Social behaviours in dog-owner interactions can serve as a model for designing social robots

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Abstract

It is essential for social robots to fit in the human society. In order to facilitate this process we propose to use the family dog's social behaviour shown towards humans as an inspiration. In this study we explored dogs' low level social monitoring in dog-human interactions and extracted individually consistent and context dependent behaviours in simple everyday social scenarios.

We found that proximity seeking and tail wagging were most individually distinctive in dogs, while activity, orientation towards the owner, and exploration were dependent on the context and/or the activity of the owner. The functional analogues of these dog behaviours can be implemented in social robots of different embodiments in order to make them acceptable and more believable for humans.

Keywords: dog-owner interaction; social robotics; low-level social monitoring; greeting behaviour; individually distinctive behaviours

Introduction

In the past two decades social robotics has aimed to develop agents that are able to fit in the human social environment (Dautenhahn & Billard, 1999). According to Fong et al. (2003) these socially interactive robots should possess several human social skills like expressing and reading emotions, communicating with humans, using and understanding gestures such as pointing and gazing, etc. Moreover, social robots will share their 'living space' with their owners which requires more elaborate and crafted social skills (Dautenhahn, Woods, Kaouri, Walters, & Werry, 2005). Humans tend to unintentionally assign intentions and social features to inanimate objects (D. Premack & A. J. Premack, 1995) and computers (Nass & Moon, 2000) thus a robot showing such skills would be more easily accepted as a social agent (Duffy, 2003). Several commercially available entertainment and therapeutic robots attempted to exploit this phenomenon (e.g. AIBO: Friedman, Kahn Jr., & Hagman, (2003), PLEO: Jacobsson, (2009), NeCoRo: Libin & Libin, (2004), PARO: Shibata & Wada, (2011)). Anthropomorphism in humans seems to be extremely important if one aims to create robots that need to engage in long-term interactions with humans (Young, Hawkins, Sharlin, & Igarashi, 2009). For example, despite its limited behavioural capacity, the popular domestic robot Roomba is regarded by many people as a pet for the first couple of month after purchase, but after the fading of novelty, it falls back to household appliance status (Sung, Grinter, & Christensen, 2010). This transient effect of novelty is well known in social robotics (Huttenrauch & Severinson-Eklundh, 2002; Takayuki Kanda, Sato, Saiwaki, & Hiroshi Ishiguro, 2007). To reveal the basic behavioural primitives necessary for successful long term social relationships it seems beneficial to investigate natural social systems in which humans interact with non-humans. We suggest that observing specific aspects of human - dog interaction may offer insights for making improvements in present day social robots.

The idea of utilising ethological knowledge and animal behaviour in robotics is not new (Blumberg, 1996), however, such applications have concentrated mainly on the behaviour regulation systems and borrowed ideas from the motivational models (Arkin, Fujita, Takagi, & Hasegawa, 2001, 2003; Breazeal, 1998). Less attention was paid to use the behaviours of non-human animals, such as dogs for modelling social behaviour (Jones, Lawson, & Mills, 2008; Kovács, Vincze, Gácsi, Miklósi, & Korondi, 2010). The dog is an obvious behavioural model for social interactions with humans because in the course of domestication they adopted social skills which allowed them to fit into human society (Topál et al., 2009). Dogs are well suited for cooperating (Naderi, Miklósi, Dóka, & Csányi, 2001) and communicating in different modalities with humans (e.g. visual: Miklósi, Topál, & Csányi, 2004; acoustic: Pongrácz, Molnár, Miklósi, & Csányi, 2005), and show attachment towards their owner that is functionally analogous to that of the human infant - mother bond (e.g. Topál, Miklósi, Csányi, & Dóka, 1998). Dogs can be categorized along similar personality dimensions as humans (Gosling, Kwan, & John, 2003; Kubinyi, Turcsán, & Miklósi, 2009). Moreover, they can serve as helpers of people living with various disabilities, they can cooperate with them in everyday tasks, and can provide social and psychological support as companions. This can give us an excellent natural model for developing socially embedded helper robots (Miklósi & Gácsi, 2012). We argue that the richness of human-dog interaction could be a promising source for improving the behavioural skills of future social robots (Syrdal, Koay, Gácsi, Walters, & Dautenhahn, 2010; Szabó et al., 2010).This might facilitate the emergence of long-term human-robot social relationship, which is one of the most important goals in social robotics (Dautenhahn, 2007; Kaplan, 2001).

Previously researchers have concentrated on focused social interactions when the actors' mutual engagement is necessary to achieve some common goal (e. g. Kerepesi et al., 2005). However, if partners share the same physical space some type of interactions may also occur at a much lower intensity. Thus it may be useful to introduce the term of social monitoring. The function of such behaviour is to maintain readiness for future social interaction. Social monitoring occurs at times when there is a lack in close range face-to face social interactions (e.g. resting after feeding), and may include looking behaviours (e.g. changing head orientation, short glances at group members), low intensity of communicative behaviours, e.g. facial signals in humans, tail wagging in dogs) and the regulation of proximity. Similar situation may occur also in human-robot interactions (e.g. no interaction is initiated by the human). The robot may lose its attraction as an autonomous ("living") creature if it always goes on standby in these situations. Thus it may be useful if the robot is able to show some low level of social monitoring for being aware about the state of the other, in order to increase its readiness to initiate interaction with the human when it is necessary, and for being ready if the partner may initiate some direct social interaction.

Our preliminary observations showed that dogs modify their proximity and gazing behaviour in the presence of the owner when their human partners focus on private activities. Analogous social skills may be advantageous also for a social robot. For example, maintaining a specific social distance (proxemics) is considered as an important factor during human-robot interaction (Walters et al., 2009). Humans tend to let robots closer than strangers in similar social contexts (Walters, Syrdal, Dautenhahn, Te Boekhorst, & Koay, 2008) and humans increased the distance they maintained toward more human-like robots expecting more humanlike proxemics (Syrdal, Dautenhahn, Walters, & Koay, 2008). However, the temporal and contextual aspects of the spatial relations among humans and social robots have not been investigated yet. Reunion and greeting after separation is a special and important episode of the dog-human relationship (Konok, Dóka, & Miklósi, 2011), and the associated behaviours originate from the ritualized greeting ceremonies of Canids (Fox, 1970). Such behaviours like proximity and contact seeking are crucial factors of individualized attachment with the owner (Topál et al., 1998). In social robots greeting behaviour is important for the initiation of interactions (Gockley et al., 2005), and its specificity toward the owner may promote the social relationship between human and robot.

Aims

In this study we investigated the low level social monitoring in dogs in order to give suggestions on behavioural improvement of social robots (Miklósi & Gácsi, 2012). We aimed to reveal behaviours that are individually distinctive and consistent across contexts, and behaviours that are mainly affected by the actual context including the owner's activity and position. We designed a series of short scenarios modelling everyday situations that frequently occur during the daily routine of dog-owner dyads in the absence of active interaction. In some episodes the owner was involved in some activity without moving (sitting at the table and writing/reading) so as we could to test whether the dogs would explore actively or tend to stay close to their owners, and also to test how these behaviours would change over time We also added an episode when the owner behaved somewhat unusually and sat down on the ground instead sitting on the chair. According to Hare, Call, & Tomasello, (1998), such scenario when the owner is sitting on the ground highly affects the dogs' proximity seeking behaviour and attentive state. The dogs' behaviour during separation and greeting can be good indicators of attachment and personality (Konok et al., 2011), thus we used these episodes to explore individual specific behaviours and dog-owner relationship. It is known from earlier studies that dogs show selective attention towards their owners and monitor their movements and prefer to look at them among strangers (Mongillo, Bono, Regolin, & Marinelli, 2010), thus we added one scenario in which the owner was active and busily moved around the room, but still without initiating any interaction with the dog. In this episode we wanted to observe whether the movements of the owner by themselves would affect the dogs' activity and proximity seeking behaviour.

These scenarios could be typical in future human-robot interactions, e.g. when the owner is busy and the robot partner should not disturb him, or during greetings by the robot. We assumed that the context independent behaviours play an important role in the dog-owner relationship because owners can rely on them as being indicators for the dogs' uniqueness (Cavanaugh, Leonard, & Scammon, 2008), that is, the companion's personality (Gosling & John, 1999) . Context specific behaviours, however, could be applied for the development of general rules of social monitoring in social robots in the future.

Materials and Methods

Subjects

Our subjects were 29 owner-dog dyads recruited from the participants of the Dog Ethology Summer Camp 2008 in Kunbaracs, Hungary (for details see Table 1). All dyads participated in the study on a voluntary basis. The dogs were well socialized family pets, 17 females and 12 males from various breeds, with 3 male and 20 female owners (5 owners participated with more than one dog). Two subjects had to be excluded from the analysis due to deviations from the protocol, thus data from 27 dogs with 22 owners were analysed.

Name	Sex	neut.	Breed	age	time w. owner	Owner	Gender	O. age	training
Alma	female	yes	Groendael	4	4	BÁI	female	30	obedience/BH, agility, habilitation
Angel	female	no	Mudi	6	6	CP	female	50	no data
Árgosz	male	no	Hovawart	5	5	BA	female	15	no data
Balcsi	female	yes	Mixed	2	1	PE	female	24	no data
Borka	female	yes	Labrador mix	2		ME	female	28	agility, habilitiation
Brigi	female	yes	Hun. Vizsla	2	2	IA	female	24	obedience/BH, guard dog, agility, hunting dog, habilitation, K99
Buksi	female	no	Mixed	2	2	KFB	female	15	obedience, agility
Charlie	male	yes	Cocker spaniel	1	1	BA	female	51	helper/assistant
Chili	female	no	Mudi	2	2	CP	female	50	no data
Csoki	male	no	Kelpie	5	2	SP	male	33	obedience/BH, herding, frisbee
Dió	male	no	Border collie	6	6	BÁI	female	30	obedience/BH, agility, therapy
Dorka	female	no	Mixed	1	1	VB	female	14	no data
Dzsina	female	no	Airedale terrier	4	4	SD	female	20	no data
Fancy	female	no	Golden retriever	6	6	EN	female	41	therapy
Fecske	female	no	Mudi	7	7	PP	male	38	obedience/BH, herding
Feri	male	yes	Labrador retriever	9	9	BI	male	33	truffle-searching
Guru	male	no	Tervueren	2	2	GM	female	45	agility, IPO, frisbee, therapy, K99
Igor	male	no	Labrador retriever	6	6	BI	male	33	truffle-searching
Jenny	female	yes	Labrador	2	2	LA	female	22	no data
Kíra	female	yes	Mixed	4	3	TL	female	32	obedience, agility,therapy
Kópé	male	no	Cairn terrier	1	1	FB	female	15	obedience, agility
Mogyoró	male	no	Border collie	1	1	BÁI	female	30	obedience/BH, agility, therapy
Mona	female	no	Hun. Vizsla	1	1	TT	female	28	no data
Rea	female	no	Ger. Shepherd	3	3	BG	female	28	no data
Suzie	female	no	Ger. Shepherd	4	3	RB	female	32	no data
Szöszi	female	yes	Poodle	1	1	TL	female	32	helper/assistant
Teo	male	yes	Ger. Shepherd	3	3	SD	female	19	obedience/BH, guard dog, agility
Tódi	male	yes	Golden retriever	2	2	EN	female	41	therapy
Vito	male	no	Aus. Shepherd	2	2	KB	female	28	obedience, herding

Location

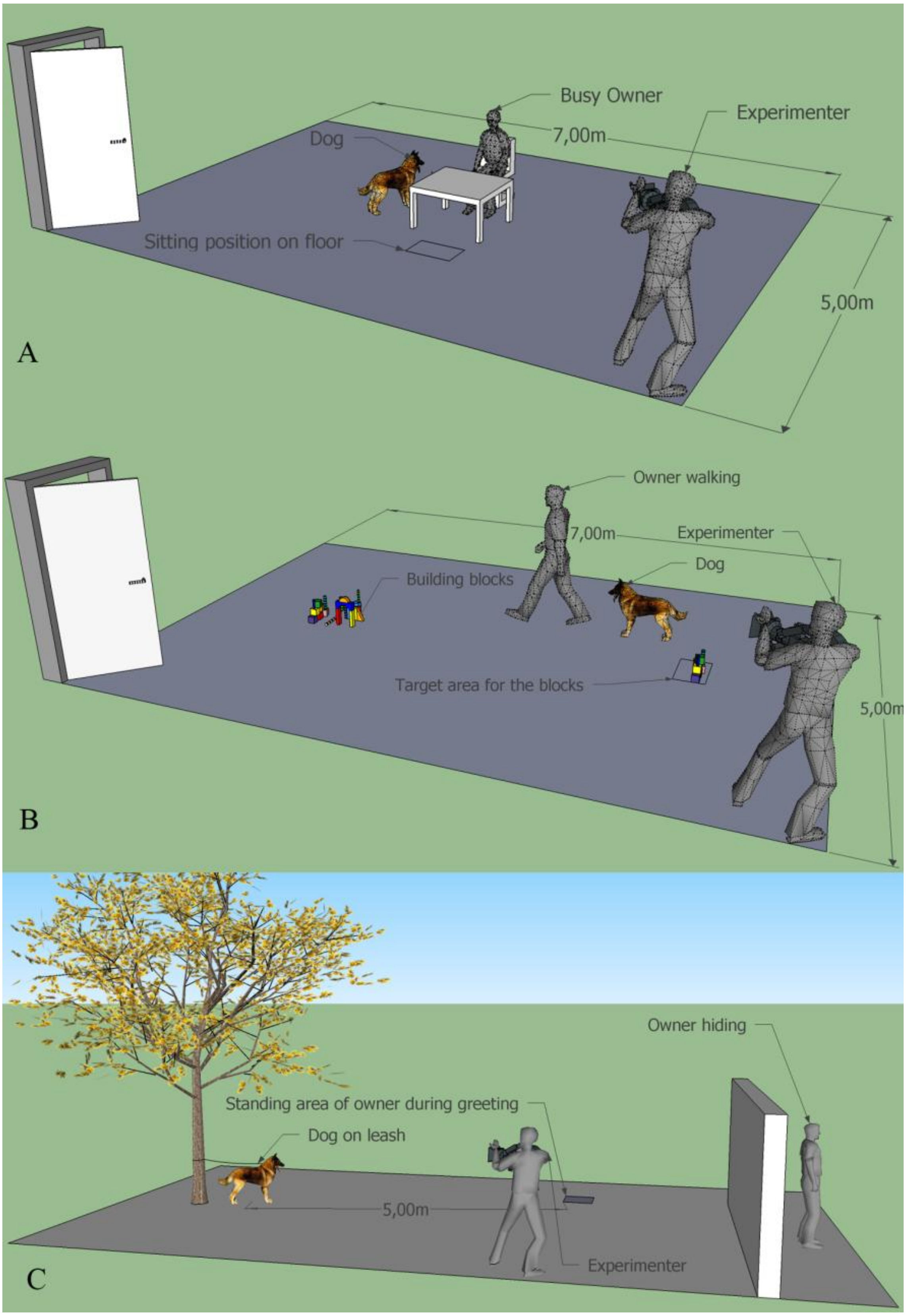
The indoor tests were staged in a 7 m x 5 m empty room that was unknown for both the dogs and owners. The outdoor tests were held on a silent, partially separated area, where no other people or dogs were allowed to come during testing.

Behavioural tests

During the tests the experimenter (B. K. in the indoor tests, M. G. in the outdoor test) recorded the events with a handheld DV camcorder for later behaviour analysis, and in Test 1/Episode 2 a helper (14 various persons [4 males and 10 females] familiar to the dog) was also present. The three tests followed each other in random order and there was a minimum 10-minute-long break between two tests. The owners were not informed *a priori* about the goal of the experiment.

Test 1 – 'Sedentary Owner'

In the middle of the room a table and a chair stood, and the experimenter recorded the events from the corner opposite to the door (Figure 1A). The test started when the owner sat down at the table, and took off the leash from the dog. This test consisted of five episodes:



Busy Owner
Experimenter
Dog
7,00m
Sitting position on floor
5,00m
A
Owner walking
7,00m
Experimenter
Dog
Building blocks
Target area for the blocks
5,00m
B
Owner hiding
Standing area of owner during greeting
Dog on leash
5,00m
Experimenter
C

Episode 1 (Owner is busy 1 – duration: 2 min): The owner sat on a chair in the middle of the room and completed a questionnaire. The dog was allowed to move freely around. The owner was asked not to talk to, look at or initiate interaction with the dog.

Episode 2 (Separation and Passive Greeting – 1.5 min & 10 s): The helper entered the room, took the dog on leash and led it out of the room, the experimenter stayed in and paused the recording. After 1.5 minutes of separation while the helper and the dog waited outside passively, the helper opened the door, unleashed the dog in front of the door and let it into the room. During the separation and the greeting the owner continued filling in the questionnaire due to having been asked not to interact in any way (verbally or physically) with or look at the dog during the reunion. The Passive greeting was recorded for maximum 10 seconds.

Episode 3 (Owner is busy 2 – 2 min): This episode is the same as episode 1.

Episode 4 (Owner sits down on the floor – 10-15 s): The experimenter asked the owner to stand up, go around the table and sit down on the floor on the other side of it (Figure 1A). The owner was told not to interact with or look at the dog during this action. This episode lasted approximately 10-15 seconds depending on the owners' speed.

Episode 5 (Owner is busy on the floor): This episode was identical to episode 1 and 3 except that the owner sat on the floor, completed the questionnaire and did not interact with or look at the dog.

Test 2 – 'Mobile Owner'

In this scenario the owner actively engaged in a task that included moving around in the room without initiating interaction with or looking at the dog. In the otherwise empty test room 20 plastic toy building blocks were placed in a pile on the floor (Figure 1B).

The owner's task was to carry these blocks walking slowly from one end of the room to the other. The owner had to pick up a single block, manipulate it and carry it to a marked spot on the floor at the other end of the room (approx. 5.5 m distance) to build a new pile and then go back for another block. The dog was unleashed and was allowed to move freely in the room. The owner was instructed not to interact with or look at the dog during the test. The test lasted for 3 minutes irrespective of the number of blocks carried by the owner. On average the owners carried 8 blocks during the test.

Test 3 – 'Separation and active greeting'

In this outdoor test the owner left the dog alone, and returned after one minute. The experimenter recorded the behaviour of the dog from approximately 20 meters (Figure 1C).

The test contained three episodes:

Episode 1 (Separation): The owner tethered the dog to a tree, left without talking to it, and hid behind a building. The owner was out of sight for one minute.

Episode 2 (Approach): Before the Approach, the owner returned on the experimenter's signal and stopped at a marked point at 5 m distance from the dog. The owner was instructed not to talk to the dog or move till the experimenter asked him/her to greet the dog. The episode started when the experimenter went to the dog and unleashed it so that it was free to go to the standing owner. The episode lasted until the dog got in reaching distance to the owner. If the dog did not approach the owner, after 1 minute the experimenter asked the owner to call the dog.

Episode 3: (Active greeting): In contrast with the Passive greeting, now the owner was allowed to greet the dog actively in the usual, habitual way, without any restrictions.

The episode was terminated when the owner or the dog broke up the greeting by turning away or shoving off.

As the experimenter was present in each episode, observed the events only via the camera, was motionless, initiated no interaction with and showed no reactions at the dogs, we can assume that the presence of the experimenter did not have significant impact on the dogs' behaviour. This is supported by the fact that dogs did not tried to interact with the experimenter. Also the sections when the experimenter instructed the owner during the episodes were not included in the analysis.

Data collection

The behaviour of the dogs was coded from the video recordings by using the Solomon Coder (© András Péter: http://solomoncoder.com/). The following behavioural units were measured on a 0.1 s basis:

- Orientation towards owner (s): duration of looking at the owner in Test 1 and 2 or orienting at her/his assumed direction during separation in Test 3, Episode 1.
- Proximity (s): duration of being within a distance of the dog's body length to the owner with or without physical contact with her/him.
- Exploration (s): duration of looking closely or sniffing at the objects both with and without body movements (except exploring the building blocks in the Mobile Owner test).
- Block exploration (s): duration of looking closely or sniffing at the building blocks in the Mobile Owner test.
- Tail wagging (s): duration of wagging the tail. Horizontal tail movements were considered as tail wagging (excluding the movements due to the hip rotation during walking or running).

- Activity (s): all locomotive behaviours (walking, running and changing body position) were coded as activity. In the Mobile Owner test owners' activity was also coded.
- Following (s): the dog is moving in the same direction as the owner either by remaining in proximity (within a distance of its body length) to the owner, or following the same route as the owner with some delay (Mobile Owner test).
- Latency of Getting close (s): the time needed for the dog to get in proximity (within a distance of its body length) of the owner during the Passive and the Active greeting (maximum latency was 10 seconds in Test 1/ Episode 2, and 60 seconds in Test 3/Episode 2).

We calculated the time ratios (percentage) of the coded behavioural variables (excluding latencies), and used these data as input for further analysis. During the Active greeting we coded also whether the owner or the dog initiated and terminated the interaction. The dog was considered as initiator when it jumped or rubbed itself against the owner's leg or sniffed the owner first. If the owner reached out for the dog and stroked it first, she/he was recorded as initiator. The dog terminated the greeting, if it backed, turned away, left the owner, or tried to leave while the human was holding it back by gentle force. The owner was regarded as the terminator when the dog kept orienting or jumping at the owner, while the owner oriented at the experimenter, or left the dog and told it to stop greeting, or ignored it.

Behaviour analysis

We applied nonparametric statistical methods because our behavioural variables were not normally distributed. As we aimed to differentiate contextually independent and dependent behaviours we attempted to simplify our dataset by pooling the behaviours between the episodes with similar contexts. We assumed that several behaviours will be similar in these similar episodes and pooling together them will enhance the difference between context dependent and independent behaviours. Therefore first we checked using Friedman tests with Dunn post hoc tests or Wilcoxon signed rank test (depending on the number of episodes), if there is any difference in the behaviours of the dogs within similar contexts (see later). If no significant difference was found, we pooled the episodes together into four possible context categories by summing the time of a behavioural unit from all episodes with similar contexts and calculating the time percentage of the total time of these episodes for further analysis. The context categories were the following:

- Busy owner (BO): owner is in a room, she/he is busy but not moving (Test 1/Episodes 1, 3 and 5)
- Moving owner (MO): owner is in a room and he/she is moving (Test 1/Episode 4 and Test 2)
- Separation (S): owner is absent (Test 3/Episode 1)
- Greeting (G): reunion after separation (Test 1/ Episode 2 and Test 3/Episode 2 and 3).

Within the Busy Owner context category we found significant differences between the different episodes in exploration (Friedman test: $\chi^2(2)=31.743$; $p<0.001$) and activity (Friedman test: $\chi^2(2)=20.579$; $p<0.001$). In Moving Owner context category the orientation (Wilcoxon signed rank test: $Z=-4.397$; $p<0.001$) and exploration (Wilcoxon signed rank test: $Z=-4.107$; $p<0.001$) differed between the two episodes, while in the greeting context category orientation (Friedman test: $\chi^2(2)=17.276$; $p<0.001$), proximity (Wilcoxon signed rank test: $Z=-4.543$; $p<0.001$) and tail wagging (Friedman test:

$\chi^2(2)=14.999$; $p=0.001$) were different. In case of the above behaviours the episodes were treated separately in the further analysis.

In the main analysis we tested whether behavioural variables are influenced by the test episodes or in case of the derived variables the context categories.

To reveal whether the movements of the owner and the dog were somewhat synchronous during the Mobile Owner test, we compared the percentage of the time when the owner and dog were both active or passive (we considered the owner being passive when he/she manipulated the blocks without moving, standing or crouching near the blocks) versus the duration when only one of them was active with Chi Square test of independence.

Individually consistent behaviours were revealed by using Kendall Tau test for behavioural variables across the different context categories or episodes. (The Kendall Tau test treats equally the extremes and the medium data points, giving more accurate results on our dataset than Spearman test (Everitt & Howell, 2005).)

Additionally, we checked if there is any correspondence among relevant behavioural units with correlation tests, and also tested whether behaviours associated with attachment and greeting affect each other, by categorizing dog-owner dyads by who initiates or stops the greeting first and comparing their behaviours in other tests with Mann-Whitney test.

Due to the multiple comparisons we applied FDR correction (Benjamini & Yekutieli, 2001) to avoid high rate of false discovery. We also tested whether the participation of owners with more dogs affected our results by repeating our statistical tests but randomly excluding one of the dogs of such owners. We found that this exclusion did not alter our results.

Results

Overview of dog behaviour in different episodes

Busy Owner

Most of the dogs actively explored the room during the first Busy Owner episode. Moreover, 18 out of the 27 dogs were active in more than 40 % of the time (higher than the average time percentage). In the Owner is busy on the floor episode eight dogs did not move at all, and the majority of the dogs showed no exploration. Although their owner initiated no interaction and showed no attention towards them, each dog oriented towards their owner and most of them wagged their tail for some time (Table 3).

Moving owner contexts

When the owner was active during changing position (Owner sits down on the floor episode) all dogs oriented at her/him.While the owner was carrying the building blocks in the Mobile Owner test, all dogs were active. We also measured the association between the activity of the dog and owner in this test, in order to see whether the owner's activity affected the dog's behaviour (Table 2). We found that the dog and the owner was in synchrony on average 60.5 % of the time, and when both were active, the dogs followed the owners for 50.4 % of the time. The dogs' activity was significantly affected by the owners' behaviour ($\chi^2_{(1)}$=2886.7; p<0.001).

		Owner	
		Active	Passive
Dog	Active	34%	20.33%
	Passive	17.67%	28%

Overall, most of the dogs wagged their tail but only in a short period of time, and 17 were active. None of them explored the room, instead 14 stayed in close proximity to the owner on average 43.7 % of the time. Most of the dogs explored the room during the Mobile Owner episode, and they looked at the owner more than the third of the time on average.All but one dog explored the building blocks (Table 3).

Separation

In the Separation episode dogs looked in the direction the owner had disappeared in the half of the time. Some dogs explored their vicinity and the maximum tail wagging of approximately 20 % of time was displayed only by five dogs (Table 3).

Passive Greeting and Approach

During the Passive Greeting, approximately half of the dogs (15 out of the 27) approached their owner within two seconds. All but one dogs oriented towards their owner during the approach, and most of them wagged their tail during the greeting in spite of the owners' unusual passive behaviour.

During the outdoor reunion in the Approach episode the dogs approached the owner with variable speed; nine dogs approached the owners in less than two seconds, other 11 dogs in 2-5 seconds. The slowest approaches took 5-30 seconds.

All the dogs oriented at the owner for some time during the approach, only one did not wag its tail, and 19 out of the 27 wagged their tail more than half of the time. (Table 3).

Active Greeting

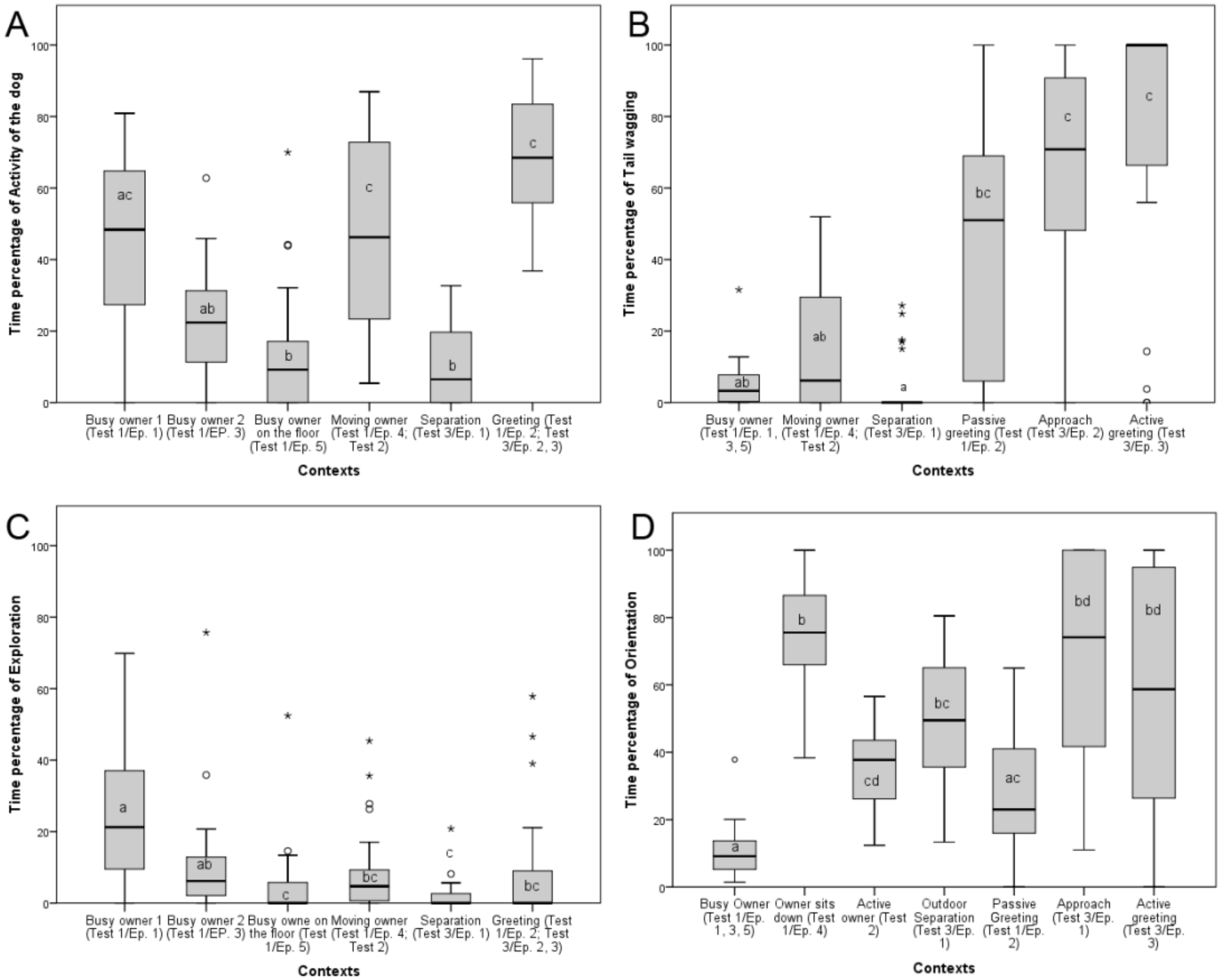
The average total duration of the Active greeting was 8 seconds. We determined which partner initiated and terminated the physical contact during the greeting. Out of the 13 dog owner dyads, in which the human was the initiator, the dog terminated the greeting in 12 cases. In the other 14 dyads, where the dog initiated, the human terminated the greeting only in 4 cases. Eighteen dogs wagged their tail for more than 80 % of the time, and only one dog did not show tail wagging. All but one dog oriented toward the owner, and most of them (16) were looking at the owner for more than half of the duration of the greeting. All dogs stayed in proximity to the owner during the episode in more than 80 % of the time (Table 3).

Context	Busy owner			Moving owner		Separation	Greeting		
Episode	**Owner is busy 1**	**Owner is busy 2**	**Owner is busy on the floor**	**Owner sits down**	**Mobile owner**	**Separation**	**Passive Greeting**	**Approach**	**Active Greeting**
Average time percentage of the behaviours									
Orientation	9.90±7.5 (2.08)			73.75±17.37 (-0.36)	34.97±11.59 (-0.34)	51.09±17.27 (-0.16)	27.70±16.33 (0.26)	67.43±31.65 (-0.42)	57,17±36.01 (-0.21)
Proximity	46.71±29.04 (0.08)			45.48±25.29 (0.18)			37.44±29.42 (0.38)		98.86±3.6 (-3.51)
Exploration	25.46±19.63 (0.67)	10.75±15.41 (3.20)	4.82±10.69 (3.69)	0.00	8.46±11.85 (1.95)	2.08±4.35 (3.42)	8,60±15.36 (2.23)		
Tail wagging	5.03±6.87 (2.44)			15.10±18.14 (0.85)		3.76±8.31 (1.98)	44.56±35.28 (0.06)	65.51±28.69 (-0.65)	78.37±33.71 (-1.49)
Activity	44.42±24.00 (-0.47)	22.75±15.31 (0.64)	13.76±17.13 (1.80)	47.83±25.79 (0.10)		10.40±11.21 (0.70)	68.98±16.92 (-0.18)		
Number of dogs showing the behaviour units									
Orientation	27			27	27	27	26	27	26
Proximity	27			27			23		27
Exploration	25	23	11	0	22	10	12		
Tail wagging	21			16		5	20	26	26
Activity	25	26	19	27		19	27		

Context dependent behaviour changes

Orientation

We compared the percentage of orientation at the owner between the Busy Owner context category and the following episodes: Passive Greeting, Owner sits down, Mobile Owner, Separation, Approach and Active Greeting. Dogs oriented less towards the owner when she/he was passive (Busy Owner) ($\chi^2_{(6)}$=83.773; $p<0.001$), and oriented the most when the owner changed position and sat down to the floor (Owner sits down) and during the Approach and the Active Greeting (Figure 2A). They also oriented slightly more in the direction of the owner when the owner left the dog during the Separation than when the owner was busy.


A
Time percentage of Activity of the dog
Busy owner 1 (Test 1/Ep. 1)
Busy owner 2 (Test 1/EP. 3)
Busy owner on the floor (Test 1/Ep. 5)
Moving owner (Test 1/Ep. 4; Test 2)
Separation (Test 3/Ep. 1)
Greeting (Test 1/Ep. 2; Test 3/Ep. 2, 3)
Contexts
B
Time percentage of Tail wagging
Busy owner (Test 1/Ep. 1, 3, 5)
Moving owner (Test 1/Ep. 4; Test 2)
Separation (Test 3/Ep. 1)
Passive greeting (Test 1/Ep. 2)
Approach (Test 3/Ep. 2)
Active greeting (Test 3/Ep. 3)
Contexts
C
Time percentage of Exploration
Busy owner 1 (Test 1/Ep. 1)
Busy owner 2 (Test 1/EP. 3)
Busy owne on the floor (Test 1/Ep. 5)
Moving owner (Test 1/Ep. 4; Test 2)
Separation (Test 3/Ep. 1)
Greeting (Test 1/Ep. 2; Test 3/Ep. 2, 3)
Contexts
D
Time percentage of Orientation
Busy Owner (Test 1/Ep. 1, 3, 5)
Owner sits down (Test 1/Ep. 4)
Active owner (Test 2)
Outdoor Separation (Test 3/Ep. 1)
Passive Greeting (Test 1/Ep. 2)
Approach (Test 3/Ep. 1)
Active greeting (Test 3/Ep. 3)
Contexts

Proximity

The time percentages in proximity were compared between the Busy and Moving Owner context categories and the Passive Greeting episode. In this analysis we did not include those episodes when the dogs' movements were limited (Separation), and their approach to their owner (Approach) or their withdrawal from the owner (Active Greeting) meant the end of the episode. We found no significant difference (Friedman test: $\chi^2_{(2)}$=4.741; p=0.093) among the Busy and Moving Owner context categories and the Passive Greeting episode. The owner's activity and the context did not affect proximity seeking significantly during the passive owner contexts.

Exploration

Dogs did not explore at all when the owner sat down onto the floor, thus we left out this episode from this analysis. Dogs showed the highest rate of exploration when the room was a novel place for them and the owner was passive in the Busy owner 1 and 2 episodes (Figure 2C). They explored the least, when they were separated (Separation), and when the owner worked on the floor (Busy owner on the floor) (Friedman test: $\chi^2_{(5)}$=54.145; p<0.001).

Tail wagging

The dogs wagged their tail mostly during the Approach and the greetings (Passive and Active), and the least when they were separated (Separation) (Friedman test: $\chi^2_{(5)}$= 80.115; p<0.001). The owners' activity had no significant effect on this behaviour (Figure 2B).

Activity

We compared the activity of the dogs among the episodes in which the owner was passive (Busy Owner 1, 2 and Busy Owner on the floor) and the Moving owner, Separation and Greeting context categories and found significant differences (Friedman test: $\chi^2_{(5)}$= 74.41; p<0.001). In the episodes with passive owners (Busy Owner 1, 2 and Busy Owner on the floor) the dogs' activity decreased: in the first episode (Busy owner 1) they were as active as during Greetings and when the owner was active (Moving Owner), while the dogs were least active when the owner sat on the floor and during Separation (Figure 2D).

Individually consistent behaviours

We calculated the correlations for each behaviour element across the context categories or episodes. We found no significant correlations in the case of orientation and exploration between all the context categories. Also the latency of approach during the Passive and Active Greetings showed no significant relationship.

Proximity

Keeping proximity with the owner was consistent across the contexts. Dogs staying close to their owner when he/she was passive (Busy Owner) spent more time in proximity also during the Passive Greeting and when the owner was active (Moving Owner). (BO - MO: $\tau_{(27)}$=0.516; p<0.001, BO – PG: $\tau_{(27)}$=0.576; p<0.001, MO - PG: $\tau_{(27)}$=0.472; p=0.001).

Tail wagging

We found strong positive association between the indoor episodes (Busy Owner, Moving Owner, Passive Greeting) where independently from the owners' activity or the context, each dog showed consistency in its tendency for tail wagging (BO - MO:

$\tau_{(27)}$=0.4; p=0.006, BO - PG: $\tau_{(27)}$=0.462; p=0.001). There were no significant correlations with the outdoor episodes (Separation, Approach, Active Greeting).

Activity

For most cases we did not find any correlations in the activity of the dogs across the episodes. Interestingly, dogs showing low level of activity in the first Busy owner episode were more active in the Greetings context category ($\tau_{(27)}$=-0.411; p=0.003). Activity of dogs when the owner was busy on the floor correlated positively with that of observed in the Moving Owner context ($\tau_{(27)}$=0.514; $p<0.001$).

Other related behaviours

We also measured correlation of behaviours that can be relevant in the dog-owner relationship and for designing social robots. We presumed that dogs that spent more time in proximity were more attached to their owners, therefore we analysed the relationship between the durations spent in proximity, orientation at the owner and greeting behaviours, which all can be indicators of the dogs' attachment. We found no significant connection between proximity and the latency of approach in neither of the contexts. Dogs that oriented more at the owner during the Passive Greeting spent more time in proximity with her/him in the same episode ($\tau_{(27)}$=0.550; $p<0.001$) and also when the owner was busy (Busy Owner: $\tau_{(27)}$=0.444; p=0.001).

Active greeting

We assumed that identifying the initiator and terminator individual in the Active Greeting reflects on the human-dog relationship, and is related to the behaviours displayed during Separation and the other episodes. We found that if the owner started the greeting interaction then the dog looked significantly less at the owner during the

Active Greeting (U=34; p=0.006). During Separation these dogs explored more (U=31; p=0.001) and were more active (U=44.5; p=0.022). In those dyads where the dog terminated the greeting, the dog spent less time in proximity when the owner was passive (Busy Owner) (U=15; p=0.013), and the dog was more active (U=12; p=0.007) and explored more (U=9; p=0.004) in the Busy Owner 1 episode. All these suggest that less attached dogs' owners tend to start the greeting, and these dogs finish the interaction sooner.

Discussion

In the present study we have utilised the interaction between family dogs and their owners for revealing low level social behaviours that can enrich the behavioural repertoire of social robots. Although the present findings are also interesting from the point of view of human-dog interaction here we emphasise their potential to be applied in social robots. Thus in the following discussion of the behavioural observations we provide some suggestions how these features of dog behaviour may inspire robot design (see also: Miklósi & Gácsi, 2012).

In general, pet dogs actively explored the novel room, and they oriented towards their owner and wagged their tail even while their owners were busy and unresponsive. These behaviours might be attempts to initiate interaction with their owners, but in the absence of the owners' response dogs discontinued these activities. They became passive but stayed attentive to the owners' actions. When the owners were active, dogs oriented more towards them and were more active because they followed the movements of the owner. When left alone, dogs showed moderate separation behaviour with low activity, no tail wagging and looking at the assumed direction of the owner. During greetings dogs approached the owner, wagged their tail, and stayed in his/her proximity for the greeting.

Due to the high variance among dogs and the marked differences between contexts we could reveal both individually consistent and context specific behavioural variables. The proximity seeking behaviour seemed to be the most characteristic feature of the individuals, because it was independent from the context. In our sample some dogs maintained proximity to the owner independently of the owner's behaviour, while others were more active and wandered farther away from their owner. Thus we can characterize our subjects by their willingness to be in proximity. Those dogs that stayed closer to their owner looked more at their owner during reunion and typically it was their owner who terminated the active greeting interaction. In contrast, owners of less attached dogs tried to "enforce" longer interactions with their dogs during the active greeting.

Proximity is one of the most important indicator of attachment behaviour in human infants (Bowlby, 1969) and in dogs (Topál et al., 1998). Proximity to a companion is advantageous in the case of unexpected events, and lowers stress and glucocorticoid levels (Tuber, Sanders, Hennessy, & J. A. Miller, 1996). It follows that proximity seeking dogs might be more attached to their owners or more stressed by the test design than the more explorative and active ones that wandered farther away from the owner. Former studies have also found that the tendency for proximity seeking can be considered as a personality trait in dogs. In the Strange Situation Test, Fallani et al. (2006) characterized dogs by the means of three behavioural categories (playfulness, fearfulness and proximity seeking), while Marinelli et al (2007) reported on two character dimensions (attachment and insecurity). In both studies the tendency for searching close contact with the owner was a strong indicator of dependency in the dog. Similarly, Henessy et al (2001) characterised a sociability trait mainly by proximity seeking behaviour.

Owner's neuroticism can positively affect the proximity seeking behaviour of dogs (Wedl, Schöberl, Bauer, Day, & Kotrschal, 2010), and in parallel the personality of the human user affects the acceptable distance with robots during interaction: more proactive humans kept longer distance (Walters et al., 2005).

Tail wagging was also individually distinctive during the indoor episodes. This suggests that the dogs' personality influences this behaviour. In dogs, the tail is considered as a signaller of inner state (e. g. Leaver & Reimchen, 2008; Quaranta, Siniscalchi, & Vallortigara, 2007). Its positioning and frequency of movements in its full length or just partially give a high degree of freedom to communicate different emotional states: e.g. during submissive displays we can see low and curved position of the tail with a high frequency wagging at the tip, while during dominant displays low frequency and high amplitude movements and elevated position is typical (Kleiman, 1967). In our study this behaviour appeared mostly during greetings, probably signalling the excitement of the dog. This can be supported by owners' tendency to interpret such tail wagging as an expression of happiness, and also inexperienced persons report tail wagging as friendly, playful signalling (Tami & Gallagher, 2009).

Other behavioural features of the dogs were mainly context dependent, thus in these cases we can assume general tendencies. The owners' activity influenced the orientation and the activity of the dogs. Dogs looked more at their owner and were more active when the human was moving. The tendency to explore depended mainly on the context and not the general activity of the owner in the episodes. Tail wagging, besides it's individually distinctiveness, was also somewhat affected by the episodes, but not the owner's behaviour.

Dogs' orientation was mostly affected by the activity of the owner, but they also oriented a lot towards their owner during greeting and towards the assumed direction of the owner when they were left alone. Earlier studies showed that this attention towards humans can be selective, dogs are more aware of the actions of their owner than those of an unfamiliar person. Studies on human-robot interaction focus mainly on the role of attention and orientation in verbal (e.g. Lang et al., 2003) or gestural (Scassellati, 1999) social interactions. In our study, the activity of dogs can be divided into two categories based on the context. First, dogs explored the room mainly when the owner was passive, but this behaviour decreased over time. The habituation of exploration in unfamiliar testing locations was also reported in the Strange Situation Test (Gácsi, Topál, Miklósi, Dóka, & Csányi, 2001; Topál et al., 1998). Second, dogs reacted with some activity if the owner was active. For example, dogs followed the owners' movements, and were attentive towards the focus of the owners' activity when the owners were manipulating the building blocks. Such behaviour and specific attention towards the owner and her/his actions can form the basis for social learning (Pongrácz et al., 2001) and cooperation (Naderi et al., 2001).

We can draw several parallels between our results and significant issues in social robotics. The importance of spatial relations in HRI has been recognized for a long time: the questions of what the suitable distance is between the interaction partners and how it should change dynamically with the change of the relationship between the partners or the context have been explored by several studies (e.g. Huettenrauch, Eklundh, Green, & Topp, 2006; Tasaki, Komatani, Ogata, & Okuno, 2005; Walters et al., 2005; Yamaoka, T. Kanda, H. Ishiguro, & Hagita, 2010). However. proximity seeking behaviour for example may be programmed not only as a function of space but also as a function of time and context in order to match users' personality and expectation (Walters et al. 2009). For example, a robot showing increased proximity seeking may convey an impression of a more dependent companion. Such robot would fit better a person with higher neuroticism, similarly to what Wedl et al. (2010) found in case of dogs.

The expression of emotions is a commonly acknowledged feature in social robots too (Breazeal, 2003). In most cases the constructors rely on displaying human-like emotions using facial displays or body gestures (Bartneck, Reichenbach, & Van Breemen, 2004). Affective behaviour in robots could be also inspired by emotional behaviour in dogs, although one should avoid using a one-to-one copy. In a recent study a Roomba robot were modified to have a doglike appearance and communicative apparatus. Humans preferred the machine like appearance and beeping sounds to barks (Jones et al., 2008). Thus, using a general visual signaller as a functional analogue of a tail, with similar dynamics but different appearance and position might be a better option, than mimicking a wagging dog tail.

Our results also suggest that a companion robot should also pay selective attention when the user moves without initiating interaction with the robot. The robot should show interest to the user's actions by orienting, approaching and attempting to interact, and the level of the interaction initiation can reflect personality types of the robot and the owner. Moreover, for a socially interactive robot, especially helper robots, it can be important to be at hand at any time but without annoying the user (Koay, Dautenhahn, Woods, & Walters, 2006). This can be achieved by a closer behavioural synchrony between the robot and the user, similarly to what we observed in the Mobile Owner contexts.

Limitations

Besides its clear potential benefit for designing social robots, being only the first step of a complex study, our work has some limitations. Dogs may behave differently at an unfamiliar place compared with a home setting, showing probably less explorative behaviour and being less active in general. Also during separation it can be assumed that at home the dogs would be less alert and behave more calmly. However we can assume that the proximity and the greeting behaviours would be less affected by the environment. Due to our relatively low sample size, we could not explore the possible effect of dogs' age, breed and other background factors. This may, however, not related closely to robotic application.

Experiments involving real robot-human interactions should be performed to test how social interactions adapted from the dog-human contexts can affect humans' acceptance and attitude towards social robots. With systematic modification of those factors we revealed in our study we plan to test how the specific robot behaviours can affect the human users' comfort and impressions on their interactions with the social robot.

Conclusion

Our initial point was that social robots might be more acceptable to humans if their behaviour is modelled on the basis of human-dog interactions. Thus we urge for the implementation of the robot analogues of these dog behaviours and test different robotic agents in realistic social settings. Adjusting the robot's behaviour by simple rules of social monitoring (e.g. modifying approach speed and the time spent in proximity, implementing gazing behaviour) will also provide it with the advantage of reacting faster to human initialisations. Thus the following guidelines may prove to be useful for constructors.

(1) Independently from the individual specifications, social robots should be aware of the movements and activity of the users, they should orient towards them when they change position, and stops orienting if they do not initiate interaction (as the dogs did in the Sedentary owner episodes). Dogs adjusted their activity to that of the owners', which suggests that robots should synchronise their movements with the human users when they are actively moving, and follow them from a distance when they move out of view to have up-to-date positional or activity information about the users.

(2) Social monitoring could be implemented also on robots lacking facial expressions (e.g. the Roomba) by adjusting the speed of approach, the time spent in proximity during greeting that were individually distinctive in our subjects, and, for example, applying a simple mechanical signaller for showing basic emotions similarly to dogs' ears or tail, which movements are interpreted by humans as emotional signals.

(3) If social robots are able to discriminate between the object of attachment (the user) and others then they could express their behaviour in an individual-specific way toward different persons in their environment.

(4) Appropriate variations of social behaviours could contribute to the robot being perceived as having a 'personality' or being more vs. less dependent on the user. This dependency can be emphasised mostly by differences in proximity seeking and greeting behaviours. More dependent companions should spend more time in the proximity of the user, approach them faster during reunion and greet them longer.

Moreover, with further fine tuning by learning and adaptation we can advance long-term relationship with humans.

In conclusion, we suggest that more acceptable robots could be created by taking insights from human-dog interactions. If done appropriately, this behavioural "enrichment" can give recognizable personality for the robots, and make them more live-like and easier to accept. This would certainly improve their chances for developing long-term relationship with humans.

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Figure captions

Figure 1.

A, The arrangement of the room in the Sedentary Owner Test.

B, The arrangement of the room in the Mobile Owner Test.

C, The arrangement of the Separation and the Active greeting

Figure 2.

A, The medians of the time percentage of orientation towards the owner in various tests and episodes.

B, The medians of the time percentage of exploration.

C, The medians of the time percentage of tail wagging.

D, The medians of the time percentage of activity.

The boxes show the upper and lower quartiles, the whiskers show the lowest and highest non-outlier values. The groups were compared by Friedman ANOVA. The different letters refer to significant differences obtained by Dunn's post hoc tests ($p<0.05$). Two letters in one box represent an intermediate between the boxes with same letters not differing from either. The order of the boxes reflects the coherent contexts and not the actual order in time.

Table captions

Table 1: The background variables of the participant dog-owner dyads, showing the sex, neutering status, breed, age and training experience of the dog. It also contains the owners' gender and age and how long the dog lives with them.

Table 2. The average time percentage of the dogs' and the owners' activity during the Mobile Owner test. We considered the owner being passive when he/she manipulated

the blocks without moving, standing or crouching near the blocks and the dog passive when it did not move at all (sitting, standing or laying). We measured the percentage of the time when both the owner and dog was active or passive, and also when only one of them was.

Table 3. The number of dogs and the mean, standard deviation and skewness (in brackets) of the time percentage of behaviour units in the context categories and episodes. The first row of the table shows the Context categories. Cells with grey background refer to these, while cells with no background indicate values measured in the episodes shown in the second row.