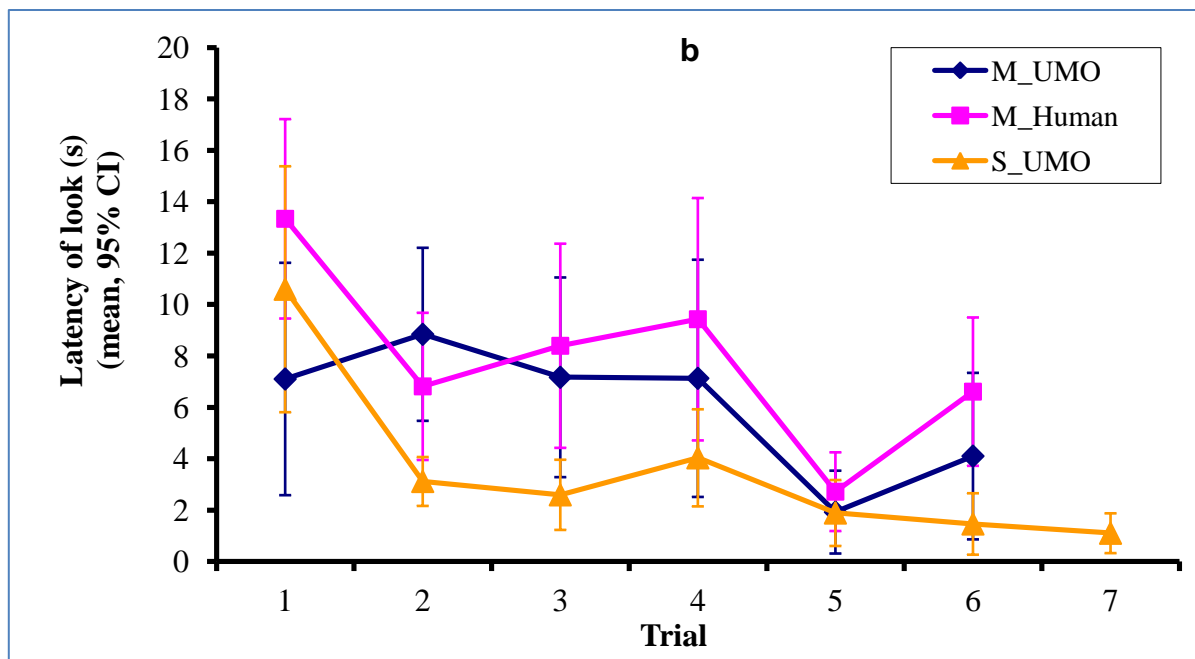


Figure 6a-b: Comparison of the ratio of looking dogs and the latency of looking at the partner in the Mechanical UMO (M_UMO), Mechanical Human (M_Human) and Social UMO (S_UMO) groups during a 30 sec period in each trial when dogs were allowed to move freely. a; ratio of dogs looked at the partner b; mean latency of looking at the partner.

Comparison of dogs' behaviour in the first and last trials

The aim of these comparisons was to examine whether dogs showed more intensive gazing and touching behaviours toward the *Social UMO* than dogs in the mechanical groups toward the *Mechanical UMO* or the *Mechanical Human*. This effect could emerge as the result of differential type of interactions in trials 2th to 6th (see Methods). In the first trial there were no differences among the three groups in any of the measured behaviour variables, however during the last trial all variables differed significantly across the groups (see Table 2).

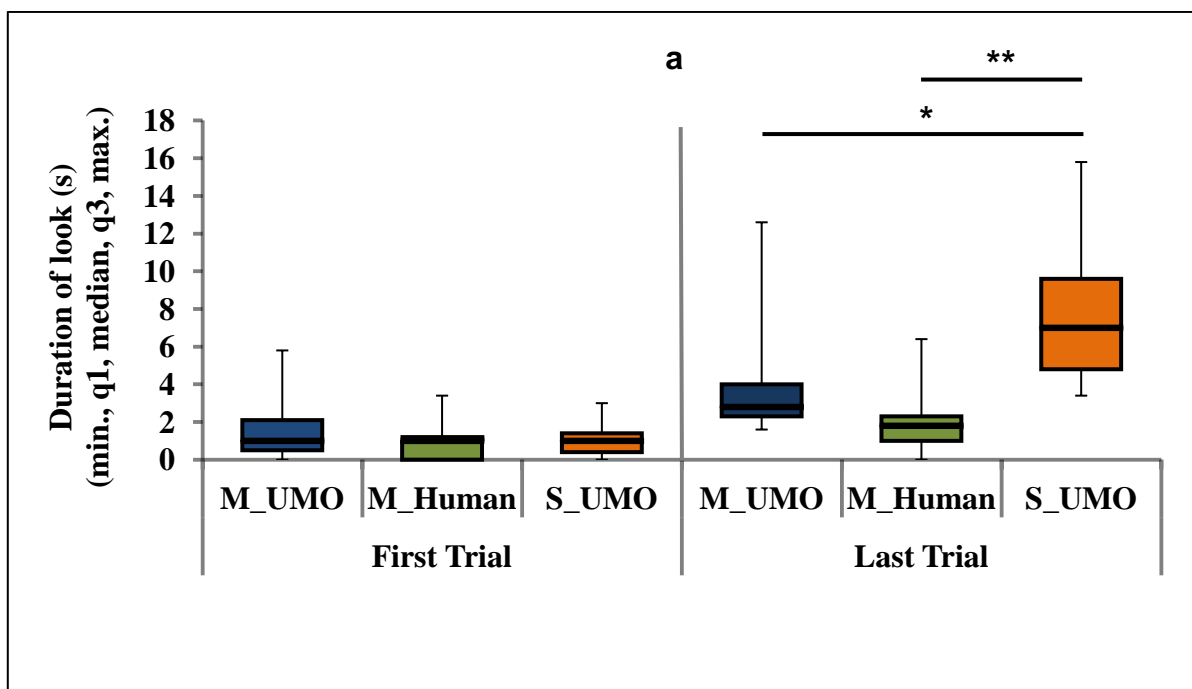
Kruskal-Wallis Test, Dunn Post-hoc (N=47, df=2)		
Name of the behaviour variable	First trial*	Last trial**
<i>Looking at the partner</i>	$\chi^2=1.59, p=0.45$	$\chi^2=27.46, p<0.0001$
		S_UMO vs. M_UMO $p=0.008$
		S_UMO vs. M_Human $p<0.0001$
<i>Frequency of gaze alternation</i>	$\chi^2=1.91, p=0.38$	$\chi^2=9.03, p=0.011$
		M_UMO vs. S_UMO $p=0.008$

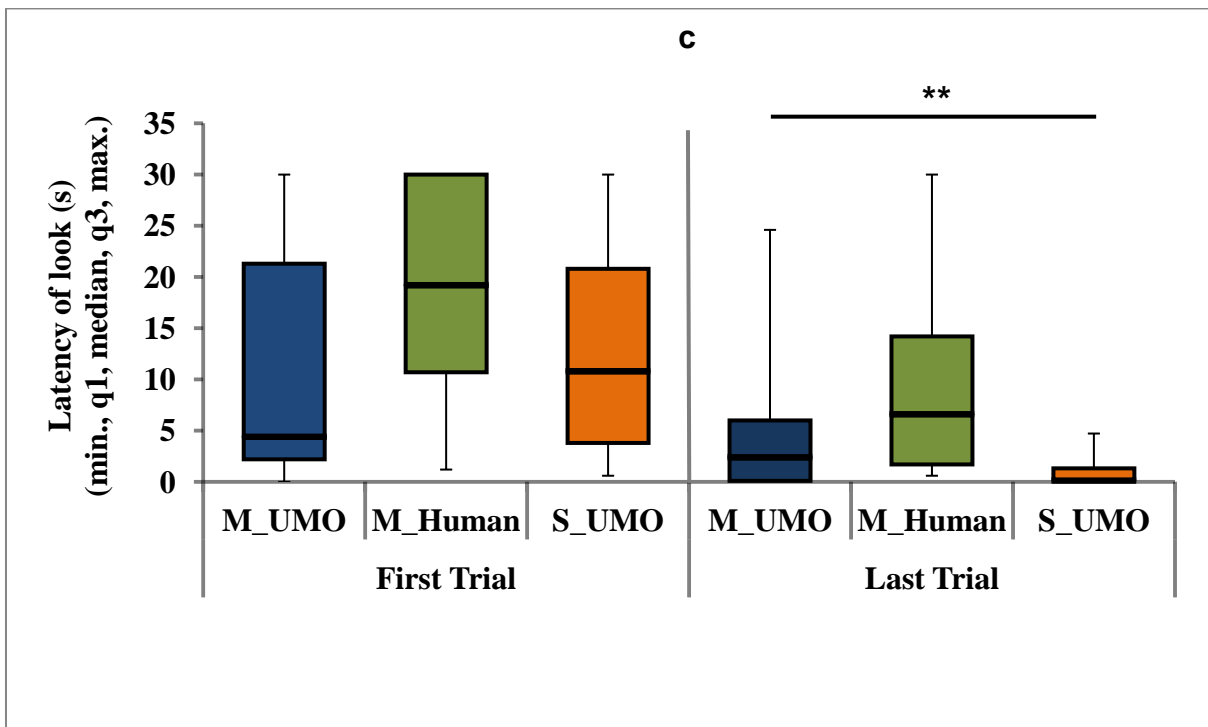
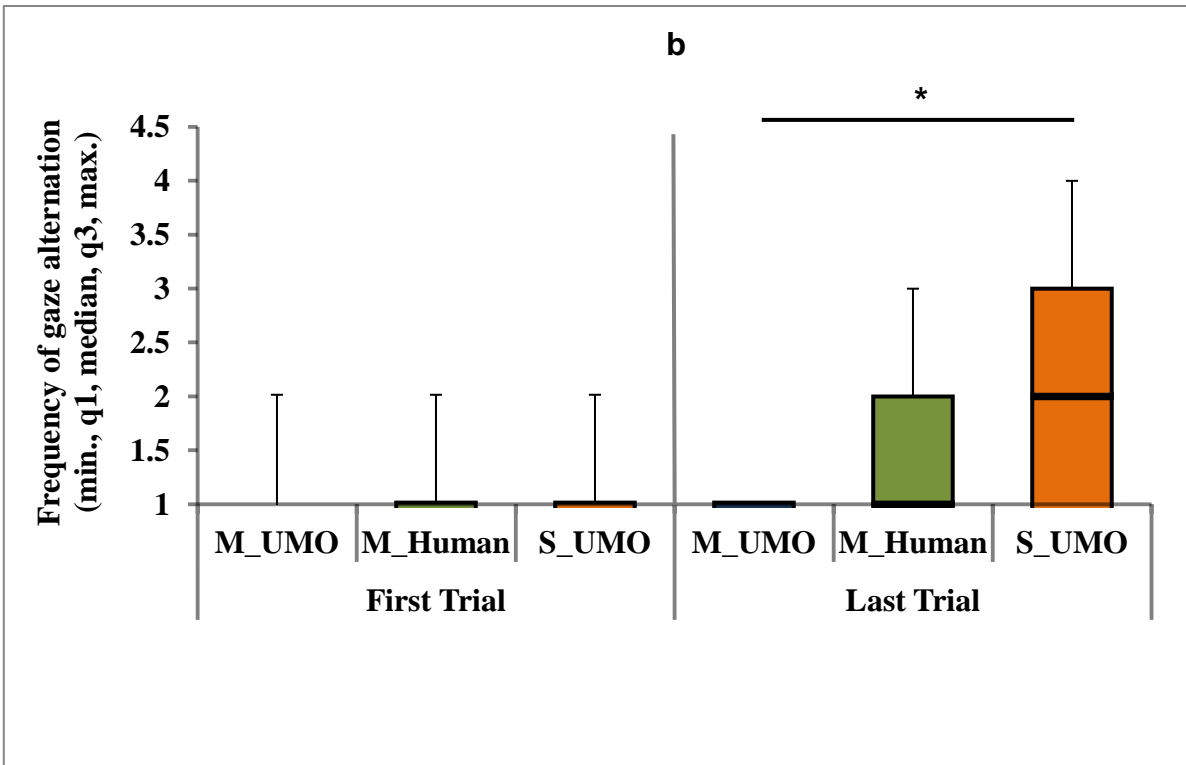
<i>Latency of looking at the partner</i>	$\chi^2=5.61, p=0.06$	$\chi^2=15.2, p<0.0001$
		S_UMO vs. M_UMO $p<0.0001$
<i>Latency of touching the partner</i>	$\chi^2=1.04, p=0.59$	$\chi^2=11.365, p=0.003$
		S_UMO vs. M_Human $p=0.003$
		M_UMO vs. M_Human $p=0.046$

Table 2: Comparison of dogs' behaviour during the first and last trials of each group.

* The second column shows the comparison of the first trials among the three groups; all are non-significant. ** Third column shows the comparison of the last trials, and Dunn's post hoc comparisons among the groups (S_UMO= *Social UMO*, M_UMO= *Mechanical UMO*, M_Human= *Mechanical Human*).

Dogs looked longer at the *Social UMO* than the *Mechanical UMO* or the *Mechanical Human* during the last trial (Figure 7/a). Dogs also altered their gaze more frequently between the *Social UMO* and the place of food during the last trial compared to the *Mechanical UMO*, but no such difference was present in relation the *Mechanical Human* (Figure 7/b). They were also faster to look at the partner in the *Social UMO* group than in the *Mechanical Human* group (Figure 7/c). Latency of touching showed the same pattern. Dogs touched the *Social UMO* and the *Mechanical UMO* sooner than the *Mechanical Human* (Figure 7/d).





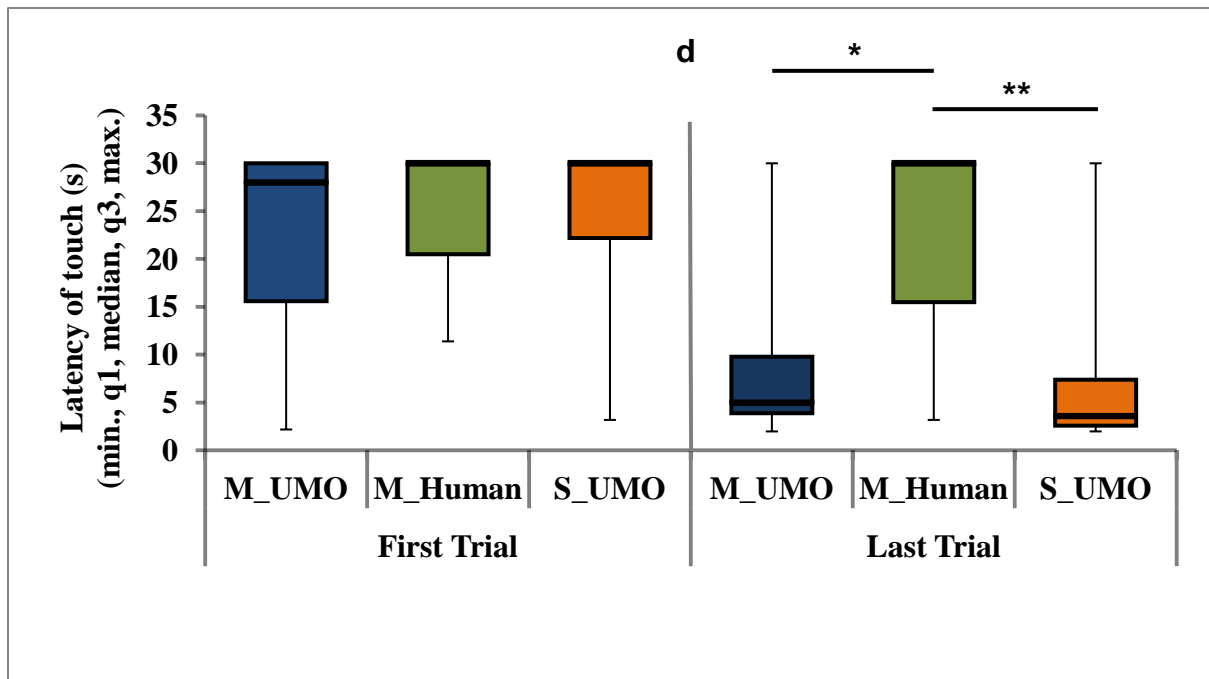


Figure 7a-d: Analysis of the dogs' behavioural variables during the first and last trials in each group. a; mean duration of looking at the partner (UMO or Human) b; mean frequency of gaze alternations between the partner (UMO or Human) and the place of food c; mean latency of looking at the partner (UMO or Human) d; mean latency of touching the partner with muzzle (UMO or Human) (* $p < 0.05$, ** $p < 0.005$).

2.1.3. Discussion

The aim of this study was to investigate whether dogs are able to differentiate agents on the basis of their behaviour and show social behaviours toward an UMO (Unidentified Moving Object) if the agent behaves appropriately in an interactive situation. The present experiment showed that these behaviour features also emerge in the dogs while they are interacting with an UMO, moreover the onset of these behaviours is facilitated by the social features of the UMO: Dogs look longer and show more gaze alternation if the UMO carries eyes, shows variations in its path of movement, displays goal-directed behaviour and contingent reactivity (reacts to the looking action of the dog by retrieving the inaccessible food item). The similarity in the dogs' behaviour toward the human (as reported in Miklósi et al 2000) and the UMOs in the present experiment leads to a range of interesting insights.

First, in order to control for the embodiment we included also a 'mechanical human' who looked very differently from the UMO but showed very similar gross movements to the Mechanical UMO, e.g. moved along the same path and did not show contingent reactivity to the dog. Naturally, the human used the hand to handle the food.

Despite the fact that dogs probably recognised the human in terms of embodiment they were attracted much less to the human as dogs looked longer and touched sooner the Mechanical UMO than the Mechanical Human (see Figure 5). This could be explained by the fact that dogs have never met the UMO before, and therefore they did not have any expectations about the behaviour of this moving object. Moreover, their previous experience with typical humans may have induced some wariness toward the Mechanical Human that manifested in shorter looking and touching duration but in increased gaze alternation.

Second, dogs show a drop in gaze alternation after the penultimate trial (5th) toward both mechanical partners but not toward the Social UMO (see Figure 6). Although the nature of this phenomenon is unclear, we suggest that dogs have changed their behaviour strategy toward these agents. The increase in looking time and gaze alternation frequency may have been caused by the dogs' tendency to generalise their previous experience with humans in such situations. Thus they may have recognised the correspondence between their earlier experience and the present situation despite the fact that the UMO is strikingly different from a human. Accordingly, this drop may indicate that dogs gave up showing communicative behaviours toward the agent, and instead 'waited' until the agent solved the problem. This is also supported by the observation that such drop did not emerge in the case of the Social UMO that replicated the behaviour of a typical human partner under these conditions.

Third, in the present experiment we did not want to account for all possible social features that may facilitate the interaction between the dog and the UMO. Thus the Social UMO displayed morphological (eyespot), motor (travelling along divergent paths) and interactive (starting to move upon being gazed at) characters which made it appear more animate and social at the same time. Despite all these differences the dogs' behaviour was very similar toward all partners in the very first trial (although they had the opportunity to observe these agents during the familiarization phase), but changed over repeated interactions (Figure 7). This indicates that the presence of the physical features, like eyespots and varied movements were not the key components for dogs in the case of the Social UMO. Instead, goal directedness and interactivity that was displayed in the first and subsequent encounters played a key role in the development and maintenance of social behaviours. These properties of the agent were found to be also significant in allowing human infants to discriminate animate-inanimate displays (Csibra et al 1999, Opfer 2002). Decreased latency of looking at the Social UMO can be explained by the fact that it started to move when the dog glanced at it once. Such contingency could emerge quickly in the case of associative learning which has been recently implicated in the development of 'sense of agency' (for a review see Heyes 2013).

Indeed, interaction between social beings (including human infants and caretakers etc.) are accompanied by such forms of learning. However, the present study is more focused on the ‘emergent’ behaviours which could be regarded as ‘by products’ of this contingency and which make the interaction appear more social. Thus we find it interesting that in parallel with dogs’ increased looking behaviour other social behaviours (e.g. touching, gaze alternation) occurred toward the Social UMO more often than toward the Mechanical UMO.

Interestingly, in another study dogs seemed not to show much social interest toward dog-like robot (AIBO) despite close morphological similarity (Kubinyi et al 2004). Although there are also parallels between the general behaviour pattern of AIBO and the dog, during the interactions the robot did not show any direct reactions to initiative behaviours of the dogs. This also suggests that, not denying the importance for certain morphological features (cf. sign stimuli) in releasing social behaviour, the interactive character of the behaviour on the part of the robot (or in our case the UMO) is more important for evoking social responsiveness than the embodiment per se.

2.2. Experiment 2: Dogs are able to adjust their social behaviour in accordance with their inanimate partners' different capabilities

In the first experiment we found that dogs were willing to interact socially with an UMO in a problem situation where they had no access to the hidden food, and displayed similar behaviours (gazing and gaze alternations) as they utilized with human partners. Our results also showed that the onset of these behaviours is facilitated by the social features of the UMO. As a next step we studied the flexibility of dogs' 'requesting behaviour' (see Miklósi et al 2000) toward UMO partners with different capabilities.

In a recent study Horn and co-workers (2012) investigated whether dogs adapt their social behaviour flexibly to the actions of their human partners in a similar problem situation. The experiment started with a training phase where dogs were trained to use efficiently a rotatable disc food-container to obtain 6 pieces of food. This apparatus was equipped with a blocking mechanism that, when activated, blocked the rotation of the disc, thus only 3 pieces of food were accessible for dogs. During this phase dogs had an opportunity to encounter with two experimenters, the Filler and the Helper. One experimenter played the role of the Filler who filled the empty apparatus up, while the other experimenter (Helper) unblocked the apparatus when it got blocked. The two experimenters entered the testing room (and left) through different doors. Training was followed by a Learning phase in which dogs had the opportunity to further learn about the specific abilities of Filler and the Helper. In this phase, dogs underwent twelve trials in which they could observe the actions of the Filler and eight trials in which they saw the actions of the Helper. Then dogs were divided into two conditions and participated in different test trials. For half of the dogs, the experimenters (with their back turned toward the dog) stood in front of the door they used routinely for enter and exit throughout the previous phases. For the other half of the dogs, however, the positions of the experimenters were swapped. In one of the test trials the apparatus was empty, while in the other trial the apparatus was blocked. Dogs were expected to choose (approach and gazing) the Filler when the apparatus was empty and the Helper when it was blocked independently of their actual position. Results showed that dogs spent more time in the proximity of the Filler when the apparatus was empty, however they preferred to approach and touch the Helper independently of the problem situation and the experimenters' position. They also found that dogs' behaviour in the second test trial was influenced by the problem situation they faced in the first test trial.

Authors concluded that dogs probably understood the problem of the empty but not the blocked apparatus (or the role of the Filler but not the Helper). At the same time increased social behaviour toward the Helper might be due to the unbalanced social experience gained through the training trials during which only the Helper interacted socially with the dog.

The method of our second experiment was based on this study (Horn et al 2012) but the different roles in problem-solving were played by UMOs with different abilities. In our task situation dogs were presented with a problem box with two lockable holes, one on the front and one on the top. Both holes were small enough to prevent the dog to reach the hidden food. However, front hole was suitable for one of the UMOs (a remote control car), while the top hole was fitted to the other UMO (a remote control crane) to help the dogs to obtain the food. Dogs had the opportunity to observe both UMOs actions 5-5 times before test trials which followed the procedure of Horn et al (2012). We aimed to find out whether dogs interact with the respective agent which was observed to be able to solve the problem and whether they display similar behaviours toward each partner. We hypothesised that dogs would approach and touch first the car when the front hole is open and the crane when the top hole ensures access to the food. Since results of Experiment 1 (see above) suggested that eyespots and varied movements were not the key components for dogs in the case of the ‘Social UMO’ we decided to exclude these attributes from the present study.

2.2.1. Materials and Methods

Subjects

Fifty-eight adult pet dogs were recruited from the Family Dog database of the Department of Ethology, Eötvös Loránd University. We excluded 10 dogs because they displayed high level of anxiety (N=6) or they were not sufficiently motivated (N=4). The remaining 48 dogs were divided into two experimental conditions (See Table 3). For details see Appendix Table 9. Only dogs older than 1 year were recruited, and there was no upper age limit to participate. Our analysis of the dogs’ mean age did not show significant differences between the 2 conditions (Mann-Whitney test, N=48, U=202.5, p=0.074). Subjects were allowed to participate only if they could be motivated with sausage.

Apparatus

Dogs were tested at the Department of Ethology, Eötvös Loránd University in a 4.5 m×3.5 m test room. Partners (UMOs) were parking (P1/P2) outside of the room and we used two guillotine doors (Door A and Door B) for operating them in and out of the test room. Experimenter 2 (E2) opened the door for Experimenter 3 (E3) by means of a string connected to the guillotine and E3 opened the other door for E2 vice versa (Figure 8). Throughout the experiment E2 and E3 were standing in the two corners of the lab and carefully avoided getting engaged with the dog. Experimenter 1 (E1) was filling up the bowl with food and acted as a hider throughout the experiment. E1 always used Door C for enter and exit (see Figure 8). A wooden opaque box (80 cm x 48 cm x 38cm) served as hiding location (B) with two holes (see Figure 9), one on the top of the box (TH) and one on the front side of the box (FH). A plastic bowl (7.5 cm x 7.5 cm) equipped with a 8 cm long metal screw and one additional metal sheet in the front of the bowl was used to contain food. The UMOs were able to bring the bowl out of the box with magnets (the car was equipped with a front magnet and the crane carried one in the end of its telescopic boom). The UMOs differed in their physical abilities i.e. the car could obtain the food through the front hole while the crane was too large to use the front hole but it could reach the food through the top hole with its telescopic boom (see Figure 9). In this experiment we used sausage instead of dry dog food because it has stronger smell, thus dogs could smell it more easily inside the opaque box. Trials were recorded by four cameras which were connected to monitoring and recording equipment in the adjacent room.

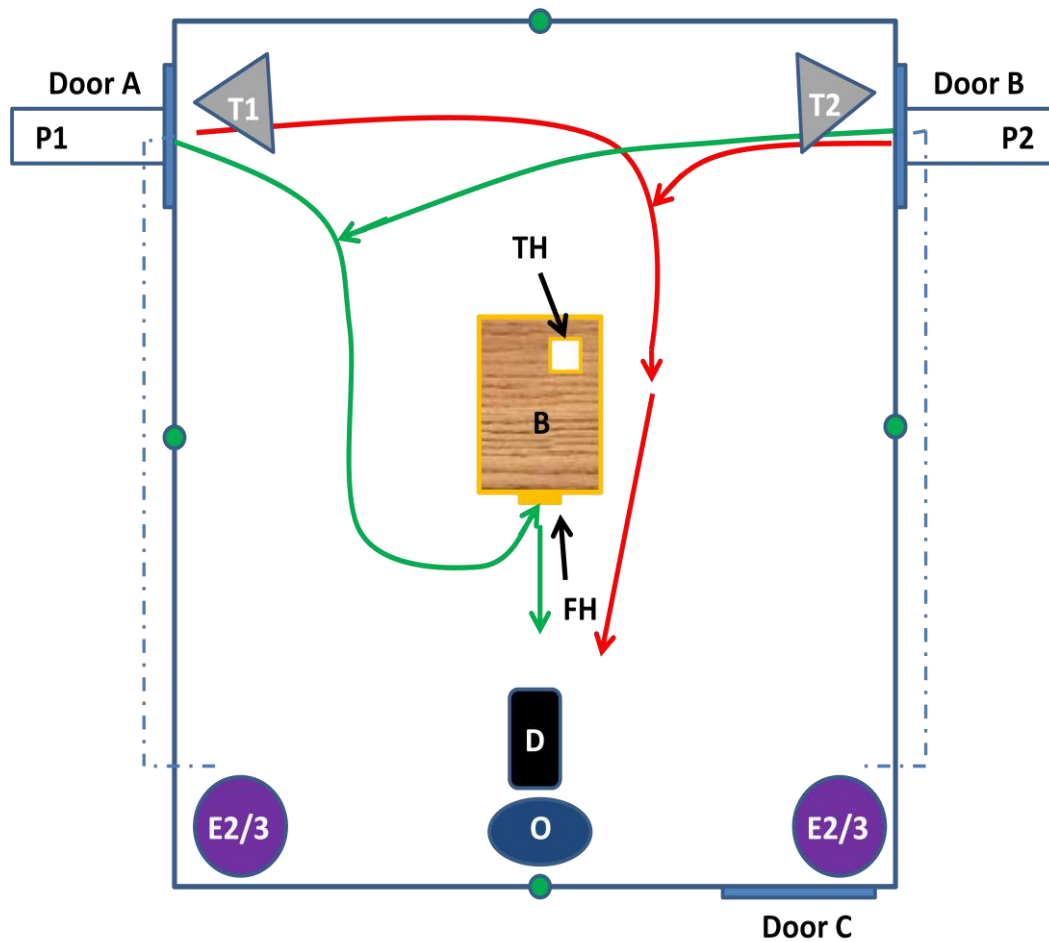


Figure 8. Experimental set-up. O=place of the owner, D=place of the dog, E2/3=position of Experimenter 2 and 3, B=place of the wooden box, FH=front hole, TH=top hole, P1&P2= outside parking places of the UMOs, T1&T2=positions of the UMOs during test trials. Green lines show the paths of the car from Door A or B to the FH and then to the dog. Red lines show the paths of the crane from Door A or B to the TH and then to the dog. Dotted lines indicate the position of the strings connected to Door A and B. Green circles indicate the location of the cameras.

Test partners

In this experiment we used the same remote-controlled car as in Experiment 1 and a remote-controlled crane (Hobby Engine Premium Label RC Crane Truck 2.4 Ghz, 65 cm x 17 cm x 15 cm) as test partners (see Figure 9). Both UMOs were equipped with magnets to attach to the bowl with food. The car was controlled by E2 and the crane was controlled by E3. Door A was used consequently by the car and Door B by the crane during the experiment for half of the subjects and vice versa for the other half of the subjects.

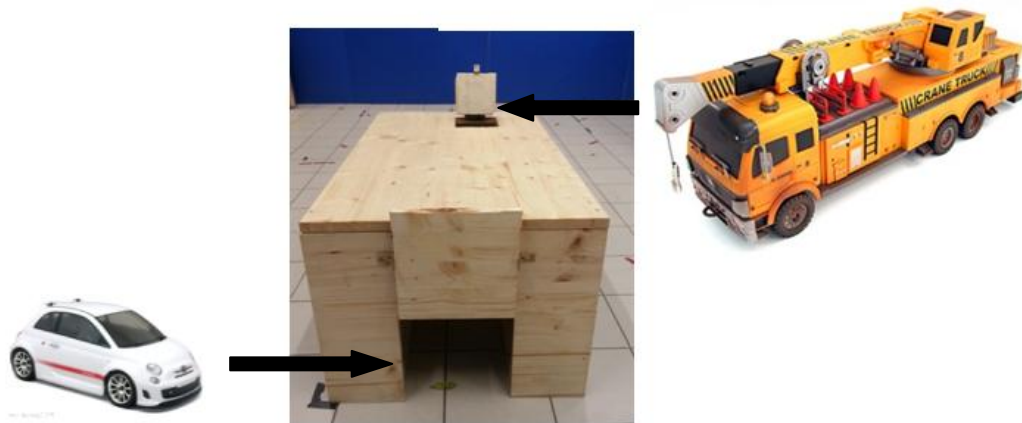


Figure 9. The wooden box with two lockable holes and the test partners (UMOs). Arrows indicate the respective hole used by the car or the crane during the test for retrieving the food for the dog.

Procedure

Familiarization

1. The owner and the dog entered the room and walked around. Inside the room the apparatus was already set up, however the UMOs were not yet present. The dog could sniff and explore the room on leash for 1 minute. Then the owner sat down at a predetermined location (O) and held the dog in front of him/herself.
2. E1 entered the room and put one piece of food into the bowl. The owner unleashed the dog and encouraged it to eat the food (e.g. „It’s yours”; „Come on take it” etc.). After having eaten the food the owner called the dog back.
3. E1 put another piece of food into the bowl and took it to one of the two determined position: next to the box (for the car) or on the top of the box (for the crane). One of the UMOs then come in, approached the bowl and carried it to the dog. This procedure was repeated two times and the order of the test partners was counterbalanced between subjects.

Learning-phase

1. After having called the dog’s attention E1 put one piece of food into the bowl and hid it through one of the two holes (FH or TH) on the box then closed the other hole and then left the room. The owner unleashed the dog and encouraged it to try to retrieve the food (note that

this was not possible). If the dog did not find the open hole the owner was allowed to point at it. After 30 seconds the owner called the dog back.

2. The UMO that was suitable for taking out the bowl via the currently open hole entered through the guillotine door, approached the wooden box and took the bowl out. Then the UMO approached the dog, stopped in front of it (within 40 cm), thus the dogs was able to eat the food from the bowl.

We repeated this procedure (Steps 1 & 2) 10 times in total: 5-5 trials with the different UMOs (i.e. car-when FH was open; crane-when TH was open) in a predetermined order (car 1, crane 2: 1-2-1-2-2-1-2-1-1-2 or 2-1-2-1-1-2-1-2-2-1). At the end of the learning phase E1 asked the owner to go out of the room with the dog for 30 seconds.

Test trials

1. While the owner and the dog were waiting outside E2 and E3 placed the two UMOs on the floor next to Door A and B (T1 and T2, see Figure 8). In the *Same side* condition UMOs were placed in front of their ‘respective’ doors (i.e. the door they used routinely for enter and exit during the learning phase).

In the *Changed side* condition the position of the UMOs was swapped (i.e. were placed at the ‘opposite’ door).2. The owner and the dog entered the room. After having called the dog’s attention E1 put a piece of food into the bowl and hid it through one of the two holes (FH or TH) on the box then closed the other hole and left the room. The owner and the dog (on leash) went to the box and the dog was allowed to sniff into the box through the open hole. After they sat back to the predetermined location the owner took of the leash, and the dog was allowed to move freely for 30 seconds. The owner was asked to encourage the dog in the same way to get the food as she/he did during the learning phase.

3. The dog was called back and held by the owner and then the UMO who was ‘able to’ help in the current situation started to move and gave the food to the dog.

4. The owner and the dog left the room again for 30 sec.

5. We repeated this procedure (Step 1-3) once more in the very same way except that the food has been hidden by E1 through the other hole, thus during Step 3, the other partner could help the dog to get the food. The order of the first opened hole (TH or FH) was counterbalanced between subjects (see Table 3).

During the behavioural coding we focused on the 30 seconds during the two test trials in order to analyse dogs’ behaviour toward the UMOs.

	Same side condition				Changed side condition			
Learning phase	car: door A crane: door B		car: door B crane: door A		car: door A crane: door B		car: door B crane: door A	
Test Phase (baited hole)	1 st FH 2 nd TH	1 st TH 2 nd FH	1 st FH 2 nd TH	1 st TH 2 nd FH	1 st FH 2 nd TH	1 st TH 2 nd FH	1 st FH 2 nd TH	1 st TH 2 nd FH
No. of dogs (males & females) mean age±SD (years)	N=12 7 & 5 4±2.2		N=12 3 & 9 3.6±2.3		N=12 3 & 9 4.2±2		N=12 7 & 5 3.2±2.2	

Table 3. Experimental design

Behavioural variables and data analysis

All trials were videotaped and dogs' behaviour (Table 4) during the 30 s free movement episode was analysed later with Solomon Coder 060612 (András Péter <http://solomoncoder.com>).

Name of behaviour element	Definition
First look (score 0/1)*	The dog looks first at one of the partners (car or crane) after owner releasing the dog
First approach (score 0/1)*	The dog approaches one of the partners within 1 m with his nose
First touch (score 0/1)*	The dog touches first the partner (car or crane) with its muzzle
Looking time toward the partner (s)	Duration of gazing toward the 'appropriate' and 'irrelevant' partner (car or crane)
Number of gaze alternations	Total number of looks from the 'appropriate' and 'irrelevant' partner (car or crane) to the box (place of food) directly or vice versa regardless of order

Table 4. The definitions of coded behavioural elements. * Score 1 was given if the dog interacted (looked at, approached, touched) the appropriate partner (i.e. car when FH open & crane when

TH open), and score 0 was given if the dog interacted with the ‘irrelevant’ partner (i.e. car when TH open & crane when FH open).

Inter-observer agreement (between two coders) was assessed by recoding a randomly selected 25% of the subjects (Cohen’s Kappa, 0.97).

For statistical analysis we used IBM SPSS Statistics 21. First we compared First look, First approach, First touch variables to chance level (0.5) to examine whether subjects showed a tendency to choose the appropriate partner first. Then we analysed these variables and the Number of gaze alternations with Binary GLMM (for Binomial distribution) in order to examine the effect of condition, test partner (car vs. crane) and the repetition of test trials. We calculated the ratio of looking at the car and crane from Looking at the partner variable and we analysed it with GLMM for Normal distribution.

2.2.2. Results

One-sample Binomial test showed that dogs looked first ($p=0.003$), approached first ($p=0.009$) and touched first ($p=0.028$) the appropriate partner according to the problem situation during test trials (Figure 10). Binary GLMM revealed that condition ($F_{3,88}=2.215$, $p=0.092$) and test partner ($F_{1,88}=0.294$, $p=0.589$) had no effect on First look variable, however repeated test trials effected this behaviour ($F_{1,88}= 6.8$, $p=0.01$) (Figure 10).

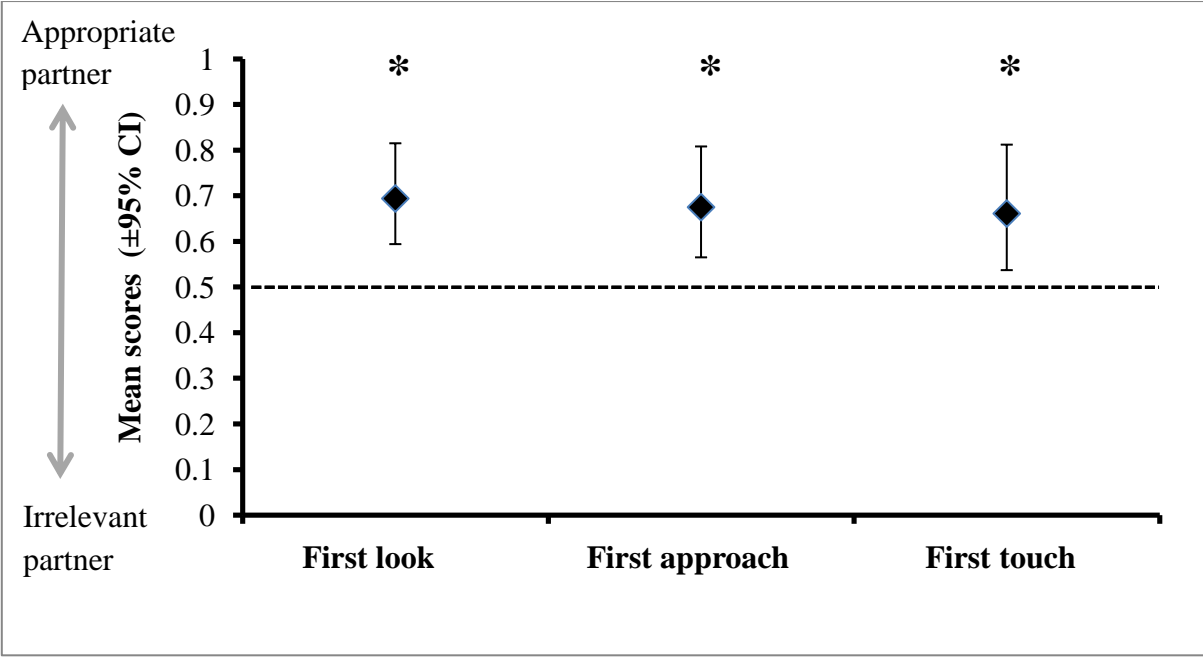


Figure 10. Mean scores for the First look, First approach and First touch variables in test trials. Dotted line indicates chance performance (0.5). * $p<0.05$

Moreover GLMM showed no main effect in case of First approach ($F_{5,72}= 2.16, p=0.07$) and First touch ($F_{5,61}= 2.33, p=0.06$) variables. Similarly, the analysis of Looking time toward the partner and the Number of gaze alternations did not show significant effects ($F_{5,90}= 0.39, p=0.85$ - Figure 11/a and $F_{5,70}= 0.604, p=0.697$ -Figure 11/b) which indicates that dogs had no preference in looking at the car or at the crane.

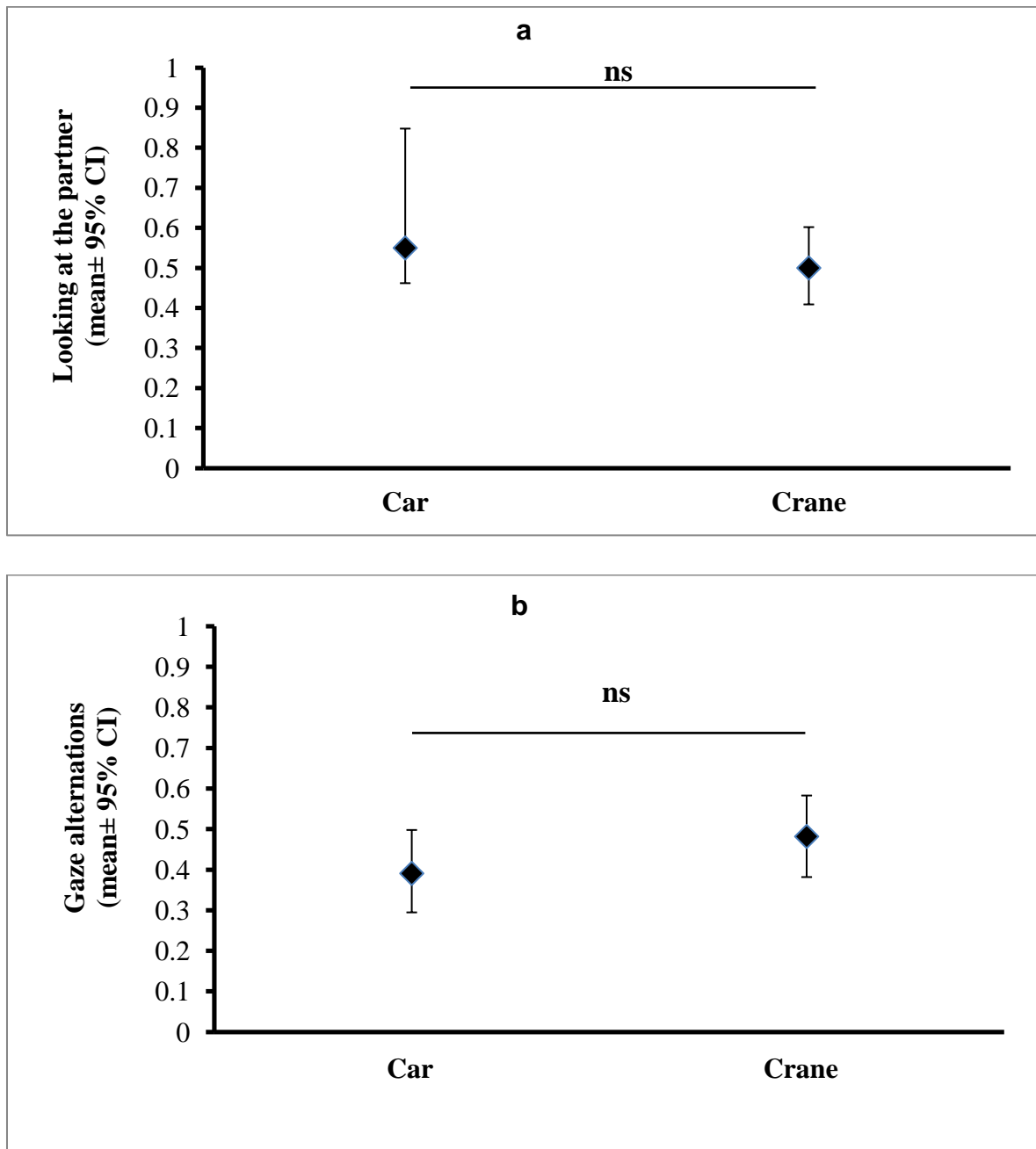


Figure 11a-b. Analysis of dogs looking behaviour toward test partners during test trials. a: Duration of looking at the car and the crane; b: Frequency of gaze alternation between car-box and crane-box. ns>0.05

2.2.3. Discussion

Results of the second study showed that dogs direct their social behaviour in accordance with the actions and different capabilities of their inanimate partners in a problem situation, i.e. they first approached, touched and looked at the partner which could help in that particular situation. However, time spent looking at the partners and the frequency of gaze alternations between partners and the place of the hidden food were independent from the type of the partner, i.e. dogs did not show any preference toward one of the partners. These results are in agreement with previous findings of Horn et al (2012) although it seems that dogs in the present study discriminate the different roles of the two partners equally well. Dogs' better performance with the UMOs might be due to methodological differences between the two studies. First, in the present study dogs' opportunity to learn about partners' actions was equalized. Second, it is possible that the problem of the box with two holes was easier to the dogs to understand compared to the blocking mechanism of the apparatus in the Horn et al (2012) experiment. Third, unbalanced social experience with the partners which proved to be an important factor for dogs in similar situation (see Horn et al 2012) was controlled in our experiment by using non-living agents as partners. Fourth, UMOs' different abilities were determined by physical constraints, i.e. the car was unable to use the top hole in the absence of a telescopic boom while the size of the crane limited access to the hidden food through the front hole. However, several studies have shown that dogs have limited abilities in physical cognitive tasks (e.g. Fiset et al 2000, Brauer et al 2006, Fiset & LeBlanc 2007), thus dogs are also expected to have difficulties to solve this task where they should comprehend the physical constraints of the different UMOs to retrieve food from the box through different openings.

In the present study we propose discrimination learning as underlying mechanism which involves the ability to learn to discriminate between similar stimuli through differential reward contingencies (Kehoe 2008). However, much of the research investigating learning mechanisms related to stimulus discrimination in dogs showed that it took dogs anywhere from 20 to 300 trials to learn to discriminate between objects that differ on figurative characteristics (e.g. shape, color, size etc.) (e.g. Milgram et al 1994, Tapp et al 2003). In these experiments dogs obtained the food reward immediately after choosing the correct object. Dogs also had difficulties to find a hidden food indicated solely by a physical marker (object) in a two-way choice task (e.g. Agnetta et al 2000, Riedel et al 2006). In this case dogs

seemingly did not associate between the place of the marker and the location of the hidden food even after more than 70 trials (Agnetta et al 2000).

Lesser need for learning in the present experiment (10 trials) can be explained as follows: (1) latter studies used stationary object, while the UMOs were moving which might triggered dogs' attention (i.e. increased salience of the UMO partners); (2) the social context of the present study might facilitate learning in dogs. The second idea is supported by the results of the marker study mentioned above that dogs' performance increased significantly in the simultaneous presence of the marker and the human experimenter (i.e. social context) (Riedel et al 2006).

2.3. Experiment 3²: Dogs rapidly develop socially competent behaviour while interacting with a contingently responding Unidentified Moving Object (UMO).

The key question in socio-communicative interaction is how do communicative signals achieve their function, i.e. how does the action of the sender become a signal for the receiver? It is widely accepted that two fundamental mechanisms play major role in the emergence of communicative interactions. (1) The hypothesis of (evolutionary) ritualization assumes (Hinde and Tinbergen 1958) that during evolution a neutral behaviour is transformed gradually into a communicative behaviour with signal properties if it has predictably modifies the behaviour of the partner. During this process the behaviour pattern is subjected to changes making it repetitive, exaggerated and stereotyped (Hinde 1970). (2) Ontogenetic ritualization takes place if the individuals shape mutually their behaviour during repeated instances of social interactions. In this case one individual originally performs behaviour X to which its partner reacts consistently with behaviour Y. As a consequence after many dyadic interactions the first individual comes to anticipate the other's action. Importantly, action X is not necessarily a communicative interaction in the first place but develops into one as a result of mutual interaction and learning (Tomasello 1996).

Several studies have focused on the relative contribution of evolutionary vs. ontogenetic mechanisms controlling certain communicative signals and their species or context specific aspects. For example Halina et al (2013) examined gestural communication of captive bonobos and suggested that ontogenetic ritualization is the main underlying mechanism due to the flexibility and variability of these signals. In contrast, Hobaiter & Byrne (2011) argued that ape gestures are rather innate and acquired as a function of evolutionary ritualization. They also claimed that observed variation across individuals can be attributed to sampling effect.

Similar argument has emerged in relation to the comprehension of human pointing gestures in dogs (see Miklósi & Soproni 2006, Udell et al 2010a for reviews). One assumption is that dogs learn to use human communicative signals during the early ontogeny (ontogenetic ritualization), thus this ability emerges as a consequence of habitual interaction between dog and human owner (e.g. Udell et al 2008, Elgier et al 2009).

² Based on: **Gergely, A., Petró, E., Topál, J., Kosztolányi, A., & Miklósi, Á.** 2014. Dogs rapidly develop socially competent behaviour while interacting with a contingently responding Unidentified Moving Object (UMO). *submitted manuscript, PNAS*.

The alternative explanation is that during the process of domestication dogs have become more sensitive to specific human behavioural cues, e.g. pointing (evolutionary ritualization: e.g. Riedel et al 2006), gazing (Soproni et al 2001). It was argued that the superior ability to rely on the human pointing gesture in young dog puppies over socialised wolf puppies supports partly this latter argument (e.g. Gácsi et al 2009).

Recent discussion converged to the idea that actually both mechanisms might play a role (e.g. Miklósi & Topál 2013, Udell et al 2014) in the emergence of such interspecific signalling but question is still open how the relative contribution of evolutionary and ontogenetic ritualization could be determined. Methodologically three different approaches were used so far: (1) Deprivation of social experience (e.g. shelter dogs, e.g. Udell et al 2010b, Hare et al 2010); (2) Demonstration of the effect of learning on the performance in a communicative interaction between dogs and humans (e.g. Udell et al 2008, Elgier et al 2009); (3) Testing the effectiveness of (relatively) novel communicative human signals in typical dog populations (Lakatos et al 2009). These methods were not really effective in determining the contribution of ontogenesis /evolution and raised also some methodological problems.

Tomasello et al (1997) proposed that observing infants' and apes' reaction to novel signals would be a feasible method to examine their understanding on communicative signs. It is also assumed that lesser need for learning (or experience) or rapid learning in these tasks with the novel signal suggests contribution of genetic predisposition. In line with the latter suggestion researchers used the so-called triangulation method in order to examine animals' mental state attribution ability (e.g. Heyes 1993). In general, this method consists two phases: (1) First, the naïve individual is exposed to specific experience (or has to learn to discriminate) in Context 1 then (2) the individual is exposed to a novel context (Context 2) which overlaps only in specific ways with Context 1 by sharing only a small set of specific features. Results with chimpanzees showed that certain problems (e.g. cue detection) were learned faster when it was presented in Context 2 than it was presented first, in Context 1, suggesting that some features of the first task had facilitated chimpanzees' performance in the second (Tomasello et al 1997).

However, in the case of socio-cognitive investigations this method is not really informative because the social partner (as a 'cue') carries over a too large part of the contextual information from Context 1 to Context 2. For example, dogs experience humans pointing gestures in everyday life (Context 1), this experience with humans including possible genetic predisposition does not allow to set up an experiment (Context 2) which overlaps only

specifically with Context 1 because the presence of the human in both contexts. Thus the relative role of evolutionary/developmental processes is difficult to judge.

In the present study we propose a new method which is based on the following ideas by introducing an unfamiliar moving object UMO to the experimental setting. Accordingly, (1) the subject is exposed to a specific social interaction in Context 1 and a different one in Context 2; (2) the social agent (UMO) shares no physical attributes with neither the subject (dog) nor other social potential social partner (human) in order to exclude previous experience; (3) social interactions share specific features with the natural social interactions among conspecifics (or familiar social partners, C). The underlying assumptions are that (1) subject has earlier experience with C and knows that C is able to perform action X and Y, (2) based on (1) subject recognises that UMO is performing action X, (3) and subject infers that UMO can also perform action Y.

The present study has been designed to provide support of the latter concept. We decided to model a well-documented communicative interaction between dog and human in which the dog has opportunity to find the hidden food based on partner's directional movement toward one of the two potential hiding places. We presented two different partners in four different conditions to the dogs in a between subject design. The Helper UMO and the Non-Helper UMO was a remote control car, in the Helper Human and Non-Helper Human group the partner was a female human (see Experiment 1). We assumed that dogs will consider human's movement as a signal from the beginning, while they were expected to need learning about the informative aspect of the UMO's directional movement. Based on previous studies with infants (Meltzoff et al 2010) we hypothesised that dogs who had opportunity to interact socially with the UMO will consider UMO's movement as an indication (communicative signal) and perform better in the two-way choice task, while dogs without any previous experiences with the UMO will failing to recognise the communicative aspects of the directional signal and perform at chance level.

2.3.1. Materials and Methods

Subjects

Eighty-two adult pet dogs were recruited from the Family Dog database of the Department of Ethology, Eötvös Loránd University. We excluded 8 dogs because they showed strong side bias (they were approached only the pot in the left/right in all 16 trials: 2 dogs in the Non-

helper Human group; 2 dogs in the Non-helper UMO group; 3 dogs in the Helper Human group; 1 dog in the Helper UMO group) and 14 dogs because they were not sufficiently motivated with food. The remaining 60 dogs were divided to four different groups: Non-helper Human (N=15, 6 males, 9 females, mean age \pm SD 4.70 \pm 2.48), Non-helper UMO (N=15, 7 males, 8 females, mean age \pm SD 3.57 \pm 1.64), Helper Human (N=15, 10 males, 5 females, mean age \pm SD 4.20 \pm 2.46) and Helper UMO (N=15, 6 males, 9 females, mean age \pm SD 3.17 \pm 2.05). For details see Appendix Table 10. Dogs' age between groups did not differ (ANOVA, $F_{3,56}=1.42$, $p=0.25$). We tested only those dogs who could be motivated by food.

Apparatus

Dogs were tested at the Department of Ethology, Eötvös Loránd University in a 4.5 m x 3.5 m test room. Each trial was recorded by four cameras (see Figure 12).

In the Helper Human and Helper UMO groups we used a metal wire mesh box (61 cm x 46 cm x 54 cm) with a magnet fixed in it. The role of the box was that the dog could only get the food with the partners' help. In these groups we also used a plastic plate (10 cm x 10 cm) with two metal sheets on its sides. The food was placed on these plates during the familiarization phase in the Helper groups.

We covered the dogs' eyes with an occluder (102 cm x 76 cm) between test trials.

Test partners

In the Non-helper UMO and Helper UMO groups we used the same remote control (RC) car as in Experiment 1 and 2. The car was equipped with a magnet on its front and a small loudspeaker under the cover. As an attention-getting cue we used a high pitched beeping sound (3200 Hz) emitted from the loudspeaker.

In the Non-helper Human and Helper Human groups the partner was played by a female human. The Non-helper Human wore sunglasses and did not use any verbal or non-verbal cues during the test. She used the same beeping sound to call the dogs' attention as the UMO. In the Helper Human group the human partner could use verbal and non-verbal cues too. She said „*Hi (Dog's Name), look!*” to call dogs' attention. Test partners' starting point was at a predetermined location (see Figure 12).

Procedure

Pre-training phase

The pre-training was necessary that the dogs understand that the pot would contain food. The owner and the dog entered and the dog was allowed to explore the room, meanwhile the experimenters informed the owner about the test. After this the owner sat in the chair and held the dog in front of him/herself (Figure 12/a). Experimenter 1 (E1) came in with a pot and put it down. She attracted the dog's attention with a piece of food in her hand (she said: „*Hi (Dog's Name), look!*”). She put one piece of food into the pot and the owner was allowed to release the dog. If the dog ate it, the owner called the dog back. We repeated it four times then E1 left the room with the pot. The pre-training was exactly the same for each group.

Familiarization phase

Non-helper Human group

The partner came in and walked around the room for 2:30 minutes, during this the owner held the dog in front of him/herself. Then the partner stopped at the starting point (Figure 12/a).

Non-helper UMO group

E2 brought the UMO inside, placed it at the starting point and then she stood in the corner on the right side of the dog (Figure 12/a). The familiarization was the same as in the Non-helper Human group, except that the human partner was replaced by the UMO.

Helper Human group

E1 brought the box in and placed it halfway between the dog and the partner on the left side of the room. During this the human partner came in and stood at the starting point. Then E1 went out for a piece of food and the plastic plate and came back. She attracted the dog's attention with the piece of food in her hand („*Hi (Dog's Name), look!*”) and put it into the plate. She attached the plate to the magnet inside the box. After E1 left the room the dog was released to explore the room and try to get the food for 15 s. When the time elapsed, the owner called the dog back. Then the partner called the dog's attention („*Hi (Dog's Name), look!*”) and brought out the plate with the food from the box to the dog. The dog ate the piece of food and the partner went back to the starting point. Then E1 came in and placed the box to

the other side of the room and the procedure was repeated described above. The trial was repeated 6 times LRLRLR order (L=box placed to the left; R=box placed to the right).

During the 15 s exploration phase, at the moment when the dog looked at the partner, the partner started to move and brought the plate out.

Helper UMO group

The familiarization was the same as in the Helper Human group, except that the human partner was replaced by the UMO and the Helper UMO was called the dog's attention with the beeping sound.

Test phase

E1 entered the room with two identical pots and placed them on each side of the partner (see Figure 12/b) and attracted the dog's attention with a piece of food in her hand („Hi (*Dog's Name*), look!"). Then the dog's eyes were covered by an occluder, E1 put one piece of food into one of the pots and then left the room. The occluder was removed and the partner called the dog's attention (according to the group) from the start point (see Figure 12/b) and approached the baited pot, touched it with her leg (in Non-helper and Helper Human groups) or its front (in Non-helper and Helper UMO groups) and went/moved back to its/her starting point (i.e. indication). The owner released the dog, and it was allowed to choose between the pots. If the dog chose the baited one, it could eat the food, but if it went to the other one, the owner did not let the dog to get it (the owner could show the piece of food in the baited one, but the dog was not allowed to eat it). Dogs were presented with sixteen test trial during which the baiting followed RLRLRLRLRLRLRL order.

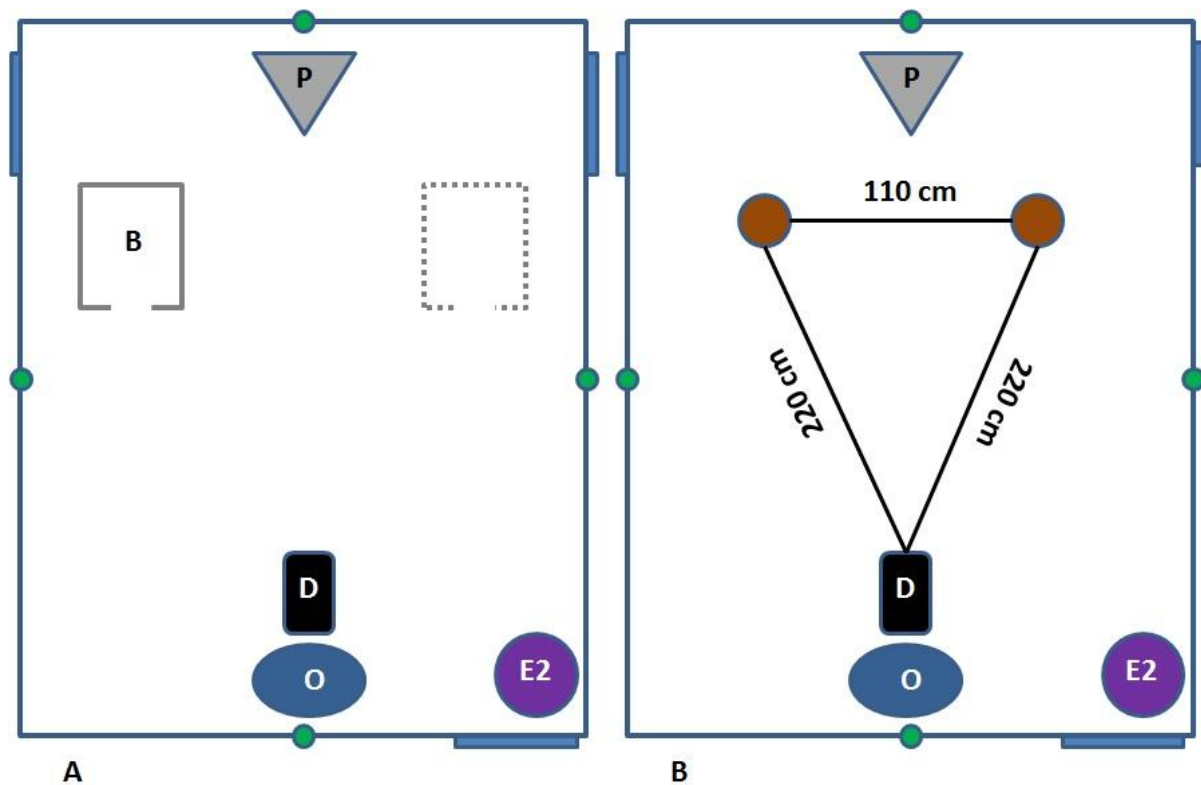


Figure 12. Experimental layout for A: Pre-training and Familiarization phase; B: Test phase. O=place of the owner, D=place of the dog, E2= position of Experimenter 2, B=place of the wire-mesh box, the interrupted line indicate box's position in the other side of the room, P= start point of the partner (UMO or Human), two brown circles indicate the place of the pots during test trials. Green circles indicate the location of the cameras.

Behavioural Variables and Data Analysis

All trials were videotaped and the dogs' behaviour (Table 5) during the familiarization and the test phase was analysed with Solomon Coder 090913 (András Péter <http://solomoncoder.com>).

Name of behaviour element	Definition
Familiarization phase	
Looking at the partner (0/1)	We scored each familiarization trial in the Helper UMO group as 1 if the dog looked at the partner within the 15 s or as 0 if the dog did not look at the partner within the 15 s

Test phase	
Looking at the partner (%)	Looking duration (s) at the partner during the indication (from the emission of the attention getting sound until the partner went/moved back to its/her starting point) divided by the total time of the indication (s) * 100
Choice	We scored each trial as 1 (if the dog approached the baited pot within 10 cm) or 0 (if the dog approached the non-baited pot within 10 cm)

Table 5. The definitions of coded behavioural elements

For statistical analysis we used IBM SPSS Statistics 21.

First we calculated the percent of correct choices from the 16 test trials for each individual. One-sample Wilcoxon signed-rank test were applied to compare dogs' performance in each group compared to chance level (50%). We used Binary GLMM (Generalized Linear Mixed Model) to compare dogs' performance among the groups and the effect of repeated trials. Sixteen test trials were divided into 4 phases in order to examine within task learning in dogs with Binary GLMM (1st phase: 1-4 trials, 2nd phase: 5-8 trials, 3rd phase 9-12 trials, 4th phase 13-16 trials). Every phase included two left and two right trials.

We also used Binary GLMM to analyse the effect of repeated familiarization trials and group (Helper UMO and Helper Human) on *Look at the partner (0/1)* variable. Moreover we compared *Looking at the partner (%)* variable among groups with Independent-samples Kruskal-Wallis Test with Dunn post-hoc tests.

2.3.2. Results

During the test phase dogs' chose the baited (correct) container more often than can be expected by chance in all groups except in the Non-helper UMO group (Wilcoxon signed rank test, Non-helper UMO N=15, T(+)=60, p=0.095; Non-helper Human N=15, T(+)=88.5, p=0.002; Helper UMO N=15, T(+)=120, p=0.001; Helper Human N=15, T(+)=115, p=0.002) (Figure 13).

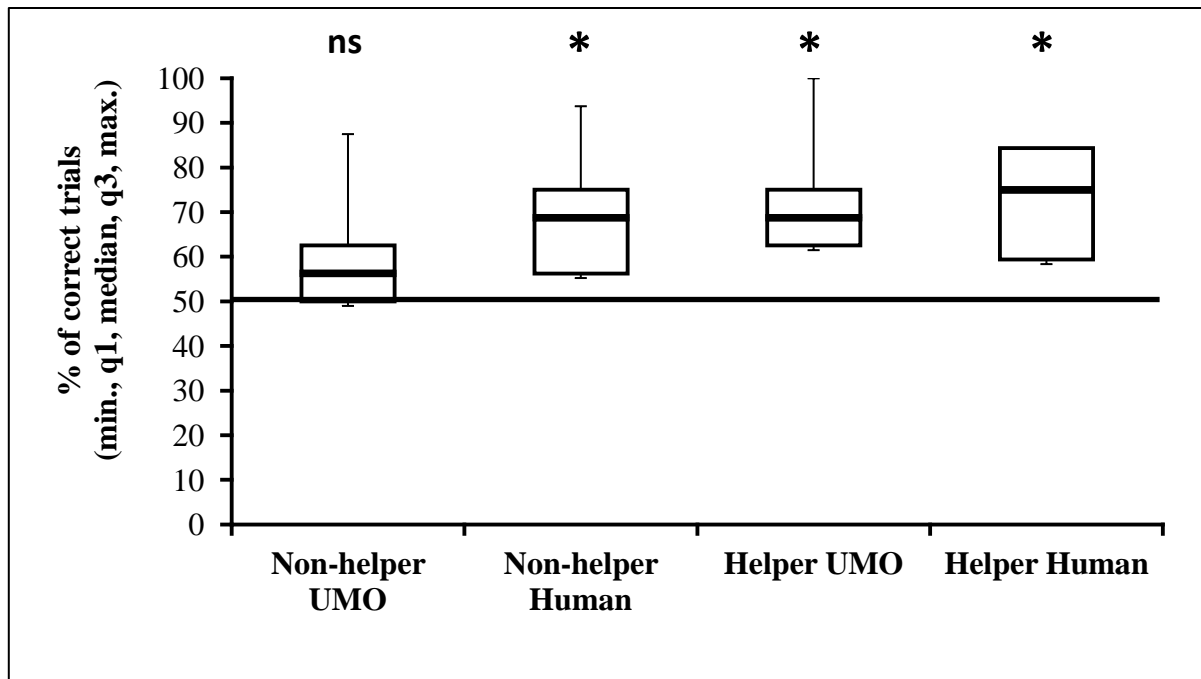


Figure 13. Dogs' performance in the 4 groups relying on partners' directional signal in a two-way choice task. Asterisks indicate significant differences from chance level (50%). ns>0.05, p<0.05; * p<0.01

The Binary GLMM showed that test group ($F_{3,941}=3.66$, $p=0.012$) and repeated test trials ($F_{15,941}=4.60$, $p<0.001$) also had an effect on dogs' performance while pairwise comparisons revealed that dogs in the Helper UMO ($p=0.005$) and Helper Human ($p=0.003$) groups were more successful than dogs in the Non-helper UMO group.

Analysis of trial phases showed that it had an effect on dogs' performance only in the Helper UMO group (Binary GLMM, $F_{3,944}=3.38$, $p=0.018$). Results of the within group analysis revealed that in the Helper UMO group dogs' performance was better in the 2nd phase ($p=0.046$) and 3rd ($p=0.004$) phase compared to the 1st phase, while it decreased during the 4th phase compared to the 3rd phase ($p=0.033$) (Figure 14/a). Results showed a similar decrease in the Helper Human group between the 3rd and 4th phases ($p=0.039$) which might be caused by fatigue or decreased motivation (Figure 14/b). In the Non-helper UMO group dogs' performance did not change during the test (Figure 14/a) while in the Non-helper Human group it increased in the 3rd phase compared to the 1st phase ($p=0.011$) (Figure 14/b). Results of the between group analysis revealed that dogs' performance in the 1st and 4th phase did not differ in the Non-helper UMO and Helper UMO group, however in the 2nd and 3rd phases dogs in the Helper UMO group were more successful than dogs in the Non-helper UMO group (1st phase: $p=0.17$; 2nd phase: $p=0.044$; 3rd phase: $p=0.017$; 4th phase: $p=0.23$).

Dogs in the Helper Human group performed better in the 1st and 2nd phases than dogs in the Non-helper UMO group (1st phase: $p=0.022$; 2nd phase: $p=0.044$).

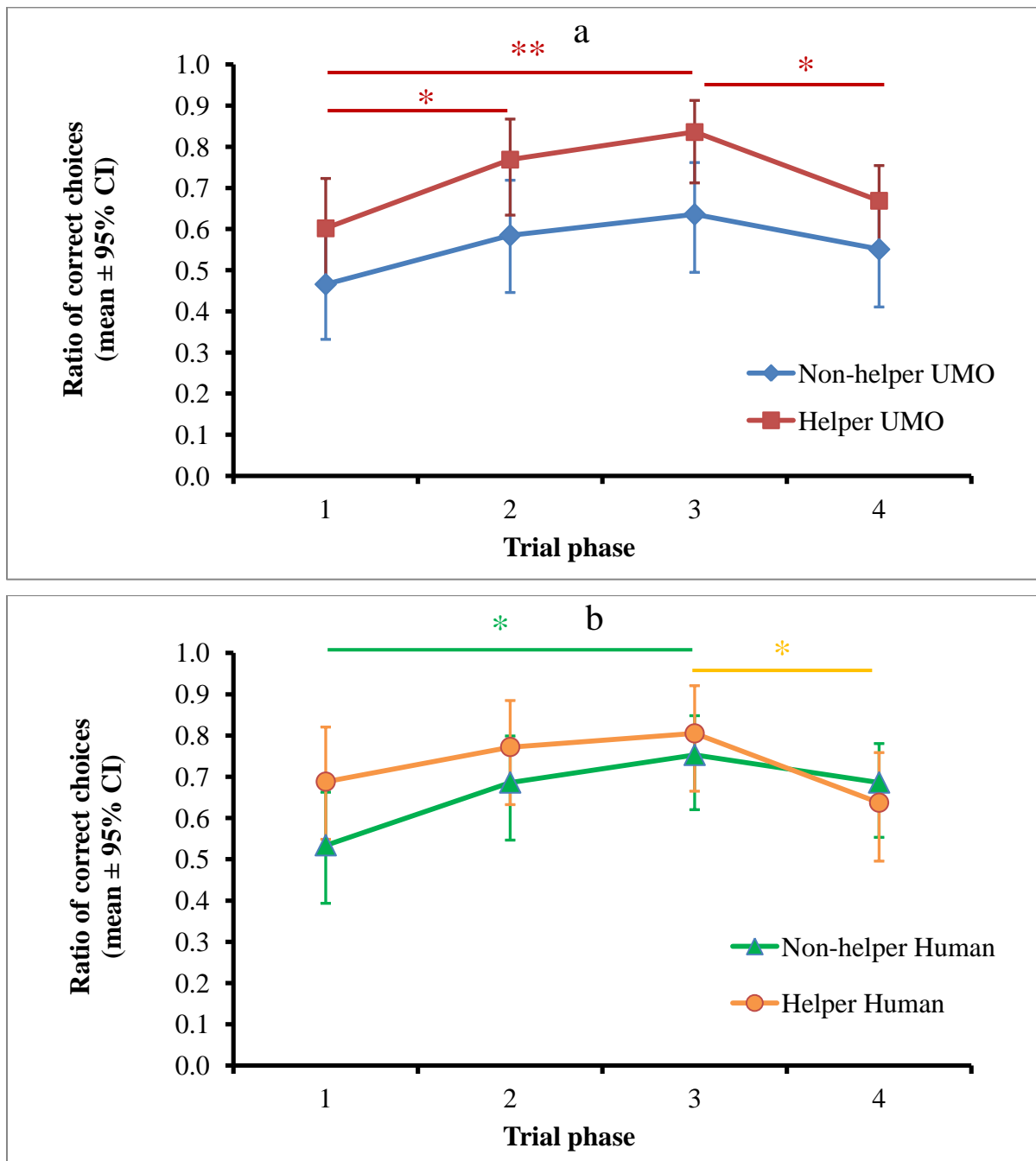


Figure 14a-b. Dogs' performance in each test phase. a: Non-helper UMO and Helper UMO groups; b: Non-helper Human and Helper Human groups. * $p<0.05$, ** $p<0.01$

Repeated familiarization trials in the Helper UMO and Helper Human groups influenced the number of dogs looking at the partner in the problem situation (Binary GLMM, $F_{5,173}=2.95$, $p=0.014$), but not the type of the helper partner (Helper UMO vs. Helper Human, $F_{1,173}=1.155$, $p=0.284$). Pairwise comparisons revealed that every trial (2nd, 3rd, 4th, 5th and

6th) differed from the 1st one (1st vs. 2nd $p=0.001$; 1st vs. 3rd $p<0.001$; 1st vs. 4th $p=0.002$; 1st vs. 5th $p<0.001$; 1st vs. 6th $p=0.001$).

As a next step we analysed Looking duration at the partner (%) in order to exclude the possibility that between-group differences in dogs' performance were due to the different amount of attention paid to the partner's action (approach) during the test trials. We found that group had an effect on how long dogs were looking at the partner (Kruskal-Wallis test, $\chi^2=27.7$, $p<0.001$). Pairwise comparisons showed that dogs were looking equally long to the indicating partner in groups where the type of the partner was similar (Dunn post-hoc test, Non-helper UMO vs. Helper UMO $p=1.00$; Non-helper Human vs. Helper Human $p=1.00$), but in general they looked longer to the Human partner during the indication compared to the UMO partner (Non-helper UMO vs. Non-helper Human $p<0.001$; Non-helper UMO vs. Helper Human $p=0.001$; Helper UMO vs. Non-helper Human $p=0.006$; Helper UMO vs. Helper Human $p=0.037$) (Figure 15).

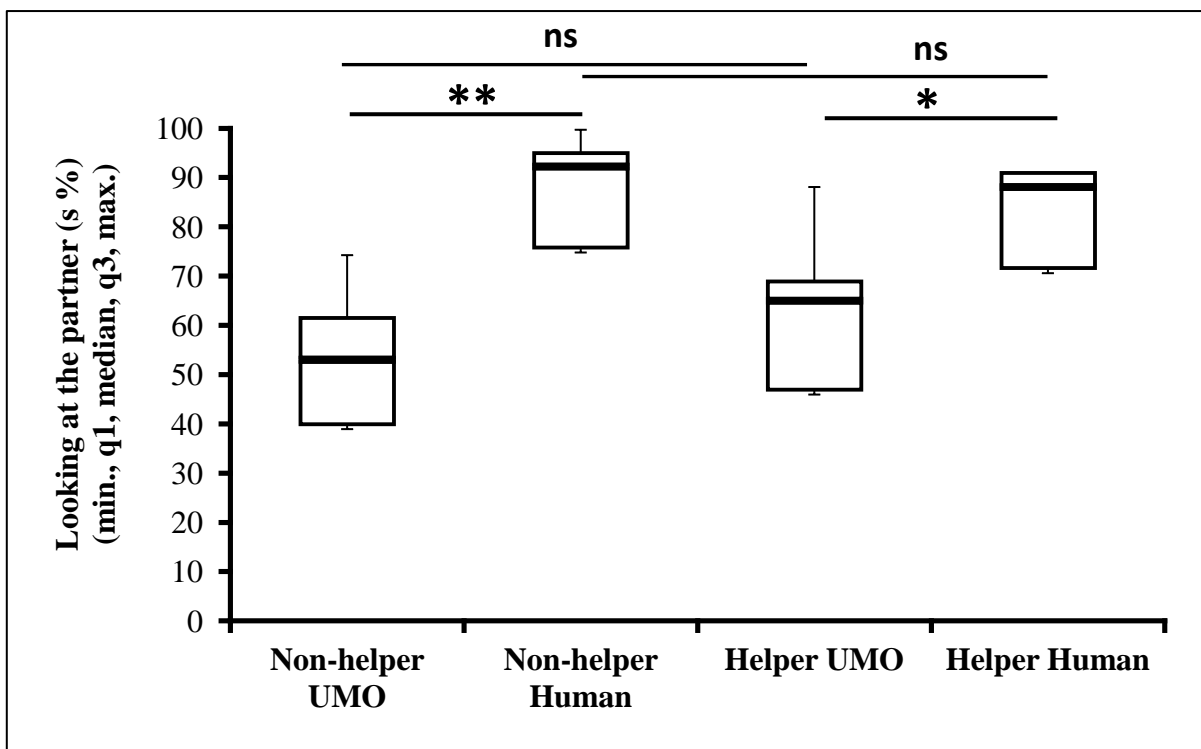


Figure 15. Percentage of time spent looking at the partner during the indication in all four test groups. ns>0.05, * $p<0.05$, ** $p<0.001$

2.3.3. Discussion

In the present study we have shown that dogs are able to use directional movement (approach) of a non-living partner (UMO) as effectively as similar human action to locate the hidden food. Previous social interaction with the UMO seemed to be indispensable for dogs to interpret partners' movement as a significant cue because dogs performed at chance with the non-helper UMO. We also found evidence that previous interaction with the UMO also enhances learning about the communicative aspects of the action. At the same time dogs utilized human indication efficiently from the beginning and irrespectively of prior experience in the familiarisation phase.

Dogs in the present study had no previous experiences with the 'signalling' UMO. They perceived its skills only in the familiarisation phase (Context 1) in which dogs in the critical group received help from the UMO to get the unreachable reward. We assume that based on this short social interaction dogs had formed some expectations about the behaviour of the UMO which facilitated the recognition of the directional action in the novel situation (Context 2).

Analysis of dogs' performance revealed further interesting results. In the Helper Human group dogs' performance was high from the beginning while dogs in the Non-helper Human group started at chance performance and improved over repeated trials. No evidence of learning was found during repeated trials with the Non-helper UMO, in contrast, a rapid learning occurred in the Helper UMO group. The lesser need for learning about a novel action of the social UMO also suggests that dogs are able to generalise from their previous social interactions.

This may suggest that dogs recognise that the partner is attempting to communicate with them via some signal (Tomasello et al 1997). The Helper UMO was probably associated with some agency cues in dogs over previous interactions, thus these dogs tended to relate to the UMO socially in the novel testing context. This interpretation is also in agreement with findings that dogs failed to use a static physical marker by itself as a simple spatial index but consider it as a communicatively significant sign if any human behaviour towards the target location involved (Agnetta et al 2000, Riedel et al 2006). Apparently, dogs consider the Non-helper UMO's action merely as a physical marker, and in the absence of specific experience they could not learn the associative link between its movements and the place of food during 16 trials.

We assume that the observed flexibility of our family dogs' social behaviour is due to the fact that they have shared environment with heterospecific agents (i.e. with their owners and other humans) thus they are probably able to generalise their wide range of social experience with humans to another type of agent as well. These results support the findings that dogs are able to attend to some social aspect of an UMO's behaviour which resembles neither conspecific neither human (see Experiment 1). The relative little experience with the UMO suggests that it is unlikely that the present results can be explained solely on the basis of ontogenetic ritualisation. Our results indicate that genetic predisposition is also involved which facilitates the competent reaction to actions performed by UMOs if they show behaviour signs characteristic to a social partner (Miklósi and Topál 2013).

2.4. Experiment 4: Dogs are willing to follow the preference of their inanimate partner in a food choice task

In order to examine an UMO's 'social influence' on dogs' behaviour, we have decided to focus on whether dogs can be influenced by an inanimate partner in a food-choice task.

In series of experiments researchers investigated dogs' choice between small (1 piece) and big amount (6 or 8 pieces) of food with or without human influence (Prato-Previde et al 2008, Marshall-Pescini et al 2011a, 2012). In these studies dogs first were presented with repeated trials in which the two different amounts of food had been offered to them, then dogs were allowed to choose freely between the two food quantities. Results showed that 70-80% of the subjects preferred the larger food quantity in the absence of any influence from the experimenter or the owner. However when an unfamiliar experimenter (Marshall-Pescini et al 2011a) or the owner (Prato-Previde et al 2008, Marshall-Pescini et al 2011a) showed preference toward the small food quantity (i.e. approached the plate containing the smaller food quantity, picked up the piece of food and with an enthusiastic tone of voice, said: "Oh wow, this is delicious, lovely, so good!") before the dogs' choice, the dogs choose randomly between the two food quantities. Marshall-Pescini and her colleagues (2012) investigated the influence of different human social cues on dogs' choice behaviour in the same task. They found that the most efficient cues were the hand-food contact presented with a 'hand-to mouth action' (when the experimenter picked up the food bringing it level to the mouth), the same action combined with voice ("Oh wow, this is delicious, lovely, so good!") and gaze alternations between the dog and the food. Authors suggested stimulus enhancement as an underlying mechanism for this social influence and suggested that dogs might considered picking up the food as a communicative cue directed to them.

In the present experiment we used a modified version of the latter experiment (Marshall-Pescini et al 2012) in order to investigate the effect of a human or an UMO partner's action on dogs' choice behaviour. One major difference between the methods was how the two food quantities were presented to the dogs. In the aforementioned previous studies plates with food were placed by the experimenter on the ground, which is a problematic point of the procedure because several experiments demonstrated the effect of the human experimenter on dogs' behaviour in various tasks (e.g. Erdőhegyi et al 2007, Riedel et al 2006). In order to remove the effect of human influence from the procedure, plates in our experiment were moved remotely (by two plastic strips) from a separated part of the lab.

We hypothesised that dogs' willingness to choose the food quantity 'preferred' by the UMO can be enhanced by previous social interaction with this unfamiliar partner.

2.4.1. Materials and Methods

Subjects

Eighty-two adult pet dogs were recruited from the Family Dog Database of the Department of Ethology, Eötvös Loránd University. We excluded 12 dogs because they showed strong side bias (they approached the same plate in every trial: 3 dogs in the *Human partner* group; 5 dogs in the *Non-helper UMO* group; 4 dogs in the *Helper UMO* group) and 7 dogs because of methodological problems (e.g. the places of the two food quantity were not counterbalanced: 4 dogs in the *Non-helper UMO* group; 3 dogs in the *Helper UMO* group). We excluded one additional dog because the owner influenced the dog's choice (i.e. she pushed him toward one of the two potential hiding places). The remaining 62 dogs were divided in three groups: *Human partner* (N=17; 7 males, 10 females; mean age \pm SD 4.11 \pm 2.32), *Non-helper UMO* (N=22; 9 males, 13 females; mean age \pm SD 3.43 \pm 2.42) and *Helper UMO* (N=23; 13 males, 10 females; mean age \pm SD 4.7 \pm 3.3). For details see Appendix Table 11. Dogs' age did not differ between the groups (one-way ANOVA, $F_{2,59}=1.29$, $p=0.28$). We only tested dogs who could be motivated by food.

Apparatus

The dogs were tested at the Department of Ethology, Eötvös Loránd University in a 3 m x 5 m test room. Each trial was recorded by three cameras (Figure 17).

We set up an occluder (2 m x 3 m) at the end of the room. The two white plates (25 cm x 40 cm) were moved by Experimenter 1 (E1) from behind the occluder by the means of plastic strips (i.e. non-social placement). Sausage was used as small (one piece) and large (six pieces) quantity of food reward.

In the *Helper UMO* group we used a metal wire mesh box (61 cm x 46 cm x 54 cm) with a magnet fixed in it and a plastic plate (10 cm x 10 cm) with two metal sheets on its sides. The role of the box was that the dog could only get the food with the help of the partner.

Test partners

In the *Human partner* group the partner was played by a female human.

In the *Non-helper* and *Helper UMO* groups we used a remote control (RC) car (#7304 Traxxas 1/16 Ford Mustang Boss 302; 37 cm x 18,5 cm x 12 cm) as a partner with a magnet on its front (Figure 16). High pitched beeping sound (3200 Hz) emitted by a speaker built into the UMO was used as attention grabber (same sound as in Experiment 4). The UMO was controlled by Experimenter 2 (E2).



Figure 16. The UMO used in Experiment 4

Procedure

Phase 1

1. E1 went behind the occluder with the two plates and waited there motionless. Then the owner and the dog entered and the dog was allowed to explore the room for 60 seconds.
 2. The owner sat on the chair, called the dog back and then held the dog in front of him/her (Figure 17/a). Meanwhile E1 put one piece of food on one of the plates and six pieces of food on the other plate and pushed them to their predetermined location by the means of plastic strips.
 3. After the dog oriented its head towards the plates E2 asked the owner to release the dog who could choose between the plates. E1 pulled back the not chosen plate before the dog could reach it. Then the owner called the dog back.
- Steps 2-3 were repeated (altogether six trials). The position of the plates containing large and small food quantities was counterbalanced (RLLRRL or LRLLLR). After the last trial the owner and the dog left the room.

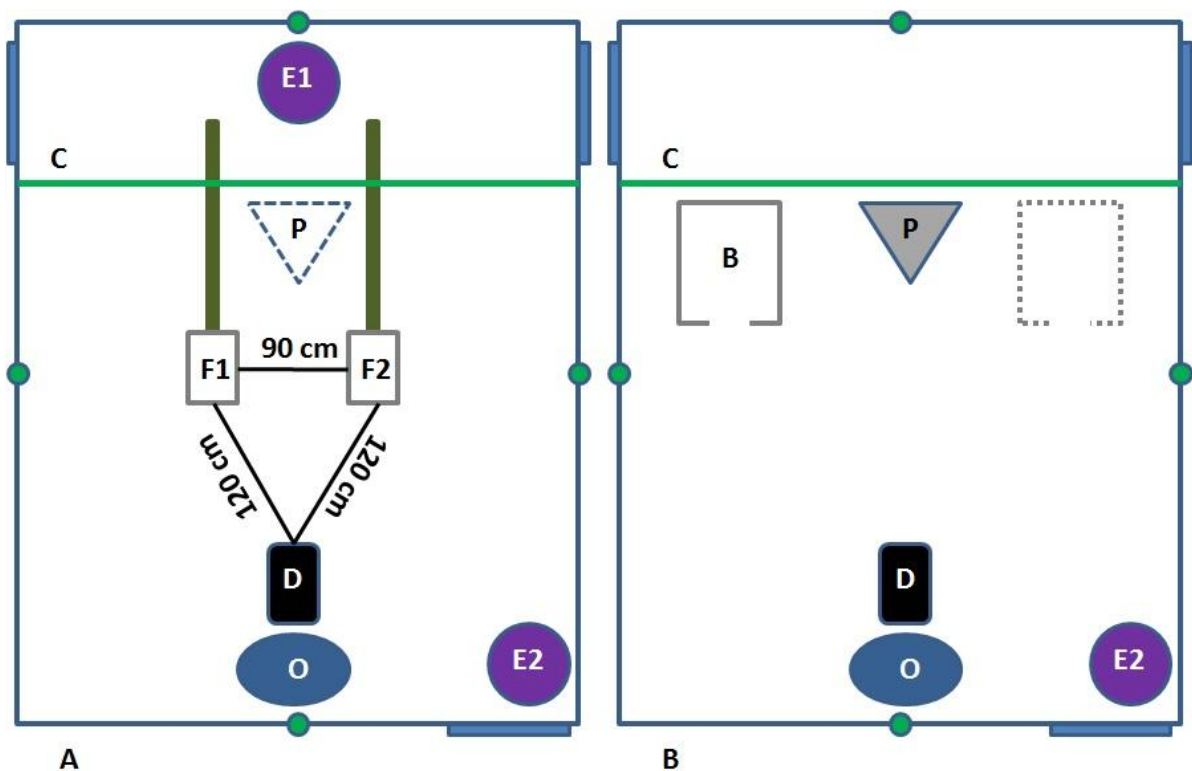


Figure 17. Experimental layout (not to scale) for Phase 1 and 3 (A) and Phase 2 (B). O=place of the owner, D=place of the dog, E1= position of Experimenter 1, E2= position of Experimenter 2, C= position of the occluder, P= start point of the partner (UMO or Human) in Phase 2 and 3, F1 and F2= place of the plates, B=place of the wire-mesh box, the interrupted line indicate box's position in the other side of the room. Green circles indicate the location of the cameras.

Phase 2

Human partner group: The owner and the dog entered the room. The dog could move freely in the room for 2 min, while E2 was talking with the owner and made contact with the dog, i.e. the partner behaved naturally.

Non-helper UMO group: Before the owner and the dog came back, E2 placed the UMO to the starting point (see Figure 17/b). Then the owner and the dog entered, the owner sat on the chair and held the dog in front of him/her. E2 stood in the corner of the lab. The UMO started to move around the room for 2 minutes and then stopped at the starting point. During the first round the UMO stopped in front of the dog for a few seconds, thus the dog could smell it.

Helper UMO group: Before the owner and the dog came back, E1 placed the box on one side of the room and E2 placed the UMO on the other side of the room (Figure 17/b). After the owner and the dog entered the owner sat on the chair and held the dog in front of him/her while E2 stood in the corner. E1 attracted the dog's attention („Hi (Dog's name), look!”) with

a piece of food in her hand, put it in the plastic plate and attached the plate to the magnet inside the box. Then she left the room and the owner released the dog who could move freely in the room and try to get the food for 15 s. After the time elapsed the UMO called the dog's attention with the beeping sound and went into the box. The UMO beeped again at the moment when it touched the plate. Then the UMO brought out the plate, approached the dog and then the dog could eat the food. E1 came in, relocated the box on the other side of the room, at the same time the UMO went to the former place of the box (i.e. the place of the box and the starting point of the UMO was switched in every trial). The above described procedure was repeated (a total of six times). From the 2nd trial onward the UMO started to move immediately at the moment when the dog looked at it (during the exploration time), and brought out the plate from the box. In these trials the UMO beeped only at the moment when it touched the plate inside the box.

After the last trial the owner and the dog left the room again.

Phase 3

In this phase the partner indicated the food quantity chosen by the dog less than 3 times out of six in Phase 1 (i.e. the non-preferred quantity of food). If the dog chose equally between the food quantities in Phase 1, the partner indicated the small quantity.

Human partner group: The owner and the dog entered the room and the owner sat on the chair and held the dog in front of him/her. The human partner (E2) stood at the starting point (see Figure 17/a). E1 put one piece of food on one of the plates and six pieces of food on the other plate and pushed the plates toward the predetermined locations by the means of plastic strips. E2 went to the plate containing the 'non-preferred' quantity of food, crouched down, lifted up one piece of food to the level of her mouth and said „*Hmmm!*” in a high pitched voice. Then she put the food back and stood at the starting point facing toward the occluder. The owner released the dog who could choose between the plates. E1 pulled the non-chosen plate back before the dog could reach it. When the dog ate the chosen food quantity the owner called the dog back and the partner turned towards the dog again. During this phase the human partner (E2) did not make eye contact with the dog.

Non-helper and Helper UMO group: Before the owner and the dog came back, E2 placed the UMO at the starting point (see Figure 17/a). After the owner and the dog entered the owner sat on the chair and held the dog front of him/her. E2 stood in the corner on the right side of the dog. E1 put one piece of food on one of the plates and six pieces of food on the other plate

and pushed the plates toward the predetermined locations by the means of plastic strips. The UMO approached the plate containing the ‘non-preferred’ quantity of food, stopped behind the plate, attracted the dog’s attention by emitting a beep and then moved back to the starting point. The owner released the dog who could choose between the plates. E1 pulled back the non-chosen plate before the dog could reach it. When the dog ate the chosen food quantity the owner called the dog back.

We repeated the above described procedures a total of six times. The sides of the small and large food quantities were counterbalanced between the sides (RLLRRL or LRLLLR).

Behavioural Variables and Data Analysis

All phases were videotaped and the dogs’ behaviour (Table 6) was analysed later with Solomon Coder 100314 (András Péter <http://solomoncoder.com>).

Name of behaviour element	Definition
Phase 1	
Choice (0/1)	Dog’s choice was scored as 1 if it selected the plate indicated by the partner in Phase 3 (i.e. touched or only approached the plate within 10 cm-s with its nose). Score 0 was given if the dog selected the non-indicated plate.
Phase 2	
Looking at the partner (0/1)	Familiarization trial was scored as 1 if the dog looked at the partner (UMO or human) within 15 s or as 0 if the dog did not look at the partner (UMO or human) within 15 s.
Phase 3	
Looking at the partner (%)	Looking duration at the partner (s) during the trial (from the appearance of the plates until the owner released the dog) divided by the total time of the trial (s) * 100

Choice	<p>A trial was scored as 1 if the dog's first choice was the plate indicated by the partner (i.e. touched or at least approached the plate within 10 cm-s with its nose).</p> <p>Score 0 was given if the dog selected first the non-indicated plate.</p>
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Table 6. The definitions of coded behavioural elements

For statistical analysis we used IBM SPSS Statistics 21.

First we calculated the percentage of dogs' food quantity choice (small vs. big) during Phase 1 and 3, then we compared them to chance level (50%) with one-sample Wilcoxon signed-rank test. Based on Prato-Previde et al (2008) only dogs who preferred the larger food quantity during Phase 1, were included in the further analysis. We used Binary GLMM in order to examine the effect of the test phase (Phase 1 vs. Phase 3), group, interaction between group and test phase and repeated test trials on dogs' choice. Looking at the partner (%) variable was compared between groups with Kruskal-Wallis test and Dunn post-hoc tests for pairwise comparisons.

2.4.2. Results

Analysis of dogs' behaviour showed that during Phase 1 dogs' choice differed from chance level in all 3 groups (one-sample Wilcoxon signed-rank test, *Human partner* N=17, T(-)=3.542, p<0.001, *Helper UMO* N=23, T(-)=3.626, p<0.001, *Non-helper UMO* N=22, T(-)=3.571, p<0.001). However in Phase 3 dogs in the *Human partner* group changed their preference toward the indicated food quantity (N=17, T(+)=2.656, p=0.008) while in the *Helper UMO* group they were at chance level (N=23, T(+)=0.97, p=0.923). Dogs in the *Non-helper UMO* group did not change their behaviour due to the indication in Phase 3, they continued to prefer the same food quantity as in Phase 1 (N=22, T(-)=2.351, p=0.019) (Figure 18).

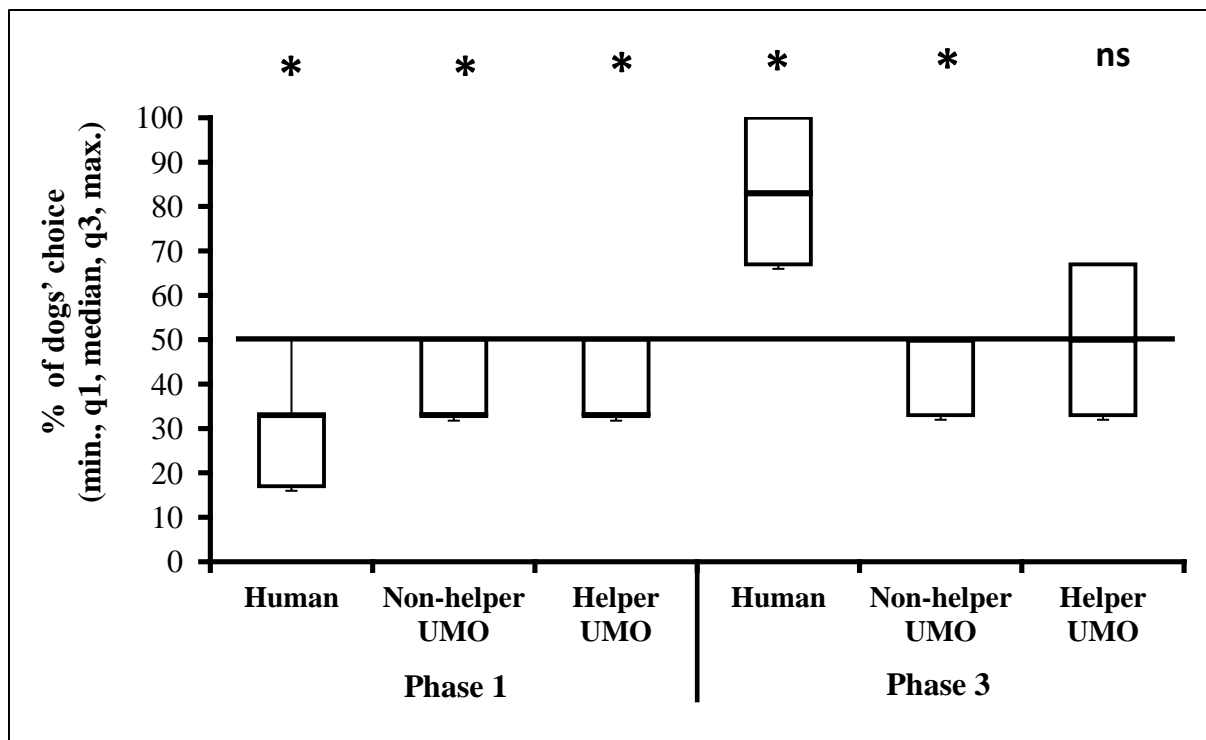


Figure 18. Percentage of dogs' choice in Phase 1 and 3 compared to chance level (50%). ns>0.05, * p<0.05

As a next step we calculated the percentage of dogs showing small/big/no food quantity preferences in each group separately. This grouping based on their choice in Phase 1 (Table 7).

Preference for	Small (S) quantity (choosing S 4-6 times)	Large (L) quantity (choosing L 4-6 times)	No preference (choosing S and L 3-3 times)
Human group (N=17)	24% (N=4)	65% (N=11)	12% (N=2)
Non-helper UMO group (N=22)	23% (N=5)	50% (N=11)	27% (N=6)
Helper UMO group (N=23)	17% (N=4)	48% (N=11)	35% (N=8)
Total N=62	21% (N=13)	52% (N=32)	27% (N=17)

Table 7. Percentage of subjects based on their preference in Phase 1.

In the following analysis we included only those 33 dogs who showed explicit preference for the big amount of food in Phase 1.

Binary GLMM showed that group ($F_{2,378}=4.559$, $p=0.011$), test phase ($F_{1,378}=21.28$, $p<0.001$) and group x test phase interaction ($F_{2,378}=3.226$, $p=0.041$) had a significant effect on dogs' 'Choice' behaviour. Pairwise comparisons revealed that this variable differed only between the *Human partner* and *Non-helper UMO* groups ($p=0.002$) (*Human partner* vs. *Helper UMO* $p=0.06$, *Helper UMO* vs. *Non-helper UMO* $p=0.218$). Phase 1 and 3 differed in the *Human partner* ($p<0.001$) and *Helper UMO* groups ($p=0.029$), while in the *Non-helper UMO* group we found no significant difference between phases ($p=0.23$). However dogs performance in Phase 1 did not differ between groups (*Human partner* vs. *Non-helper UMO* $p=0.637$, *Human partner* vs. *Helper UMO* $p=0.999$, *Helper UMO* vs. *Non-helper UMO* $p=0.636$), while Phase 3 varied between the *Human partner* and *Non-helper UMO* group ($p<0.001$), *Human partner* and *Helper UMO* group ($p=0.004$) (Figure 19).

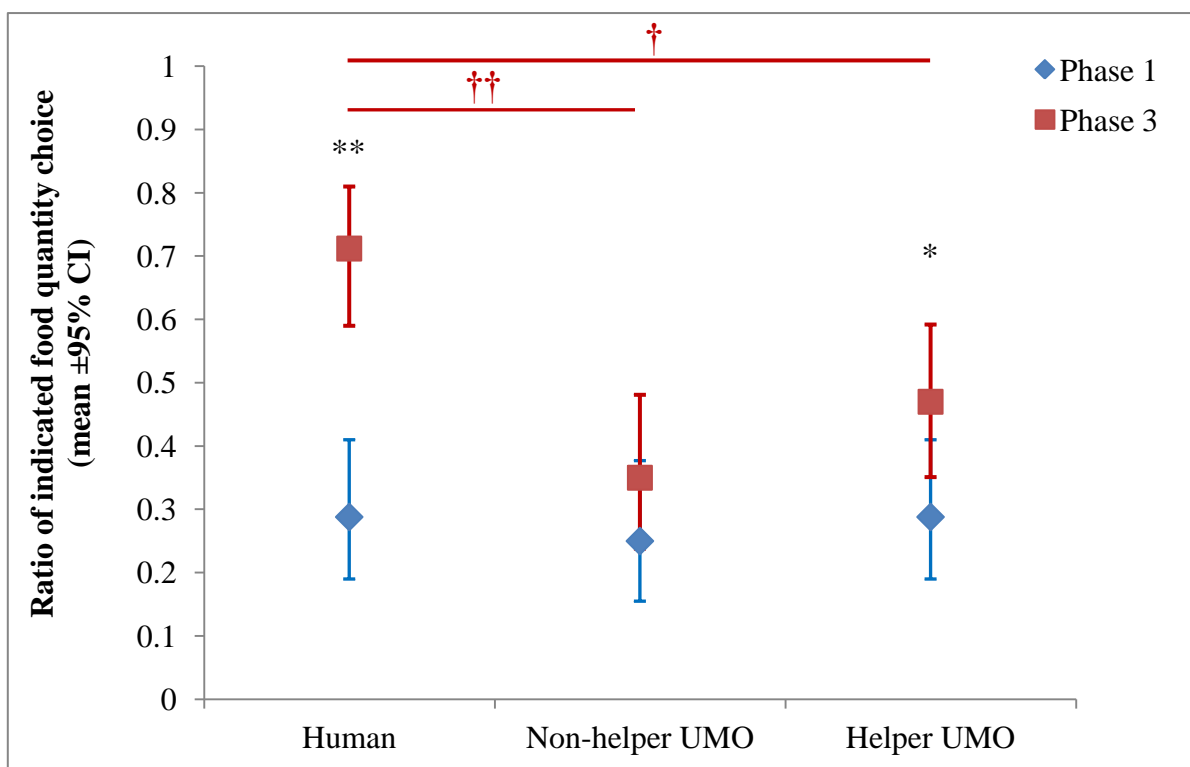


Figure 19. Analysis of dogs' choice in Phase 1 and 3. * indicates difference between phases within group, † indicates difference between groups. * $p<0.05$, ** $p<0.001$, † $p<0.01$, †† $p<0.001$

During Phase 2 dogs looked longer at the partner through repeated trials in the *Helper UMO* group ($F_{5,84}=67.13$, $p<0.001$), actually all trials differed from the first trial (1. vs. 2.: $p<0.001$; 1. vs. 3.: $p<0.001$; 1. vs. 4.: $p<0.001$; 1. vs. 5.: $p<0.001$; 1. vs. 6.: $p<0.001$).

In Phase 3 Looking at the partner behaviour was affected by group ($\chi^2=9.59$, $p=0.008$). Dogs in the *Human partner* group looked longer at their partner than dogs in the *Non-helper UMO* ($p=0.025$) and *Helper UMO* group ($p=0.016$), while there was no difference in this variable between the two UMO groups ($p=1.00$).

2.4.3. Discussion

The aim of the present experiment was to investigate whether dogs' choice behaviour between small and large amount of food can be influenced by different partners (human or UMO) and previous interactions with the non-living partner (UMO).

Earlier it has been reported that 70-80% of the dogs choose the larger food quantity in similar situation (Prato-Previde et al 2008, Marshall-Pescini et al 2011a, 2012). However our results showed that only 52% of the subjects preferred the larger quantity (in Phase 1), while 21% preferred the smaller amount and 27% showed no explicit preference. We assume that dogs' reduced preference for the larger quantity in our study (as compared to earlier reports) was due to the changes in the procedure (i.e. plates containing food were presented in a non-social manner for details see Materials and Methods). Our results support the notion that the human presence and touch had an impact on dogs' behaviour in previous experiments (e.g. Prato-Previde et al 2008, Marshall-Pescini et al 2012).

In accordance with Prato-Previde et al (2008) and Marshall-Pescini et al (2012) we found that the human partners' preference has the potential to change dogs' choice behaviour. In contrast, dogs in the Non-helper UMO group did not change their preference after observing the UMO approaching the 'non-preferred' food location. At the same time after having witnessed that the Helper UMO favoured the small quantity dogs chose the large quantity of food significantly less than in the free choice situation (see Figure 19). This result is in line with our former findings that previous social interaction with the UMO has an effect on dogs' behaviour (see Experiment 1 and 3). Using the terminology of previous studies (e.g. Prato-Previde et al 2008, Marshall-Pescini et al 2011a, 2012) we can conclude that after a short social interaction an UMO can 'change dogs' preference' in a food choice task.

It has been shown that dogs have the tendency to follow human signals (e.g. pointing, gaze following, for a review see Miklósi et al 2004) especially in socio-communicative context (e.g. Téglás et al 2012). This behaviour occurs also when these signals are contradictory (e.g. Szetei et al 2003, Bräuer et al 2006). For example Szetei and co-workers (2003) demonstrated that dogs tend to choose the food location pointed at by a human even if the human indicated

the empty location, however direct visual information about the location of food reduced the effect of the human's indication. Partner's signal in the studies mentioned above usually named as 'incorrect' or 'misleading', while the behaviour of the dogs following this indication interpreted as 'counterproductive'. At the same time we can assume that in everyday life human directional gestures are reliable sources of information about the environment for dogs, thus it seems adaptive to follow them, even if they in contrast with direct perceptual information (like small vs. big food quantity). Several experiments showed that individual food preference can be affected and changed by social learning in different species and highlighted the adaptive value of this flexibly behaviour (e.g. rabbits -Bilkó et al 1994, rats - Galef 1995, Galef & Whiskin 2001). Thus, we propose that dogs' willingness to follow their partners' preference in a food choice task might have adaptive value and can be interpreted as an effective and flexible behaviour.

2.5. *Experiment 5³: Dogs are able to generalise directional acoustic signals to different contexts and tasks*

Results of Experiment 1-4 investigated the key elements of dog-robot social interaction and provide important insights for SWARMIX project aimed to build up a system in which flying robots, rescue dogs and human handlers are cooperating with each other efficiently to solve search and rescue tasks. The so-called *mixed swarms* require high level of autonomy of each participant and fluent information flow between all system components. The most challenging tasks are (1) that dogs must work efficiently in the absence of the handler and (2) be able to follow commands and use given information by the flying robot in order to complete the task. These two requirements led us to design an experiment where we focused on dogs' spatial navigation and signal generalisation ability.

Several studies have shown that dogs are able to use both egocentric and allocentric navigation spontaneously to solve different spatial tasks (e.g. Head et al 1995, Milgram et al 1999, Chan et al 2001) and that their spatial encoding process is flexible and can be adjusted to the particularities of the situation. For example, Fiset et al (2006) examined the geometric components used by domestic dogs in an object permanence task and reported that dogs preferred a linear egocentric frame of reference when they were searching for the location of a disappearing object regardless of the distance between their own spatial coordinates and those of the hiding position. Thus, dogs' performance in finding the hidden object did not differ when the object was moved from 100 cm to 142 cm from the starting point, that is, they did not simultaneously use the vector components of direction and of distance to locate the target object. At the same time, dogs seem to have difficulty using allocentric cues to locate a hidden object in some situations (e.g. detour task, see Fiset & Malenfant, 2013), but they may be able to use allocentric spatial information when the linear egocentric information is not available. Fiset et al (2006) also found that the angular deviation between adjacent hiding locations and the position of the dog had an effect on dogs' performance: the subjects performed more correctly if the angular deviation between the two hiding places was 15° rather than only 5°. Dogs tried to minimise angular deviation from the target in a detour task in which the shortest route to reach the desired goal was unavailable but the target was visible.

³ Based on: **Gergely, A., Topál, J., Dóka, A., & Miklósi, Á.** 2014. Dogs are able to generalise directional acoustic signals to different contexts and tasks. *Applied Animal Behaviour Science*, 156, 54–61.

Thus, they preferred the less divergent path over the shortest route. However, if the target was invisible they chose the shortest route regardless of the angular deviation (Chapuis 1983).

In a landmark discrimination task Milgram et al (2002) trained dogs to choose the food-container closest to a small landmark (yellow wooden peg) in a two way choice task. Next, dogs were exposed to a similar task with a novel landmark (pink heart-shaped object), and finally, this novel landmark was moved to novel positions. Dogs' performance remained stable throughout these novel conditions. The authors concluded that dogs generalised both to the shape and relative position of the landmark, thus they were using a general concept of the landmark to solve this two-way choice task.

Dogs are also able to learn go/no-go tasks based on differences in stimulus quality and go-left/go-right tasks based on differences in stimulus location, whereas the opposite stimulus-action pairings are more difficult to learn (Lawicka 1964, Dobrzecka et al 1966, Dobrzecka & Konorski 1967, Konorski 1967, Dobrzecka & Konorski 1968, Lawicka 1969). The authors suggested that the quality of a stimulus best serves as a cue for the quality of a response, whereas the location of a stimulus facilitates the orientation of the action (Quality-Location Hypothesis). Although several researchers assumed that this hypothesis is fundamental to understanding possible constraints of learning (e.g. Miller & Bower 1982), others argued that the quality-location distinction effect in these studies stems from the experimental design and is highly affected by the inclusion or exclusion of naturalistic features (e.g. Harrison 1984, Neill & Harrison 1987). The finding that herding dogs can be directed by voice commands (or whistles) of different tone and pitch of the human shepherd during cooperative herding (McConnell & Baylis 1985) also casts some doubt on the Quality-Location Hypothesis.

The main goal of the present study, therefore, was to find out whether dogs trained to perform oriented movement (go left/ right) in response to different acoustic signals are able to generalise this experience to novel contexts. In this latter phase of the training we also investigated whether or not salient objects placed in the target area improve dogs' learning efficiency in the go left/ right task. We assumed that dogs trained to approach a conspicuous target (small object on the ground) upon hearing the signal would show a better performance than those who had to approach a specific spatial location (left/right corner) in the room. The less specific nature of the latter task (i.e. the absence of a specific target object which could be approached) predicts a slower learning rate (c.f. Fiset et al 2006). In the second part of the study, dogs were exposed to novel situations where they had to rely on the same acoustic signals to solve a series of new spatial tests. We applied several novel targets in these test situations at different distances and angular deviations in relation to the dogs' starting

position. We measured the dogs' performance which was calculated on the basis of the number of correct choices after receiving the sound signal. We assume that dogs' performance would not drop in the novel context independent of their distance to the target, partly because they are able to generalise learnt behaviour to novel contexts (e.g. Lindsay 2000, Braem & Mills 2010).

2.5.1. Materials and methods

Subjects

Sixteen adult pet dogs (mean age \pm SD: 5.5 \pm 2.5 years) were recruited for this study. The participants were 5 male and 11 female dogs from different breeds (for details see Appendix Table 12). All dogs were previously clicker trained by the owner (by the means of the shaping procedure) and trained for fetching and going ahead. Regarding the training of the 'going ahead' command, dogs were trained for two different tasks as a part of the obedience training: (1) based on the combination of owners' verbal and hand signals, owners used clicker-training to positively reinforce moving away from the owner in a straight line (0% deviation) in a given direction without a visible target, (2) dogs were also trained with clicker to go ahead and lie down next to special visible targets (yellow cones) based on the direction of the owners' hand signal. Dogs and their owners were recruited through the website of Department of Ethology (<http://kutyaelologia.elte.hu/>).

Equipment and Signals

The Click & Treat (C&T) Collar was developed by Tamás Ferenczy (see Figure 20). It consists of two parts: the collar and the remote control unit. The collar is a cylindrical collar-mounted device in which the double-barrelled treat storage, the dispenser, the control electronics, the loudspeaker, the radio modules, and the batteries are located. The storage can be baited with 16 pieces of dry dog food (Kennel Kost premium dog food), by placing 8-8 pieces into each barrel. Four different signals can be emitted directly from the collar by pressing different buttons on the remote control: (1) click sound (0.3 s long; 1700 Hz); (2) click sound + food; (3) high pitched (HP) sound (0.3 s long, 2150 Hz 'beeping' repeated 3 times, 0.1 s pauses in between trials); (4) low pitched (LP) sound (0.3 s long, 1150 Hz 'beeping' repeated three times 0.1 s pauses in between trials). The radio connection has a working radius of maximally 400 m.



Figure 20. The Click&Treat collar and the controller

Procedure

Familiarization, Basic training, Advanced training, and warm-up session before testing took place in a 4.5 m x 3.5 m test room at the Department of Ethology, Eötvös Loránd University Budapest. Testing was carried out on a plain green area on the University Campus.

Familiarization

The aim of the familiarization was to introduce the C&T Collar to the dogs, and to train them to go to one of the potential targets in the room. After arriving at the department with their owner, the dog took part in the following procedure (Steps 1 to 6):

1. The experimenter filled up the collar with dry food then gave it to the owner. The owner held the collar in his/her hand, called the dog, then pushed the ‘click + food’ button on the controller. The dog was allowed to eat the reward (one piece of dry dog food) which dropped from the collar to the floor. We repeated this procedure 10 times. Then, the experimenter asked the owner to push the ‘click’ button but no food was given. If the dog looked down to the floor after the click sound, we moved to the next step. If the dog did not look down, then the dog was given another set of 10 trials of ‘click + food’ until the dog looked down after the click sound in the absence of food rewards.

2. The owner gave verbal commands (for example Sit!, Down!, Lay! etc.) to the dog. All commands referred to actions known by the dog prior to this study. If the dog acted in line with the command, then she pushed the ‘click + food’ button and the dog received a piece of reward. Each dog participated in 14 trials.
3. The owner put the collar on the dog and Step 2 was repeated 14 times.
4. The owner and the dog sat down. The experimenter brought a small black cardboard rectangle (18x24 cm) to the room and put it on the floor. She placed it in front of the dog at a distance of 1.5 m. She called the dog and acted as if she placed one piece of food under the rectangle and then stepped back. The owner encouraged the dog to approach the rectangle verbally (Let’s go!). If the dog approached the rectangle within 10 cm, the experimenter pushed the ‘click + food’ button and the dog was allowed to eat the treat. We repeated this two times.
5. We repeated Step 4, except that the rectangle was now at a distance of 3 m from the dog.
6. The experimenter brought a second rectangle (which was identical to the first one) to the room. She placed the rectangles into the two corners of the room 3 m from the dog. She stepped next to one of the rectangles and repeated the previous training four times (in LRLR or RLRL order; L=left, R=right).

Training phase

Basic training

The aim of this phase was to develop associations between sounds and spatially oriented motor responses (going left or right). This phase consisted of series of training trials.

Two target objects (cardboard rectangles) were placed at two corners of the lab. The owner and the dog (with the mounted collar) were sitting in front of the rectangles (see Figure 21). Upon hearing one of the two sounds (HP or LP) emitted from the collar, the owner encouraged the dog to approach one of the rectangles (using only neutral verbal utterances like “Let’s go!”). Owners did not display any gestures e.g. pointing. If the dog approached the object located in the designated corner (i.e. which matched with the emitted sound) in 10 seconds within 20 cm (‘approaching zone’), the dog received the reward from the collar.

In the first series, we played one sound 10 times (left or right) and then the other sound also 10 times. This was followed by a second series in which sound signals were alternated in LRLRRLRLRL (trials 1-10) and RLRLRLRLRL (trials 11-20) order.

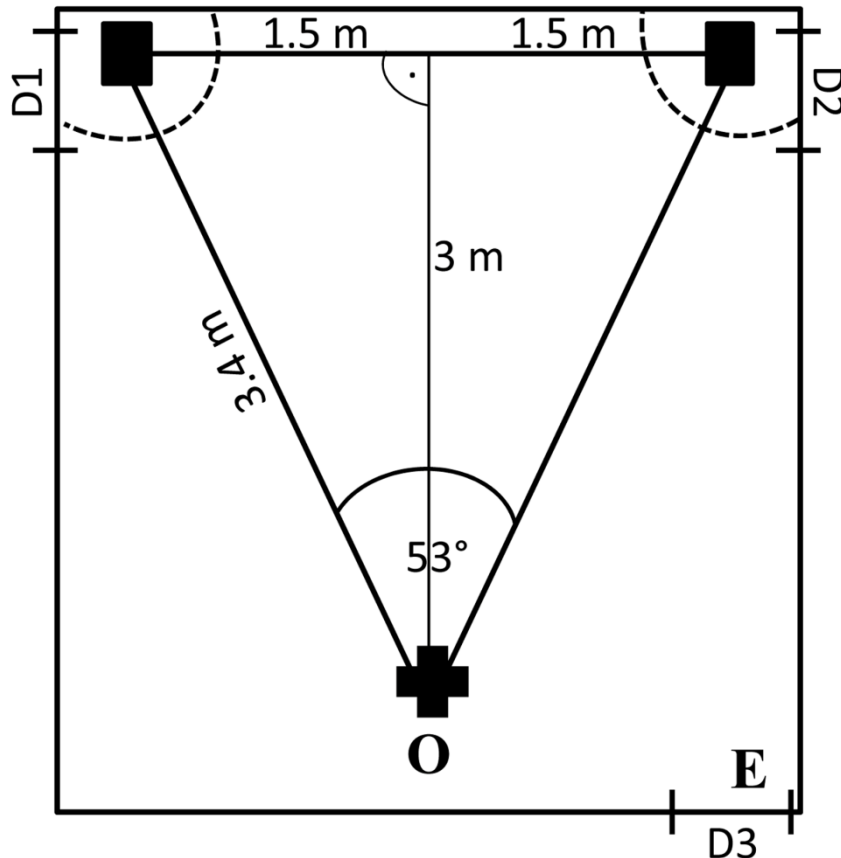


Figure 21. Experimental layout for the Basic training phase. The black cross indicates the dogs' starting position, the O indicates the owner's and the E the experimenter's position. The black rectangles indicate the location of two identical target objects, the interrupted lines indicate the 20 cm 'approaching zone'. D1, D2 and D3 indicate the locations of the three doors (0.6 m width) in the lab.

These blocks of ten trials were then repeated until they reached learning criterion. Criterion for learning the basic training task was set as 10 consecutive correct trials.

If the dog approached the 'incorrect' object (within 20 cm), the owner called the dog back and the trial was repeated with the same sound signal. If the dog failed to show the correct response two times in a row, then the owner was allowed to point at the correct rectangle during the subsequent trial. We considered the trial also as incorrect and the dog did not get the reward if it passed along the midline in between the objects without approaching either of them.

For half of the subjects (N=8) the HP sound was the 'go left' signal and the LP sound was the 'go right' signal. For the other half (N=8) of the subjects we reversed the reference (left/right) of the signals.

Dogs participated in 10-30 Basic training trials per session (mean \pm SE: 16 \pm 4) and each training session was terminated when the owner indicated that the dog was getting tired and inattentive. Owners and their dogs visited the department once or twice weekly.

Advanced training

The aim of the advanced training was to investigate whether changes in the training situation influence dogs' performance and generalization capability. Subjects were divided into two groups:

Rotation training: For half of the dogs (N=8) we rotated the position of the rectangles and the orientation of the dog and the owner by 90°. Then subjects participated in 10-trial training sessions as described above until reaching the criterion (10 consecutive correct trials).

No target training: For the other half of dogs (N=8) we repeated the Basic training without target objects until they reached the criterion (10 consecutive correct trials). Dogs received the reward if they approached the former location of the rectangle within 20 cm.

Owners and their dogs visited the department once or twice weekly, and they participated 10-20 Advanced training trials per visit (mean \pm SE: 14 \pm 2).

Testing phase

Test trials were staged outdoors on the campus of the Eötvös Loránd University in a 40 m x 40 m grassy area with some peripheral woods. We could not use a fenced area, thus some students and dog walkers were usually walking nearby during the test and were asked verbally to avoid the test area during the testing. Each session started with a short 6-trial warm-up training performed in the experimental room (in these trials we used the same procedure as in the Advanced training). Each testing session consisted of 5 different types of trials ('condition'). Three different targets and 5 different distances with different angular deviations from the position of the dog were utilized: Close ball, Distant ball, Close tree, Distant tree and Human (see Figure 22). We decided to use the unbaited C&T collar during the testing in order to exclude accidental falls of the reward during fast running and the possible loss of the reward in high grass or snow in winter. Reward was provided by the owner after the dogs' return.

In each condition the owner and the dog were standing in front of two targets (trees, balls or two female humans). Dogs were wearing the empty C&T collar. After the sound was emitted from the collar, the dog was allowed to set off. The owner was not allowed to say anything to the dog except "GO!" or "Go ahead!" without any additional verbal or gestural signals.

Clever Hans control trials

The aim of these trials was to control for owners' and experimenter's influence on dogs' performance. After finishing the testing sessions, dogs participated in 10 additional Advanced training trials in the laboratory setting, but in this case owners were wearing opaque sunglasses and they were listening to loud music during the test. This prevented them from hearing the played sound signal and from seeing in which direction the dog was moving. The experimenter, who controlled the C&T collar, was facing the wall when she pushed the sound button on the controller, thus she did not see the dog either. The experimenter turned back to the scene only after the sound was emitted and informed the owner what had happened (if the dog went to the proper side the owner had to praise the dog, if the dog went to the wrong side the owner had to call the dog back). We predicted that, if no Clever Hans effect was involved in the Basic and Advanced training, then the changed appearance and behaviour of the owner and experimenter would not affect the dogs' performance.

Variables and Data analysis

The experimenter coded the performance of the dog in situ during the basic and advanced training, test conditions and also during Clever Hans control (she marked each trial as correct or incorrect). Test conditions were videotaped and analysed later with Solomon coder 060612 (András Péter <http://solomoncoder.com>). Trials of training sessions were also supervised by coding recorded videos.

Measured variables:

Target: The dog approached one of the targets within 20 cm during training trials (rectangle), or within 1 m during test trials (tree/ball/human).

First movement: The direction of dog's first three steps from the start point (left/right/straight from the middle line) in test trials.

We scored correct trials with 1, and incorrect trials with 0. We considered a trial as correct if (1) the dog went to the specific target (rectangle/tree/ball/human) on the side indicated by the specific sound (left/right) (i.e. Target variable), (2) the dog made the first three steps toward the target (rectangle/tree/ball/human) indicated by the specific sound signal (left/right) (i.e.

First movement variable). If the dog moved towards the middle area we considered it as an incorrect trial.

Sometimes it happened that dogs stopped before reaching one of the targets and did not go further in 10 sec. In this case, the owner was instructed by the experimenter to call the dog back, and the same trail was repeated. In this case, the First movement score was based on the direction taken on the first trial and Target score was determined by the performance on the subsequent trial.

For the statistical analysis, the test conditions were split into two groups based on their angular deviations. Test conditions in which the angular deviation was sharper or wider than the training angle (53°) were grouped together, thus Close tree and Distant ball tests formed the ‘Angle $< 53^\circ$ ’ condition, and Close ball, Distant tree and Human tests formed the ‘Angle $> 53^\circ$ ’ condition. For statistical analysis we used IBM SPSS Statistics 21.

First we compared dogs’ performance between the last 15 trials of the Basic training and first 15 trials of the Advanced training with Wilcoxon matched-pairs signed rank test in order to analyse the effect of changes in the training environment (i.e. the absence and rotated position of the targets). We also compared dogs’ performance in the Rotation and the No target group with Mann-Whitney test. As a next step, we analysed dogs’ choice in all test conditions and Clever Hans control and we compared dogs’ performance to chance level (50%) with one-sample Wilcoxon signed-rank tests. We used GLMM for Binomial Distribution in order to examine the effect of the training type, condition and repeated test trials on dogs’ performance in all test conditions and Clever Hans control. In the end we also compared dogs’ accuracy between the two test condition group, the Angle $< 53^\circ$ and the Angle $> 53^\circ$ condition, with GLMM for Binomial distribution.

2.5.2. Results

Dogs reached the criterion in 72 ± 36 (mean \pm SD) correct trials on average in the Basic training, and in 34 ± 12 (mean \pm SD) additional trials in the Advanced training. We excluded one dog because it failed to reach the training criterion in 180 trials in the Basic training. Another dog’s owner quit the study after completing the first test condition; therefore the data of this dog are included only in the analysis of the Basic training, Advanced training and Distant tree test condition.

Due to our criterion, dogs’ accuracy was 100% in the last 10 trials of the Basic training, thus we decided to use the last 15 trials in the Basic training and the first 15 trials in the Advanced

training in order to compare dogs' performance between the two training types. We found that dogs' performance decreased significantly (Wilcoxon matched-pairs signed rank test, $N=15$, $T(+)=120$, $p=0.001$), which indicates that dogs in neither group generalised automatically from the Basic training to the Advanced training in which the objects were either rotated or removed. The performance did not differ between the Rotation and the No target group (Mann-Whitney test, $N=15$, $U=36$, $p=0.397$). However, dogs in both groups showed a rapid recovery, because they needed 16 ± 3 and 15 ± 1 trials respectively to reach the criterion which did not differ between the two groups (Mann-Whitney test, $U=28$, $p=0.95$).

In the test conditions, only two dogs failed to reach targets in 60 seconds in the Distant tree condition, and one of them failed also in the Close tree condition.

According to test conditions, first we compared mean scores for the Target and First movement variables. We found that these two variables did not differ (matched samples McNemar test, $N=15$, $df=1$, $p=1.00$), thus we decided to use Target variable for further analysis. Subjects performed better than chance in each test condition (one-sample Wilcoxon signed-rank test, Close ball $N=14$, $T(+)=105$, $p<0.001$; Distant ball $N=14$, $T(+)=105$, $p<0.001$; Close tree $N=13$, $T(+)=91$, $p<0.001$; Distant tree $N=13$, $T(+)=91$, $p<0.001$; Human $N=14$, $T(+)=105$, $p<0.001$). This shows that the dogs went to the correct target (ball/tree/human) more frequently than to the target on the incorrect side (Figure 23). Dogs performed also above chance level in the Clever Hans control condition (one-sample Wilcoxon signed-rank test, $N=14$, $T(+)=105$, $p<0.001$). The order of test conditions did not have any effect on dogs' performance (Friedman test, $N=15$, $df=4$, $p=0.92$).

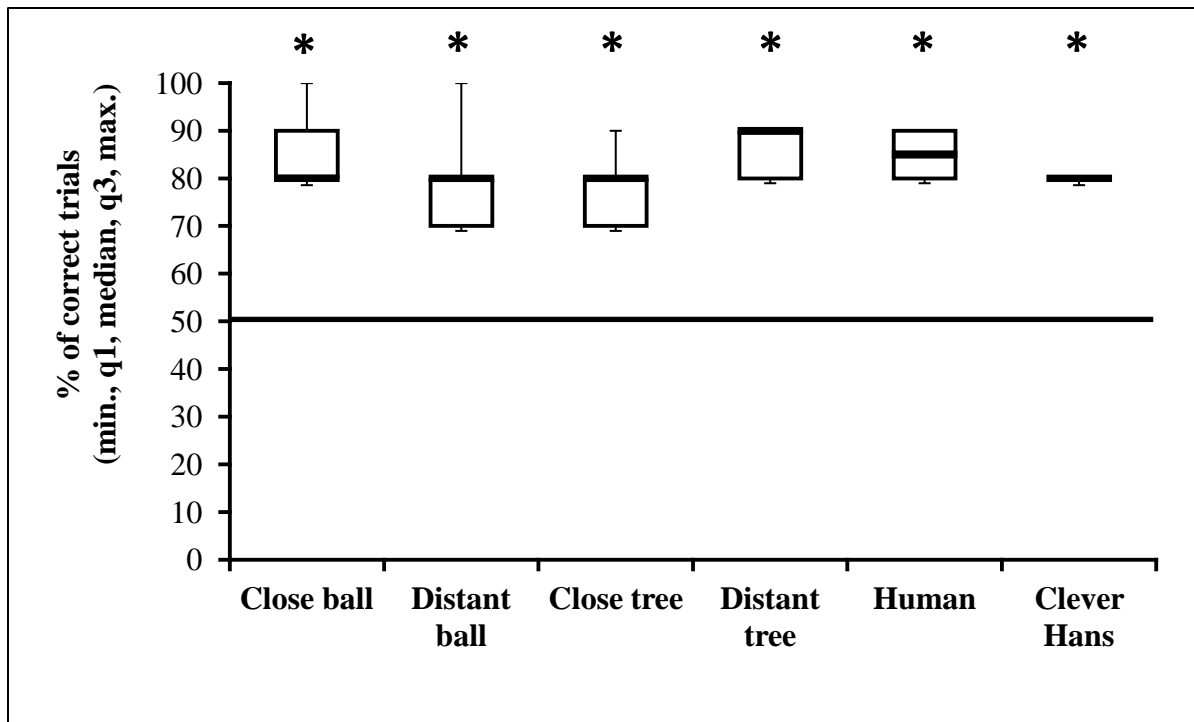


Figure 23. Percent (%) of correct trials in each Test conditions (Close ball, Distant ball, Close tree, Distant tree, Human) and in the Clever Hans control. Asterisks indicate the significant differences from chance level (50%). * $p < 0.001$

Results of the Binomial GLMM showed no significant variability among test conditions ($F_{5,761}=1.11$, $p=0.35$), and repeated trials had also no effect ($F_{9,761}=1.3$, $p=0.230$). Dogs' accuracy in Test conditions was independent from the Advanced training type ($F_{1,809}=0.004$, $p=0.947$) and interaction between Advanced training type and Test condition was also not significant ($F_{1,809}=0.68$, $p=0.630$).

Results of the GLMM for Binomial distribution showed that dogs' performance was lower in the Angle $< 53^\circ$ condition group, in which the angular deviation was sharper than the training angle compared to dogs' accuracy in the Angle $> 53^\circ$ condition group ($F_{1,661}=5.33$, $p=0.021$) (Figure 24).

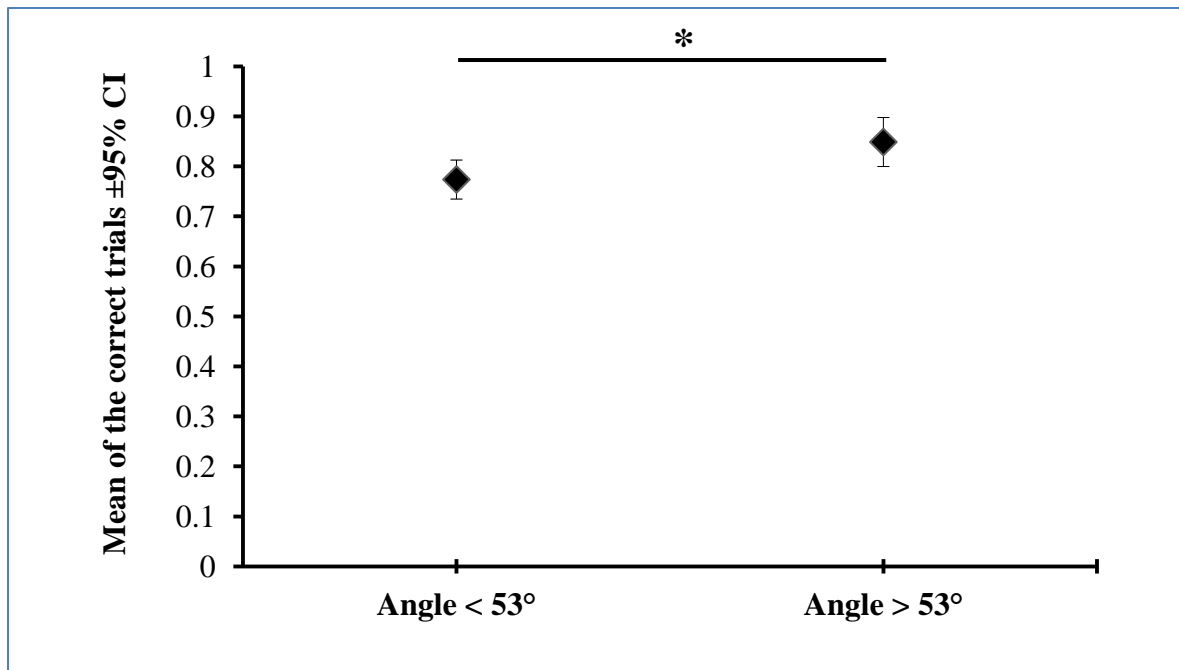


Figure 24. Means of the correct trials in the two experimental groups which differ with regard to the visual angle (Angle < 53°: Distant ball, Close tree; Angle > 53°: Close ball, Distant tree, Human). * $p < 0.05$.

2.5.3. Discussion

The objective of the present study was to investigate whether dogs are capable of learning to go left/right after training using two qualitatively different sound signals and whether they can generalise this experience to novel contexts. Contrary to previous findings suggesting that dogs failed to rely on tone frequency cues in a go left/go right task (e.g. Lawicka 1969), our results showed that dogs had no difficulty in learning directional responses based on qualitatively different sound signals after a relatively short training. The control testing aimed to exclude human influence (i.e. Clever Hans effect) also supported our findings that the dogs' performance was based on their attention to the signals.

Methodological differences may explain this discrepancy: (1) Dogs in our study were clicker trained family dogs from different breeds with well described training history, while Lawicka tested 8 laboratory mongrels with unknown training background. (2) In our study, signals were emitted and dogs were rewarded directly from the C&T collar, while in Lawicka's experiment sound sources were loudspeakers situated at 2 m from the starting platform and the target objects contained the reward.

This latter difference might have drawn dogs' attention more toward the target object than the sound signals from the C & T collar and caused the prolonged learning time. Our results support the presumption that the Quality-Location effect is not a general constraint of learning, but more likely it emerges under particular experimental designs and conditions (Harrison 1984, Neill & Harrison 1987).

In order to examine context dependency of learning, we changed the training situation after the Basic training by either removing the target objects (No target training) or rotating the position of the targets and the dog (Rotation training). We found that dogs' performance decreased equally in both conditions. Braem & Mills (2010) reported also that dogs show a decline in performing a newly learned command in a novel environment. In contrast to our prediction, dogs that participated in the No target training showed as rapid recovery as dogs in the Rotating training. We presume that during the Basic training, dogs learnt to 'go left/right' (egocentric action) instead of 'approaching the target on the left/right', thus the absence of the target objects in the Advanced training (in the No target training condition) did not affect their performance. The lack of such difference could also be explained by the fact that the reward was not hidden into/behind the target object (c.f. Lawicka 1969, Fiset et al 2006) but it was dropped directly from the C&T collar worn by the dog.

In the testing phase, dogs were exposed to a novel area (outdoor field), novel targets (balls/trees/humans), and extended distances (9.5 to 19.5 m) and angular deviations (36° to 87°) in order to reveal whether they are able to generalise the 'go left/right' task (see Figure 22). Dogs' performance was significantly above chance level in all test conditions, thus they approached the correct target matching with the sound command significantly more often than expected. Target types and their relative distance from the dog had no influence on dogs' performance, similarly to previous findings in search for disappearing objects in dogs (Fiset et al 2006). However dogs' performance in this task decreased as a function of angular deviation between two adjacent hiding locations and the relative position of the dog (Fiset et al 2006). If the target is visible, then the angular deviation is the most relevant factor for dogs in a detour task, and they show a preference for using the less divergent route (Chapuis 1983). A similar result was also reported for chimpanzees. The spatial separation of two adjacent hiding locations together with the varying angular deviation influenced animals' accuracy in a spatial delayed response object choice task (Harrison & Nissen 1941). Our results also showed that dogs' performance was lower if, in the test condition, the angular deviation between the adjacent targets and the dogs' position was sharper than the angle experienced in the training

angle. This is the first evidence that angular deviation influences dogs' ability to generalise learned directional commands from the training context to a novel context.

Dogs' similar accuracy in all test conditions after different Advanced training suggests that dogs learnt the general rule of 'go left/right', and that they were able to utilize this rule in unfamiliar environments. Dogs showed similar generalization ability in a landmark discrimination task by efficiently using novel landmarks in novel positions for locating target objects. This was also interpreted as learning the general concept of the landmark (Milgram et al 2002).

3. General discussion

In our studies we found evidence that dogs are willing to interact with an Unidentified Moving Object (UMO) resembled neither conspecific nor human. Behavioural elements displayed by the dogs during these encounters were in line with previously observed social behaviour toward human partners (e.g. Miklósi et al 2000, Horn et al 2012, Lakatos et al 2009, Marshall-Pescini et al 2012).

In the first study we showed that dogs' social behaviour toward the UMO increased as a function of the sociality of the inanimate partner. This result supports the hypothesis that interactive behaviour of the artificial partner might affect dogs' social behaviour (Lakatos et al 2014). We endowed the 'social' UMO with different behavioural features like goal-directedness and interactive behaviour (i.e. contingent reactivity) that are typical characteristics of entities with minds. These properties were proved to be important for infants during the development of animate-inanimate distinction (for a review see Rakison & Pouline-Dubois 2001). This result suggests that dogs and human infants might be sensitive to similar social features in an artificial partner. This is in line with previous studies that demonstrated 'human-like' social competence in dogs (see Miklósi & Topál 2013 for a review).

At present most researchers aim to use robots that resemble the studied species as closely as possible (e.g. Faria et al 2010). Although such an approach is important in the study of the effect of morphological and behavioural features in different situations, our findings highlight that the use of UMOs could have several advantages, primarily because this way one can separate the effects of behaviour from the embodiment (Krause et al 2011). This allows the researchers to investigate to what degree the animal is able to deal with the UMO purely on the basis of behaviour displayed. Our results suggested that morphological features of the UMO (i.e. varied movements and the presence of eye-spots) were probably not as effective as the behavioural characteristics (i.e. goal-directedness and interactive behaviour) to elicit dogs' social behaviour. This might indicate that it is not the embodiment but the behaviour of the artificial partner that is crucial for dogs to engage in social interaction.

In our second study (Experiment 2) we found that dogs are able to discriminate between different roles of their UMO partners within a short period of time and they used similar behaviours flexibly toward these agents in accordance with their different capabilities.

This study followed the methodological paradigm used by Horn et al (2012) in a similar problem situation. Results of this experiment suggested that physical complexity of the given problem might affected dogs' ability to recognise different problem solving abilities of their human partners (i.e. filling up the empty apparatus with food vs. solve the physical problem of the blocked apparatus). Authors also assumed that unbalanced social experience with the human partners influenced dogs' behaviour independently from their abilities. Our results supported the latter statement as dogs in Experiment 2 had the same amount of social experience with the two UMOs and they were able to discriminate the different roles of the two partners equally well.

At the same time we can raise the possibility that previous social experience with humans might also affected dogs behaviour in such situations. For example in everyday life dogs had opportunity to observe that the owner is able to solve different physical problems and, at the same time, she provides food. These experiences about the owners' abilities can be generalised to other humans (i.e. the experimenters) and novel context (i.e. test situation). We emphasise that these factors were eliminated from our study by using a social partner which was completely unfamiliar to the dogs, therefore they did not have any expectations about the UMOs' abilities and behaviour.

Another alternative explanation would be that dogs in the present study discriminated the two partners on the basis of the association between hiding place (front hole vs. top hole) and the physical (observable) characteristics of the UMO (car vs. crane) which could be observed consistently next to that particular location during the Learning phase. In this case it is not necessary for dogs to recognise the role and/or any specific ability of their partner. For success, a dog must simply recognize and follow the "rule" of choosing the UMO whose location was used as a food-hiding place in the test trial. Therefore, we can assume that the most important moment of the Learning trial for the dogs was the presence of the particular UMO next to the particular hiding location. From this perspective dogs' opportunity to learn about the partners' location was unequal. That is, the crane was constantly visible next to the box while taking out the food via the top hole whereas the car, after having reached the box, disappeared through the front hole and then reappeared with the food. If we accept this explanation, then, we would expect higher performance in test trials in which the appropriate partner was the crane compared to test trials in which the appropriate partner was the car. However, results do not show significant effects of the different UMOs on dogs' performance. Moreover, previous findings on dogs' discrimination learning ability showed that they had difficulties using a visual cue (referred to as landmark or beacon) as a marker of the food

location even after 400 trials (Milgram et al 1999). Although this alternative hypothesis cannot be fully excluded, the lesser need for learning in our study (which consisted of only 10 trials) suggests that this explanation might not clarify the observed performance.

Our third study (Experiment 3) provided evidence that dogs are able to find the hidden food based on the directional movements of an UMO in a two-way choice task exclusively after short social interaction. This result is in line with a previous study with infants as they were more willing to follow a humanoid robot's gaze after they have observed a social interaction between the experimenter and the robot (Meltzoff et al 2010). In contrast, dogs failed to use a humanoid robot's pointing gesture even if they have previously witnessed a socio-communicative interaction episode between the owner and the robot (Lakatos et al 2014). Authors concluded that sociality shown by the robot was not enough to elicit the same set of social behaviours from the dogs as was possible with humans. However, we can raise an alternative explanation to interpret dogs' poor performance in the aforementioned study. It is also possible that dogs had difficulties to obtain information about the artificial partners' sociality via third-party interaction in which dogs participated as observers (i.e. social eavesdropping). It has been shown that dogs are capable of discerning cooperative and noncooperative human intent based on third-party interactions (Marshall-Pescini et al 2011b), however no study have investigated this issue in dogs with non-living social partners. Dogs' performance in our study suggests that direct social interaction with the artificial partner might be more efficient to gather information about the partner's sociality than third-party interaction.

We emphasise that this experiment also provides some notable insights for human-dog communicative interaction. Several studies have shown that dogs are especially skilful in comprehending human gestural signals (e.g. Lakatos et al 2009), however several different (not necessarily exclusive) hypotheses have been raised in attempting to interpret dogs' high performance in these tasks. One assumption is that dogs must learn to use human communicative signals during the early ontogeny, thus this ability due to the fact that they have wide range of experiences in communicating with humans (e.g. Udell et al 2008, Elgier et al 2009). Another explanation suggested that during the process of domestication dogs have been selected by humans to be sensitive to human behavioural cues including behaviour directed toward some locations (e.g. Agnetta et al 2000, Riedel et al 2006).

In Experiment 3 dogs only had opportunity to engage in a short social interaction with the unfamiliar UMO during the familiarisation phase in which the UMO helped the dogs to get the unreachable food. This experience seemed to be enough for dogs to consider the UMO's

movement as a signal during test trials. Tomasello et al (1997) suggested that lesser need for learning about novel signals indicates subjects' ability to generalise from previous experiences in the novel situation and considering the new signal as a communicative one. On the other hand, if the subjects are failing to recognise that the other is intending to communicate with them via some sign they must learn the sign through prolonged learning process. Thus our results might indicate that dogs' social skills are flexible enough to generalise from previous experience with humans and give rise to the notion that specific evolutionary (selective) processes might be associated with the emergence of such 'flexibility'.

It should be noted that our findings are open to post hoc interpretations of associative nature (Byrne & Bates 2007), however a close investigation shows that this interpretation may be actually more complex. Taking on face value one may argue that dogs associate the actions of the UMO with getting food reward. However, dogs in the familiarisation phase (Context 1) observe the following sequence of events (E_{fam}): (1) Produces attention-getting sound (E_{fam1}) UMO approaches the food plate in the cage (food visible) (E_{fam2}); (2) UMO approaches the dog (E_{fam3}). In contrast, in the test (Context 2), the dogs observe (E_{test}) the following sequence: (1) UMO produces attention-getting sound (E_{test1}); (2) UMO approaches the bowl (E_{test2}); UMO leaves the bowl (E_{test3}). Apart from many contextual differences between Context 1 and 2 (location of food, food bowls etc.), only E_{fam1} and E_{test1} is the same, and the following events are different ($E_{fam2} \neq E_{test2}$ and $E_{fam3} \neq E_{test3}$). Note that in E_{fam3} and E_{test3} the UMO actually moves in different directions (approach vs. departure). Based on learning theory dogs should have associated the last action with the reward during familiarization phase and learn the whole sequence of events backward. In addition there is much everyday experience that family dogs' performance in executing a newly learnt actions drops significantly in a novel context (Bream & Mills 2010), and usually more trials (experience) are need to establish an association between an arbitrary action of the partner and the presence of food (e.g. Udell et al 2008, Elgier et al 2009). Although some underlying associative mechanisms may play a role here, in our view the interpretation of the dog's behaviour and performance as being based on more general inference from previous social experience is a viable alternative explanation.

Our last study (Experiment 4) which focused on the effects of UMOs' sociality on dogs' behaviour showed that dogs have tendency to follow the UMOs' indication in a food-choice task, even if it is clearly went against their preference.

Same behaviour observed in dogs with human experimenter in a study, in which the human picked up the food bringing it level to the mouth and holding it there for 5 seconds (i.e. hand-to-mouth movement, Marshall-Pescini et al 2012). It has been suggested that dogs' 'counterproductive' behaviour (i.e. choosing the smaller amount of food) in this experiment might be due to certain types of training requirements (i.e. dogs need to follow their handlers' signals). Following the 'rule' to choose the food indicated by the human might serve to maintain owner-dog social cohesion (Prato-Previde et al 2008). Contrary to these assumptions later studies demonstrated that the owner and the stranger (i.e. unfamiliar experimenter) did not influence the dogs' behaviour differently (Marshall-Pescini et al 2011a). Researchers concluded that the stranger's unfamiliarity was overshadowed by the communicative cues displayed by her during the experiment. Several studies provided evidence that human ostensive-communicative cues are important in the dogs' learning process from humans (e.g. Pongracz et al. 2004, Topál et al 2009a), in contrast Marshall-Pescini et al (2012) showed that human influence on dogs' choice behaviour also occurred independently from these cues. At the same time, the hand-food contact proved to be essential for dogs to change their choice behaviour while they ignored the experimenter's behaviour in certain conditions where the human only approached the food and displayed ostensive-communicative cues (i.e. high pitched voice, gazing and gaze alternations). They concluded that such social bias is induced predominantly by the goal-directedness of the human action (e.g. grasping the food), and in some measure, is also affected by the ostensive dog-directedness of the human demonstration (eye contact, dog-directed talk). Our results are in line with this statement hence demonstrating goal-directedness (in this case approaching the target) by the UMO during the test phase was not effective to elicit this social bias (i.e. changed choice behaviour). However, altogether with dog-directedness of the UMOs' behaviour during the familiarization phase (in this case attention getting and contingent reactivity) seemed to be more powerful.

Furthermore, in this study (Marshall-Pescini et al 2012) authors suggested stimulus enhancement (in this case grasping the food) as an underlying "social influencing/learning mechanism". Since the UMO in our study was unable to picking up the food but rather approached it which suggested local enhancement as an underlying mechanism which occurs when an animal directs its behaviours to a certain place because that individual observed another individual in that location (e.g. Galef & Giraldeau 2001). This indicates the possibility that social influencing can emerge between dogs and an UMO and support latter findings that social influencing may often be explained by relatively simple (but powerful) mechanisms in dogs (Mersmann et al 2011).

In Experiment 5 we showed that dogs are able to learn directional responses (i.e. go left/right) based on qualitatively different sound signals and generalise this rule to novel contexts and tasks. In accordance with Harrison (1984) and Neill & Harrison (1987) we found that the Quality-Location effect (see introduction of Experiment 5) is not a general constraint of learning but rather emerges as a result of specific experimental designs and conditions. Our results showed that dogs had no difficulties to generalise previously learned sound signals to novel context where they faced with different target objects at different distances. Only the training angle between the target objects and the dog influenced dogs' performance in the novel context. It has been shown that dogs' are sensitive to the angular deviation between two adjacent hiding locations and the relative position of the dog in an object permanence task (Fiset et al 2006) and also in a detour task (Chapuis 1983), however this is the first evidence that angular deviation influenced dogs' ability to generalise learned directional commands from the training context to a novel context. This study also provide significant findings for dog training and the Swiss SWARMIX project aimed to develop an autonomous flying robot working in cooperation with rescue dogs and human handlers to solve efficiently search and rescue tasks. This system requires high level of autonomy of dogs since they have to working at distance from the human handler. Combined with recently developed motion tracking system (Gerencsér et al 2013), our new device (the Click & Treat collar) offers the potential to control dogs' movements and maintain dogs' motivation also in the absence of the handler. Furthermore sound signals can be utilized also by the flying robot in order to lead the dogs to particular locations. In summary, these results clearly show that dogs can internalise a simple behaviour rule for taking directional action upon hearing qualitatively different signals. This capacity of dogs has long been used in traditional settings (e.g. shepherds have long known how to train herding dogs by whistle sound), but our elaborated method offers the possibility to train dogs explicitly if needed for specific employments (e.g. search and rescue, Ferworn et al 2006).

In conclusion our studies provided new insights in the social behaviour of dogs. The utilization of an unfamiliar UMO as a social partner revealed that dogs are reacted to particular behaviours (e.g. goal-directedness and interactivity - i.e. contingent reactivity) even if the partner's embodiment is distinct from familiar social partners with which the subject interacts in a social way. In human infants the understanding of basic concepts defining the other (e.g. agency, directedness, attention etc.) has been investigated by the means of visual displays showing moving simulated agents in 2D (e.g. Gy. Gergely et al 1995, Csibra et al 1999, Kovács et al 2010).

After being habituated to certain events, infants are confronted with unexpected, unnatural events, and researchers deduce the infants' ability of representing these specific concepts by noting increase in looking time at the time of change ('surprise effect', see Munkata 2000 for a review). Although it is possible to apply the method to some species of animals we have little knowledge about how animals perceive the two dimensional representations of real world objects (see Bovet & Vauclair 2000 for a review). Thus it would be more advantageous to use real 3D situation to test for similar mental skills in non-human species. We believe that the systematic use of UMOs offers this possibility. Moreover the use of UMOs could also help answering the question of how much of the social skills are grounded in the species' embodiment, that is, whether animals are able to represent and deal with social behaviour independently from the body displaying it. Previous social experience makes testing of such socio-cognitive abilities difficult among conspecifics, but the unfamiliarity to UMOs and the possibility to use wide range of embodiments make such investigations possible. For example, interaction with UMOs could help in discerning the mental mechanisms related to different forms of social learning (Buchsbbaum et al 2005). The use of UMOs can also expand the comparison of socio-cognitive skills in different species. The comparison of behavioural data collected within a species is often difficult because there are many possible factors that could account for the observed differences (Kamil 1998). The use of UMOs, which are unfamiliar to all participants that, however, behave in a certain way, could offer a potential way to study the differential capacities of species to interact socially. If the UMOs are deployed in a systematic way (varying their social behaviour) then flexibility of social behaviour across different contexts could also be revealed.

We emphasise that dogs are especially good candidates for being studied in this way. They are living and have been selected for living in a relationship with humans whose embodiment and behaviour is very different. Despite this divergence dogs and humans are able to develop complex communicative and cooperative interactions (Topál et al 2009b). At the moment we do not know to what extent dogs rely on general behavioural homologies present in the social behaviour of both species, and to what degree they extend this basic understanding by learning through everyday experience. Future experiments could reveal the ability of dogs to generalise across contexts and agents, and whether this ability is species specific or emerges as a result of exposure to humans.

3.1. Outlook

Future comparative studies between human infants, primates, wolves (*Canis lupus*) and dogs could provide useful insights about species specific social competence in dogs and humans by using different UMOs as social partners. This might also reveal more precisely the relative contribution of evolutionary and ontogenetic mechanisms behind certain social skills in dogs.

Further investigations also needed to assign different learning mechanisms involved in dog-UMO interactions. For investigating the role of the associative explanation of dogs' performance in Experiment 3 we already started to develop different social interactions between the subjects and the UMO (e.g. social play with toys) which allow dogs to gather information about the sociality of the partner without making associations between the actions of the UMO and getting food reward. We are also planning to replicate Experiment 3 with the remote-control crane that has telescopic boom, thus we could model more realistically human's pointing gesture and investigate dogs' understanding on different visual features of this signal.

We also designed an experiment in order to examine whether perseverative search error in dogs contributed to social cues displayed by an UMO in the A-not-B object search task. It has been demonstrated that dogs tend to commit perseverative search error in the presence of human ostensive-communicative signals (e.g. Topál et al 2009b). One may hypothesize that dogs, after having interacted with an UMO socially, would commit perseverative error in an A-not-B error task in which the UMO 'acted as a Hider'. If so, this would indicate a more flexible social competence in dogs or might suggest an alternative mechanism behind this search error.

In summary, we can conclude that the diverse usability of the UMO makes this method a valuable source of studying general and specific questions of animal behaviour such as interspecific communication, social learning, physical and social cognition.

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6. Summary

This dissertation contains the results of experiments on the socio-communicative aspects of dog-robot interaction. In contrast to previous studies, which often relied on using artificial agents (i.e. robots) as social partner resembled to the species studied, we utilized an Unidentified Moving Object (UMO) with bodily appearance (embodiment) distinct from familiar social partners. We emphasised that this method has the potential to identify separately external and behavioural features (i.e. key stimulus) of the partner that are important for the animal to engage in social interaction.

To test this, we designed an experiment in which dogs faced with a problem situation where partners, differed in particular external and behavioural characteristics, helped the dog to get the food. We found that dogs displayed similar social behaviours (i.e. gazing and gaze alternations between the partner and the food) toward a human and an UMO partner. Our results also showed that dogs' social behaviour increased as a function of the UMO's social features (i.e. goal-directed behaviour, contingent reactivity etc.). In our second experiment we demonstrated that dogs' are able to discriminate between different roles of their helping UMO partners in a similar problem situation and they used same social behaviours flexibly toward these agents in accordance with their different capabilities.

Previous studies suggested that dogs are especially skilful in comprehending human communicative signals with directional components (e.g. pointing gesture). At the same time researchers argued about the contribution of evolutionary and ontogenetic mechanisms in the emergence of this social skill. Our third study provided evidence that dogs are able to find the hidden food based on the directional movements of an unfamiliar UMO after short social interaction. Based on this result we can assume that dogs' social skills are flexible enough to generalise from previous experience with humans and highlighted the importance of evolutionary mechanisms behind this social skill.

In our next experiment we tested whether dogs' choice behaviour can be influenced by an UMO partner as effectively as a human experimenter in a food-choice task. We found that dogs have tendency to follow the UMOs' "indication" in a food-choice task after short social interaction, even if it is clearly went against their preference. The nature of the UMO's indication suggests local enhancement as an underlying mechanism and indicates the possibility that this type of social learning can emerge also with non-living partners with agency cues in dogs.

Our last experiment focused more on practical applications on dog-robot interaction and investigated whether dogs are able to generalise different directional acoustic signals to novel contexts. Our results showed that dogs had no difficulties to use previously learned sound signals in novel context where they faced with different target objects at different distances, however dogs' performance decreased as a function of angular deviation between two adjacent hiding locations and the relative position of the dog.

In summary, this work provides the first evidence that certain social characteristics of an artificial partner resembled neither dog neither human can affect dogs' social responsiveness and also enhance social learning. All these suggest that the use of UMOs' has the potential to study different aspects of dogs' social behaviour and cognition.

7. Összefoglaló

Disszertációmban a kutya-robot interakció különböző szocio-kommunikatív aspektusait vizsgáltuk. Korábbi tanulmányokkal ellentétben, melyek a vizsgált fajhoz hasonló robotokat alkalmaztak szociális partnerként, mi olyan Azonosítatlan Mozgó Tárgyat (AMoT) használtunk mely külső megjelenésében távol áll minden ismert szociális partnertől, amellyel az alany korábban interakcióba léphetett. Véleményünk szerint ez a módszerrel lehetővé teszi, hogy meghatározzuk a partner azon külső (megjelenés) és belső (viselkedés) tulajdonságait melyek az alanyok számára fontosak a szociális interakció kialakításához.

Ennek vizsgálatához először egy problémamegoldó helyzetben vizsgáltuk a kutyák szociális viselkedését ahol különböző viselkedésű és kinézetű partnerek segítettek a kutyáknak hozzájutni a jutalomfalathoz. Eredményeink szerint a kutyák hasonló szociális viselkedéselemeket (pl. nézés és tekintetváltás) mutattak mind az AMoT mind az ember irányába. Továbbá kimutattuk, hogy az AMoT szociális viselkedésének (cél-orientált és interaktív viselkedés) hatására a kutyák AMoT felé mutatott szociális viselkedése kifejezettebbé vált. A következő kísérletünk eredményei arra utalnak, hogy a kutyák hasonló helyzetben képesek különbséget tenni eltérő képességekkel rendelkező AMoT-ok között és rugalmasan alkalmaznak hasonló szociális viselkedéselemeket az adott helyzetben segíteni tudó AMoT irányába.

Számos korábbi tanulmány kimutatta, hogy a kutyák kifejezetten hatékonyan alkalmaznak különböző emberi jelzéseket, mint pl. a mutató ujj vagy a tekintet iránya. Ugyanakkor vita alakult ki arról, hogy milyen mértékben felelősek evolúciós és egyedfejlődési mechanizmusok a kutyák fent említett képességének kialakításában. Harmadik kísérletünk kimutatta, hogy rövid szociális interakciót követően a kutyák egy AMoT jelzése (mozgásiránya) alapján is képesek megtalálni az elrejtett jutalomfalatot. Ez az eredmény arra utal, hogy a kutya szociális viselkedése kellőképpen flexibilis ahhoz, hogy korábbi, emberekkel való tapasztalatait alkalmazza egy ismeretlen partnerrel szemben. Mindezen felismerések erősítik az evolúciós mechanizmusok jelentőségét a kutyák szociális képességeinek kialakításában.

Következő kísérletünkben arra voltunk kíváncsiak, hogy az AMoT is képes-e az emberhez hasonlóan befolyásolni a kutyák viselkedését egy étel-választó feladatban. Az AMoT eredményeink szerint hatással volt a kutyák étel-választó viselkedésére egy rövid szociális interakciót követően akkor is, ha az AMoT „jelzése” a kutyák által eredetileg nem preferált

étel felé irányult. Ez az első vizsgálat mely arra utal, hogy szociális tanulás kialakulhat nem-élő, de az ágencia jegyeit mutató partner esetében is kutyáknál.

Utolsó vizsgálatunkban a kutya-robot interakció gyakorlati alkalmazhatóságára koncentráltunk és arra kerestük a választ, vajon a kutyák képesek-e a különböző hangok irányjelző funkcióját megtanulni, és ezt az ismeretüket új helyzetekben is alkalmazni. Eredményeink szerint a kutyák gond nélkül alkalmazták a hangjelzéseket új helyzetekben is, és teljesítményükre csak a céltárgyak és a kutya között bezárt szög változása volt hatással.

Összefoglalva, az általunk végzett kísérletekben elsőként mutattuk ki, hogy egy mesterséges partner bizonyos szociális tulajdonságai hatással vannak a kutyák társas viselkedésére és tanulási folyamatokra akkor is, ha a partner nem hasonlít se kutyára se emberre. Ezek az eredmények alátámasztják, hogy az AMoT-ok alkalmazása kutyák esetében lehetőséget nyújt a szociális viselkedés és kogníció különböző aspektusainak vizsgálatára.

8. Appendix

Table 8. The parameters of the subjects in Experiment 1.

Name	Sex	Age (year)	Breed	Condition
Bambusz	male	1	Golden retriever	Mechanical UMO
Bilbó	male	5	Border collie	Mechanical UMO
Bodza	female	4	Labrador retriever	Mechanical UMO
Kamiko	female	4	Mongrel	Mechanical UMO
Kócos	male	1	Mongrel	Mechanical UMO
Kyra	female	5	Mongrel	Mechanical UMO
Luna	female	10	Hungarian vizsla	Mechanical UMO
Lüszzi	female	3	Samoyed	Mechanical UMO
Max	male	5	Mongrel	Mechanical UMO
Mignon	female	1	Mongrel	Mechanical UMO
Panka	female	4	Hungarian Vizsla	Mechanical UMO
Römi	female	4	Mongrel	Mechanical UMO
Smafu	female	3	Mongrel	Mechanical UMO
Sonja	female	2	English setter	Mechanical UMO
Zserbó	male	2	Mongrel	Mechanical UMO
Angel	female	10	Mudi	Social UMO
Baltazár	male	1.5	Dachshund	Social UMO
Boldizsár	male	9	Mongrel	Social UMO
Chili	female	6	Mudi	Social UMO
Csicsi	female	1	Mudi	Social UMO
Early	male	5	Mongrel	Social UMO
Ebony	female	3	Schipperke	Social UMO
Jenny	female	2	Mongrel	Social UMO
Kormi	male	9	Mongrel	Social UMO
Maci	male	5	Mongrel	Social UMO
Nózi	male	4	Bichon havanese	Social UMO
Remy	female	3	Mudi	Social UMO
Rumli	male	1.5	Mongrel	Social UMO
Shiva	female	2	Mongrel	Social UMO
Szépség	male	1	Labrador retriever	Social UMO
Zora	female	10	Mongrel	Social UMO
Zserbó2	male	4.5	Mongrel	Social UMO
Akira	female	2.5	Mongrel	Mechanical Human
Babzsák	male	4	Chiwawa	Mechanical Human
Borisz	male	6	Whippet	Mechanical Human
Csibész	male	3	Mongrel	Mechanical Human
Csoki	female	3	Bichon havanese	Mechanical Human
Fecske	female	11	Mudi	Mechanical Human

Gina	female	2	Mongrel	Mechanical Human
Kabala	male	11	Hungarian Vizsla	Mechanical Human
Kormi2	male	1	Mongrel	Mechanical Human
Lolka	female	2	Hungarian Vizsla	Mechanical Human
Momo	female	1	Golden retriever	Mechanical Human
Olivér	male	1.5	French bulldog	Mechanical Human
Rozi	female	2	Miniature snauzer	Mechanical Human
Szofi	female	4	German Shorthair Pointer	Mechanical Human
Zorro	male	2	Mongrel	Mechanical Human

Table 9. The parameters of the subjects in Experiment 2.

Name	Sex	Age (year)	Breed	Condition	Door used by the car
Dorka	female	5	Groenandale	Same side	Door A
Bregyó	male	2	Golden retriever	Same side	Door A
Zoé	female	3	Foxi	Same side	Door A
Misu	male	3	Mongrel	Same side	Door A
Milo	male	3	Jack russel terrier	Same side	Door A
Walter	male	2.5	Golden retriever	Same side	Door A
Peti	male	2	Labrador retriever	Same side	Door A
Panka	female	1.5	Cocker spaniel	Same side	Door A
Vackor	male	8	Puli	Same side	Door A
Hermi	female	4	Mongrel	Same side	Door A
Zizi	female	7	Malinois	Same side	Door A
Shaggy	male	7	Nova Scotia duck tolling retriever	Same side	Door A
Bekecs	female	1.5	Mudi	Same side	Door B
Szörpi	female	5	Aussie	Same side	Door B
Ozzy	male	6	Aussie	Same side	Door B
Miró	male	1.5	Aussie	Same side	Door B
Happy	male	5	Collie	Same side	Door B
Dóri	female	7	Hungarian vizsla	Same side	Door B
Zselé	female	5	Mongrel	Same side	Door B
Eni	female	3	Shiba Inu	Same side	Door B
Luna	female	1	Mongrel	Same side	Door B
Lola	female	6	Mongrel	Same side	Door B
Pandia	female	5	Dogo Argentino	Same side	Door B
Lea	female	4	Boxer	Same side	Door B
Bodor	male	8	Mongrel	Changed side	Door A
Fruti	female	4	Mongrel	Changed side	Door A
Csele	female	3	Mudi	Changed side	Door A
Gyurma	female	1	Mongrel	Changed side	Door A
Kira	female	2	Husky	Changed side	Door A

Mázli	female	1.5	Mongrel	Changed side	Door A
Bambusz	female	7.5	Hungarian vizsla	Changed side	Door A
Orka	male	4.5	German shepherd	Changed side	Door A
Leki	male	5	Mongrel	Changed side	Door A
Jamie	female	1.5	Labrador retriever	Changed side	Door A
Rose	female	2	Mongrel	Changed side	Door A
Panka	female	3	Golden retriever	Changed side	Door A
Negro	male	8	Mongrel	Changed side	Door B
Chili	female	1.2	Mongrel	Changed side	Door B
Roy	male	1	Mongrel	Changed side	Door B
Fanny	female	3	Groenendael	Changed side	Door B
Kevin	male	6	Golden retriever	Changed side	Door B
Tofu	male	5	Mongrel	Changed side	Door B
Balu	male	3	German shepherd	Changed side	Door B
Lessie	male	3	Labrador retriever	Changed side	Door B
Zotya	male	3	Mongrel	Changed side	Door B
Shelly	female	2.5	Dogo Argentino	Changed side	Door B
Jenny	female	1	Hovawart	Changed side	Door B
Muffin	female	1.5	Golden retriever	Changed side	Door B

Table 10. The parameters of the subjects in Experiment 3.

Name	Sex	Age (year)	Breed	Group
Dylan	male	8	Labrador retriever	Non-helper Human
Valter	male	1.5	Golden retriever	Non-helper Human
Liza	female	9	Hungarian vizsla	Non-helper Human
Dóri	female	5	Hungarian vizsla	Non-helper Human
Freya	female	1.5	Pitbull	Non-helper Human
Berry	male	2	French bulldog	Non-helper Human
Fifi	male	5	Mongrel	Non-helper Human
Ananász	female	8	Labrador retriever	Non-helper Human
Luna	female	6	Mongrel	Non-helper Human
Panka	female	3	Golden retriever	Non-helper Human
Lea	female	4.5	Boxer	Non-helper Human
Szamóca	female	7	Whippet	Non-helper Human
Swini	male	2	Border collie	Non-helper Human
Vito	male	4	Bullmastiff	Non-helper Human
Arwen	female	4	Border collie	Non-helper Human
Sessi	female	3	Dogo Argentino	Non-helper UMO
Lujzi	female	3.5	Mongrel	Non-helper UMO
Mazsi	male	6	Mongrel	Non-helper UMO
Fanta	female	4	Labrador retriever	Non-helper UMO
Zsakett	male	3	Beagle	Non-helper UMO
Foltos	female	5	Beagle	Non-helper UMO
Joker	male	3	Border collie	Non-helper UMO
Pimpa	female	2	Mongrel	Non-helper UMO
Joker2	male	4	West highland white terrier	Non-helper UMO
Zora	female	1	Border collie	Non-helper UMO
Lili	female	1	Mongrel	Non-helper UMO
Panni	female	6	Mongrel	Non-helper UMO
Matt	male	3	Border collie	Non-helper UMO
Zserbó	male	6	Mongrel	Non-helper UMO
Baltazár	male	3	Mongrel	Non-helper UMO
Marci	male	1.5	Mongrel	Helper Human

Maci	female	6	Mongrel	Helper Human
Zselé	female	4	Mongrel	Helper Human
Lír	male	2	Border collie	Helper Human
Joda	male	8	Mongrel	Helper Human
Füge	male	1	Mongrel	Helper Human
Kencefice	female	5	Mongrel	Helper Human
Kárin	female	7	Mongrel	Helper Human
Yahoo	male	8.5	Border collie	Helper Human
Zserbó	female	3	Mongrel	Helper Human
Faust	male	5	Groenendale	Helper Human
Tony	male	4	Beagle	Helper Human
Buksi	male	5	Transylvanian Hound	Helper Human
Apollo	male	2	Husky	Helper Human
Peti	male	1	Golden retriever	Helper Human
Arnie	male	3	Hungarian vizsla	Helper UMO
Amper	male	5	Border collie	Helper UMO
Hamu	female	1	Newfoundland	Helper UMO
Zsebi	female	3	Golden retriever	Helper UMO
Suvi	female	3	Border collie	Helper UMO
Cooper	male	1	Border collie	Helper UMO
Josephin	female	2	Border collie	Helper UMO
Frida	female	4	Mongrel	Helper UMO
Boci	female	2.5	Mongrel	Helper UMO
Macska	male	5	Golden retriever	Helper UMO
Lovag	male	1	Hungarian vizsla	Helper UMO
Maja	female	3	Border collie	Helper UMO
Nia	female	9	Labrador retriever	Helper UMO
Athina	female	2	Miniature schnauzer	Helper UMO
Joey	male	3	Golden retriever	Helper UMO

Table 11. The parameters of the subjects in Experiment 4.

Name	Sex	Age (year)	Breed	Group
Zizi	female	7	Malinois	Human partner
Bodor	male	8	Mongrel	Human partner
Kira	female	2	Husky	Human partner
Negro	male	5	Mongrel	Human partner
Rozi	female	3	Puli	Human partner
Mázli	male	1.5	Mongrel	Human partner
Walter	male	2.5	Golden retriever	Human partner
Matyi	male	5	Mongrel	Human partner
Flamy	male	2	Golden retriever	Human partner
Bambusz	female	7.5	Hungarian vizsla	Human partner
Jamie	female	1.5	Labrador retriever	Human partner
Csele	female	3	Mudi	Human partner
Gyurma	female	1	Mongrel	Human partner
Lili	female	5	Hungarian vizsla	Human partner
Orka	female	4.5	German shepherd	Human partner
Bendegúz	male	7.5	Labrador retriever	Human partner
Lili2	female	4	Mongrel	Human partner
Cyndi	female	1	Whippet	Non-social UMO
Füge	male	2	Mongrel	Non-social UMO
Zara	female	2	Mongrel	Non-social UMO
Scotch	male	3	Dachshund	Non-social UMO
Lina	female	4	Staffordshire terrier	Non-social UMO
Szaffi	female	8	Cocker spaniel	Non-social UMO
Zsigmond	male	1	Mongrel	Non-social UMO
Boni	female	7	Fox terrier	Non-social UMO
Kifli	female	5	Jack russel terrier	Non-social UMO
Mandula	male	1	Dachshund	Non-social UMO
Lola	female	2	Dogue de Bordeaux	Non-social UMO
Brenda	female	4	Fox terrier	Non-social UMO
Twiggy	female	3	Sheltie	Non-social UMO

Zora	female	4	Mongrel	Non-social UMO
Vito	male	5	Bullmastiff	Non-social UMO
Saphira	female	1	Sheltie	Non-social UMO
Casper	male	3	Sheltie	Non-social UMO
Joda	male	10	Mongrel	Non-social UMO
Misu	male	3	Mongrel	Non-social UMO
Zserbó	female	1	Cocker spaniel	Non-social UMO
Dolli	female	4	Mongrel	Non-social UMO
Kanóc	male	1.5	West highland white terrier	Non-social UMO
Maci	male	5.5	Mongrel	Social UMO
Marcipán	male	1	Hungarian vizsla	Social UMO
Boni	female	2	Mongrel	Social UMO
Kessy	female	8.5	Mongrel	Social UMO
Csoki	male	3.5	German pointer	Social UMO
Csoma	male	9	Transylvanian Hound	Social UMO
Brúnó	male	4	Mongrel	Social UMO
Ada	female	10	Doberman	Social UMO
Ropi	female	9	Mongrel	Social UMO
Sissy	female	1	Yorkshire terrier	Social UMO
Lili	female	3	German shepherd	Social UMO
Redőny	male	2	Mongrel	Social UMO
Raiki	male	3	German shepherd	Social UMO
Mese	female	3	Hungarian vizsla	Social UMO
Scotty	male	11	Sheltie	Social UMO
Pandora	female	3	Mongrel	Social UMO
Zsömi	male	1.5	Mongrel	Social UMO
Vackor	male	7	Pumi	Social UMO
Jona	male	10	Bichon bolognese	Social UMO
Lizy	female	1.5	German shepherd	Social UMO
Alfi	male	1.5	Tervueren	Social UMO
Borzas	male	3	Mongrel	Social UMO
Dorka	female	5	Mongrel	Social UMO

Table 12. The parameters of the subjects in Experiment 5.

Name	Sex	Age (year)	Breed	Left sound	Advanced training type
Brigi	female	6	Hungarian vizsla	High	Rotation
Echo	male	3	Boucheron	High	No target
Mangó	female	5	Nova Scotia duck tolling retriever	High	Rotation
Nia	female	9	Labrador retriever	High	Rotation
Tücsök	female	9	Mudi	High	No target
Bodor	male	8	Mongrel	High	No target
Frutti	female	3	Mongrel	High	Rotation
Tódor	male	8	Border collie	High	No target
Dorka	female	5	Groenendale	Low	Rotation
Csele	female	1.5	Mudi	Low	No target
Lana	female	2	Croatian sheepdog	Low	Rotation
Amper	male	5	Border collie	Low	Rotation
Maja	female	2.5	Border collie	Low	No target
Angie	female	9	Golden retriever	Low	No target
Hermi	female	3	Mongrel	Low	Rotation
Nico	male	3	Boxer	Low	No target

a doktori értekezés nyilvánosságra hozatalához

I. A doktori értekezés adatai

A szerző neve:.....Gergely Anna.....
 MTMT-azonosító:..... 10044728.....
 A doktori értekezés címe és alcíme:
 Dog (*Canis familiaris*) – robot interaction.....
 Experimental research on dogs' socio-communicative behaviour.....
 DOI-azonosító³⁹:..... DOI: 10.15476/ELTE.2014.019.....
 A doktori iskola neve:....Biológiai Doktori Iskola.....
 A doktori iskolán belüli doktori program neve:....Etológia Program.....
 A témavezetők neve és tudományos fokozata:...(1) Miklósi Ádám - DSc;
 (2) Topál József - DSc.....
 A témavezetők munkahelye:....(1) ELTE TTK Etológia Tanszék; (2) MTA TTK Kognitív
 Idegtudományi és Pszichológiai Intézet.....

II. Nyilatkozatok

A doktori értekezés szerzőjeként⁴⁰

a) hozzájárulok, hogy a doktori fokozat megszerzését követően a doktori értekezésem és a tézisek nyilvánosságra kerüljenek az ELTE Digitális Intézményi Tudástárban. Felhatalmazom a Természettudományi Kar Tudományszervezési és Egyetemközi Kapcsolatok Osztályának ügyintézőjétBíró Évát....., hogy az értekezést és a téziseket feltöltse az ELTE Digitális Intézményi Tudástárba, és ennek során kitöltse a feltöltéshez szükséges nyilatkozatokat.

b) kérem, hogy a mellékelt kérelemben részletezett szabadalmi, illetőleg oltalmi bejelentés közzétételéig a doktori értekezést ne bocsássák nyilvánosságra az Egyetemi Könyvtárban és az ELTE Digitális Intézményi Tudástárban;⁴¹

c) kérem, hogy a nemzetbiztonsági okból minősített adatot tartalmazó doktori értekezést a minősítés (2014.12.30)-ig tartó időtartama alatt ne bocsássák nyilvánosságra az Egyetemi Könyvtárban és az ELTE Digitális Intézményi Tudástárban;⁴²

d) kérem, hogy a mű kiadására vonatkozó mellékelt kiadó szerződésre tekintettel a doktori értekezést a könyv megjelenéséig ne bocsássák nyilvánosságra az Egyetemi Könyvtárban, és az ELTE Digitális Intézményi Tudástárban csak a könyv bibliográfiai adatait tegyék közzé. Ha a könyv a fokozatszerzést követően egy évig nem jelenik meg, hozzájárulok, hogy a doktori értekezésem és a tézisek nyilvánosságra kerüljenek az Egyetemi Könyvtárban és az ELTE Digitális Intézményi Tudástárban.⁴³

2. A doktori értekezés szerzőjeként kijelentem, hogy

a) az ELTE Digitális Intézményi Tudástárba feltöltendő doktori értekezés és a tézisek saját eredeti, önálló szellemi munkám és legjobb tudomásom szerint nem sértem vele senki szerzői jogait;

b) a doktori értekezés és a tézisek nyomtatott változatai és az elektronikus adathordozón benyújtott tartalmak (szöveg és ábrák) mindenben megegyeznek.

3. A doktori értekezés szerzőjeként hozzájárulok a doktori értekezés és a tézisek szövegének plágiumkereső adatbázisba helyezéséhez és plágiumellenőrző vizsgálatok lefuttatásához.

Kelt: Budapest, 2014.10.17



 a doktori értekezés szerzőjének aláírása

³⁸ Beiktatta az Egyetemi Doktori Szabályzat módosításáról szóló CXXXIX/2014. (VI. 30.) Szen. sz. határozat. Hatályos: 2014. VII.1. napjától.

³⁹ A kari hivatal ügyintézője tölti ki.

⁴⁰ A megfelelő szöveg aláhúzendő.

⁴¹ A doktori értekezés benyújtásával egyidejűleg be kell adni a tudományági doktori tanácshoz a szabadalmi, illetőleg oltalmi bejelentést tanúsító okiratot és a nyilvánosságra hozatal elhalasztása iránti kérelmet.

⁴² A doktori értekezés benyújtásával egyidejűleg be kell nyújtani a minősített adatra vonatkozó közokiratot.

⁴³ A doktori értekezés benyújtásával egyidejűleg be kell nyújtani a mű kiadásáról szóló kiadói szerződést.