The emergence of social interaction between Dog and an Unidentified Moving Object (UMO)

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Abstract. With the help of robots important novel questions can be answered in animals' social behaviour. One of the several advantages of this method is that the morphology (embodiment) and behaviour of the robot can be decoupled and combined. In the present study we investigated dogs' social behaviour in a problem solving situation (in which the dog has no access to the food) with three different partners. The *Mechanical UMO* (Unidentified Moving Object) and the *Mechanical Human* differed only in their embodiment, but showed similar behaviour toward the dog. The *Social UMO* was interactive, showed contingent responsiveness, goal-directed behaviour and moved along varied routes. Dogs' showed increased social behaviour toward the *Social UMO* compared to the *Mechanical UMO* which suggests that they recognise some social aspects of UMOs' behaviour. This is the first evidence that dogs are willing to interact socially with a non-living agent that resembles neither dog nor human.

1 INTRODUCTION

In the past few years there has been a huge interest in developing social robots which are able to interact with humans in a meaningful way and immersed in human social networks [1]. It has been suggested that companion animals (especially dogs) may provide useful biological model for developing companion robots which should be designed with a broad range of social skills [2]. From an ethological point of view utilizing robots as a social partner provide also several methodological and theoretical advances: (1) this method enhances the controllability and reproducibility of the experiment (2) and it allows also the experimental separation of the effects of the embodiment and behaviour [3].

Therefore several recent studies have been focused on different aspects of animal-robot interaction. The common feature of these approaches was that the investigators wanted to make the robot as similar as possible to the species studied. For example, Kubinyi and her colleagues [4] investigated dogs' social behaviour toward a dog-like robot (AIBO) and showed that the dogs' age, the experimental context and external features of the AIBO had an effect on dogs' behaviour. In another study dogs encountered a life sized dog model which had either a short or a long, wagging or not wagging tail. Dogs approached more likely the long-tailed model if it was wagging the tail [5]. Examining the importance and key-elements of the embodiment would be important to reveal the flexibilities of animal and also human mind, including evolutionary and developmental factors.

Using artificial agents in a social context may 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. Importantly, in this case the embodiment should be as distinct as possible from the range of objects with which the subject interacts in a social way under habitual conditions. In principle this agent can take any form and shape, so we would 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.

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 agents.

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 [6-8]) where dogs witness the hiding of a piece of food which they cannot get access to. In most cases dogs were successful in directing the naive human to the hiding place by utilizing both gazing and gaze alternations between the food and the human.

Based on these findings, we aimed to compare how adult pet dogs perform in an analogous problem solving task with different partners: 'mechanical' or 'social' UMOs and a 'mechanical' human. 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 to which infants may be sensitive (for a review see [9]). We have hypothesised that dogs would display similar behaviour toward the mechanical partners (UMO and human). At the same time we expected that dogs would increase their social behaviours toward the social UMO after repeated encounters, which would indicate that they are able to recognise some aspects of UMOs' social behaviour.

2 MATERIALS AND METHODS

47 adult pet dogs from different breeds were participated in the test and were assigned to one of three experimental conditions: Social UMO (N=17), Mechanical UMO (N=15) and Mechanical Human (N=15). In the Mechanical UMO and Social

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UMO conditions we used the same remote-controlled 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 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). In order to control for the embodiment we included a Mechanical Human condition in which a female human was the partner. We wanted to make her behaviour highly similar to the Mechanical UMO. She was wearing sun glasses to avoid any kind of eye contact with the dog, 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 condition.

In Mechanical UMO and Mechanical Human conditions the experiment consisted of 6 trials. One trial consisted of the following steps: (1) the experimenter (E) entered the room put three pieces of food into one of the three bowl placed in front of the dog (she baited always the same bowl during the trials), and 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) The owner released the dog from the leash, and it was allowed to move freely for 30 seconds then the dog was called 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 condition consisted of 7 trials. The 1st and the 7th trials were exactly the same as test trials in the Mechanical UMO and Mechanical Human conditions; including the position of the start point of the partner. 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 and finally during Step 3 the car started to move into the box after the dog displayed the first, short (approximately 1 s long) glance at it.

All trials were videotaped and dogs' behaviour during the 30 s of free movement was analyzed later with Solomon Coder 12.06.06 (András Péter http://solomoncoder.com).
Behavioural variables: (1) Looking at the partner (s): looking duration at the partner (UMO or human) (2) Latency of looking at the partner (s): time span from owner releasing the dog until the dog looks first at the partner (UMO or human) (3) Latency of touching the partner (s): time span from owner releasing the dog until the dog touches first the partner (UMO or human) with its muzzle (4) Frequency of gaze alternation: number looks from the partner (UMO or humaon) to the box (place of food) directly or vice versa regardless of order. 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 Binomial GLMM 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 conditions. The square-transformed Looking at the partner was analyzed by the means of a GLMM (Generalized Linear Mixed Model) for Normal distribution. We analyzed Ratio of looking/ touching dogs variables with Binomial GLMM 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 analyzed whether there was a difference in the Latency of touching the partner between the Mechanical UMO and Mechanical Human conditions (GLMM for Normal distribution). We also analyzed the frequency of gaze alternations between the partner and the place of food in the two Mechanical conditions (GLMM for Poisson distribution).We compared the Ratio of looking dogs (with Binomial GLMM), and Latency of looking at the partner (GLMM for Normal distribution) variables among all the 3 conditions. Finally, we compared all first trials and last trials among all three conditions for all observed behavioural variables (Kruskal-Wallis test with Dunn post-hoc test).

4 RESULTS

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

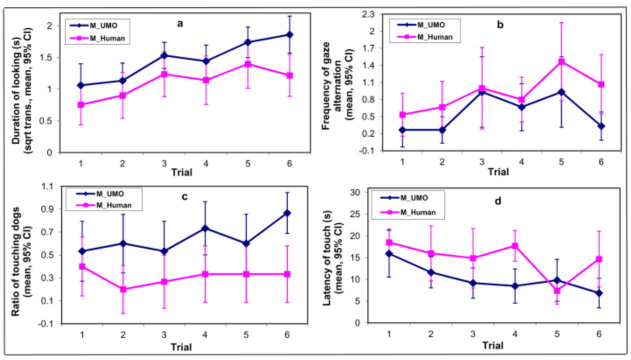

Figure 1. Comparison of different behavioural measures between the Mechanical UMO and Mechanical Human condition

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 ($F_{6,39}=36.7$, $p<0.0001$). Conditions 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 condition than in the Mechanical UMO ($p=0.001$) or in the Mechanical Human condition ($p=0.033$). 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 condition also had an effect ($F_{2,46}=11.15$, $p<0.0001$). Dogs in the Social UMO condition looked first to the partner sooner than dogs in the Mechanical Human condition ($p=0.0001$), but there were no differences between the two types of UMOs ($p=0.069$) or between the two mechanical partners ($p=0.18$).
The aim of the comparisons of dogs' behaviour in the first and last trials was to examine whether dogs showed more intensive gazing and touching behaviours toward the Social UMO than dogs in the mechanical conditions 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 conditions in any of the measured behaviour variables, however during the last trial all variables differed significantly across the conditions (see Table 1). Dogs looked longer at the Social UMO than the Mechanical UMO or the Mechanical Human during the last trial. 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. They were also faster to look at the partner in the Social UMO condition than in the Mechanical Human condition. Latency of touching showed the same pattern. Dogs touched the Social UMO and the Mechanical UMO sooner than the Mechanical Human.

Table 1. Comparison of dogs' behaviour during the first and last trials of each condition.

Kruskal-Wallis Test, Dunn Post-hoc (N=47, df=2)		
Name of the behaviour observed	First trial	Last trial
Looking at the partner	$Chi^2=1.59$, $p=0.45$	$Chi^2=27.46$, $p<0.0001$ SU vs MU p=0.008 SUvs MH p<0.0001
Frequency of gaze alternation	$Chi^2=1.91$, $p=0.38$	$Chi^2=9.03$, $p=0.011$ MU vs SU p=0.008
Latency of looking at the partner	$Chi^2=5.61$, $p=0.06$	$Chi^2=15.2$, $p<0.0001$ SU vs MU p<0.0001
Latency of touching the partner	$Chi^2=1.04$, $p=0.59$	$Chi^2=11.365$, $p=0.003$ SU vs MH p=0.003 MU vs MH p=0.046

(SU= Social UMO, MU= Mechanical UMO, MH= Mechanical Human)

5 CONCLUSION

In the present study we examined 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. In order to observe such interaction we modelled an experimental situation in which the dog is faced with inaccessible food. Miklósi et al [6] showed that in this case dogs increase their looking time at a human helper and show gaze alternation between the inaccessible food and the human. 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 interactivity.
Interestingly, in another study dogs seemed not to show much social interest toward dog-like robot (AIBO) despite close morphological similarity [4] but did not show any direct reactions to initiative behaviours of the dogs. This also suggests that the interactive character of the behaviour on the part of the robot (or in our case the UMO) might play more important role in evoking social responsiveness than the embodiment.
Using an UMO as social partner provides several advantages: (1) 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. (2) It could also help answering the question of how much of the social skills are grounded in the species' embodiment. (3) With the unfamiliarity of the UMO previous social experience which might influenced the interaction can be eliminated. (4) Interaction with UMOs could help in discerning the mental mechanisms related to different forms of social learning [10]. (5) It can also expand the comparison of sociocognitive skills in different species. 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 [11].
In summary, results of the present study revealed that dogs are willing to interact socially with an Unfamiliar Moving Object and easily form expectations about the behaviour of the UMO after a short period of time. This and similar studies might offer useful information in creating social robots which are able to interact and live together not only with humans but also companion animals.

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