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# Social behaviour of dogs encountering AIBO, an animal-like robot in a neutral and in a feeding situation

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**Abstract**

The use of animal-like autonomous robots might offer new possibilities in the study of animal interactions, if the subject recognises it as a social partner. In this paper we investigate whether AIBO, a dog-like robot of the Sony Corp. can be used for this purpose. Twenty-four adult and sixteen 4–5 months old pet dogs were tested in two situations where subjects encountered one of four different test-partners: (1) a remote controlled car; (2) an AIBO robot; (3) AIBO with a puppy-scented furry cover; and (4) a 2-month-old puppy. In the neutral situation the dog could interact freely with one of the partners for 1 min in a closed arena in the presence of its owner. In the feeding situation the encounters were started while the dog was eating food. Our results show that age and context influence the social behaviour of dogs. Further, we have found that although both age groups differentiated the living and non-living test-partners for some extent, the furry AIBO evoked significantly increased responses in comparison to the car. These experiments show the first steps towards the application of robots in behavioural studies, notwithstanding that at present AIBO's limited ability to move constrains its effectiveness as social partner for dogs.


*Keywords:* Social recognition; Social behaviour; Dog; AIBO; Artificial ethology; Robot design

## 1. Introduction

Several studies have shown that robots can be used as a tool in biological research; robots can model many aspects of animal structure and function; robots can gather data from animals; and performance of animal-like robots in life-like situations can be studied by behavioural scientists (Holland and McFarland, 2001; Webb, 2000). We argue for yet another role, that is, carrying out interactive behavioural experiments with animals. A few attempts to apply robotics in animal behaviour tests have already taken place. Studying the communicative behaviour of honeybees Michelsen et al. (1992) found that these insects readily respond to the signals displayed by a 'dancing robotic bee' in collecting food to be taken back to their home. Takanishi et al. (1998) staged interactions between rats and robot-rats using a social learning set-up. However, it is not necessary for an ethologist to develop a robot on his own. The recently available animal-like 'entertaining' robots (e.g. AIBO, Sony Corp., 1999; NeCoRo (robotcat), Omron, 2001) could be used.

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Fig. 1. A first and second generation AIBOs are "playing football" (left), an adult Tervueren encounters the furry AIBO in the neutral situation (middle). A juvenile German shepherd interacts with the furry AIBO in the feeding situation (right).

AIBO (Fig. 1.) was commercialised by Sony in 1999 (Fujita and Kitano, 1998; Fujita et al., 2000). It was the first product of a new generation of autonomous robots not designed to be useful but rather to be entertaining (Kusahara, 2000; Kaplan, 2001). Some features of its shape and its motion resemble those of a dog-like animal. Its behaviour was planned as making it attractive for the customer but also to release affective behaviour on the part of the human that could develop into a friendly relationship similarly to the dog–owner attachment (Topál et al., 1998). The AIBO ERS-210, due to its numerous joints, is able to perform realistic movements: it walks on four legs, flaps its ears, wags its tail and makes gestures, although at the moment these are still jerky. They resemble those of a few-week-old puppy rather than an adult dog. AIBO senses the situation and surroundings of its environment by a camera built-in, microphones and sensors. AIBO with a special software (Memory Stick$^{TM}$) is able to learn, to express its needs and six emotions (e.g. "happiness", "sadness"), via light-emitting diodes in the eyes and in the tail, body language and using sounds.

There is a growing intention to develop the behaviour of the AIBO as if it were a living being. Behavioural studies on dogs could prove to be very useful for this purpose (Kaplan, 2001; Kaplan et al., 2002).

Although species recognition and social recognition is a favoured topic (for review see Colgan, 1983), the number of studies on dogs is limited. Fox (1971) by using a two-dimensional real-sized painting of an adult male, neutral-positioned hunting dog has shown that even adult dogs approached and investigated specific regions of the picture, although puppies investigate it more intensively. Visual communication between dogs is often described in terms of the signals during dominance–submission interactions of wolves (Scott and Fuller, 1965). Related studies presented evidence that olfaction might play an important role in individual recognition (Bekoff, 2001). Dunbar (1978) showed that male dogs sniff the urine of females longer, while females seem to concentrate on the head area during olfactory exploration (Bradshaw and Lea, 1993). Mech (1970) provided evidence that wolves use sniffing for individual identification. Indeed, there is chemical evidence that the anal sac of dogs carries individual-specific odours (Natynczuk et al., 1989).

Studies on other species showed that during development recognition abilities might change with age as a result of experience. Learning can contribute to a great extent to recognition of conspecifics by making recognition more 'accurate'. Based on behavioural observations, it is clear that in many species younger conspecifics can be "fooled" for a longer time using models (i.e. Miklósi et al., 1995). Besides, at least at the behavioural level, social recognition depends often on the context. For example, male robins (*Erithacus rubecula*) attack a red cotton ball in the spring, as if it was a real male, but in other instances they may respond socially only to dummies with a more natural appearance (Lack, 1939).

By testing a series of systematically different models one can reveal the most important components (visual, acoustic, olfactory aspects of 'sign stimuli') and their relative contribution to the object of recognition (Colgan, 1983). When a male stickleback attacks a dummy fish that is moved toward his nest, we deduce that he responded to it as a conspecific male

(Tinbergen and Tersel van, 1947). The necessary features of the dummy (in this case mainly the red spot on the belly) can be determined as minimal requirements for the emergence of the species-specific (in this case attacking) behaviour.

However, it should be kept in mind that animals often habituate very fast to models, especially when these lack important features, such as movement (Pongrácz and Altbäcker, 2000). In ideal circumstances we have a perfect replica of the living animal, whose gradual and systematic removal of component cues leads to a minimal configuration of stimuli, which is still enough to evoke the appropriate social behaviour in the animal. Autonomous robots present a new possibility, since contrary to the previous stationary dummies, they resemble living creatures both in their appearance and self-propelled motion with high degree of freedom.

In summary, here we investigate whether at its present stage of development AIBO is an appropriate scale model for emitting social behaviour in dogs.

## 2. Method

### 2.1. Subjects

To compare the behaviour of adults and juveniles, 24 adult dogs (12 males, 12 females, age $\pm$ S.E. $=$ $6.0 \pm 0.58$) and 16, 18- to 22-week-old juveniles (9 males, 7 females) were tested. Both age groups were assigned into two experimental groups by taking into account their breed and sex: One group from each age group undertook the experimental trials with the neutral, the other with the feeding situation (see the following). The owners (aged between 19 and 55) were recruited from among participants of a dog training school (Top Mancs, Budapest, Hungary).

### 2.2. Test-partners

Each dog encountered all four test-partners in both test situations: a puppy, a puppy-scented furry AIBO, AIBO and a toy car (Fig. 2). The toy car served as the control of AIBO, because it moved and emitted a strange noise like the robot, but its shape and movement patterns was clearly different. The puppy was included to assess the dog's overall interest in an AIBO-sized and shaped conspecific. Finally, AIBO was covered with a puppy-scented artificial fur, to observe whether the scent will enhance the interest toward the robot. The sequence of encountering the partners was fixed (puppy, robot, car, furry robot), but only one of every four dogs started with the same partner (6 out of 24 adults encountered the puppy first and the robot next, 6 started with the robot and finished with the puppy, etc.).

#### 2.2.1. Puppy

The male Hungarian short-haired Vizsla puppy was 6 weeks old at the beginning of the testing period, 9 weeks old at the end. During the experiments the puppy lived with the experimenter (E.K.), and was later adopted by a new owner.

The behaviour of the puppy was not controlled in a rigid manner in the arena. We stopped the testing if the puppy showed signs of exhaustion. To provoke a food-approaching behaviour during the feeding situations, it was not fed at least 6 h before the experiments. In the neutral situations the puppy preserved its originally sociable and curious nature, and constantly tried to approach the subjects. In the feeding situations, the puppy tried to approach the red bowl (where the food had been placed) and "steal" some food. If the dogs started to growl toward the puppy while it was approaching, the test was terminated, and the experimenter picked up the puppy.

The puppy did not vocalise during the tests.

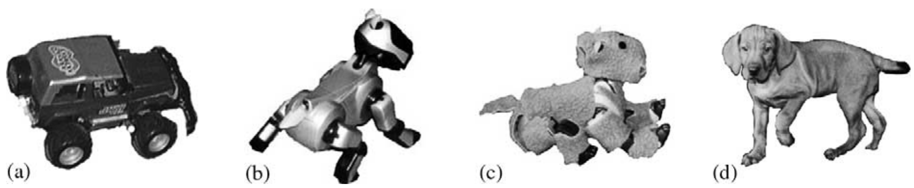


Fig. 2. The different models used in the encounters: (a) remote controlled car, (b) the AIBO, (c) furry AIBO, (d) Vizsla puppy.

#### *2.2.2. Robot*

AIBO ERS-210 (dimension: 154 mm × 266 mm × 274 mm; mass: 1.4 kg; colour: silver) is able to recognise and approach red objects. This in-built ability was exploited for attracting the robot toward the bowl. To generate a constant behaviour, the robot was used only in its after-booting period for the testing. (During booting the robot was lying and wiggled its head for approximately 2 min. Booting was finished with a stretching movement. The robot was put down on the floor after this movement.) When the robot has finished the booting, it "looked around" (turned its head), noticed the red object, stood up and approached the bowl. ("Approaching" meant several steps toward the ball. If the robot lost the red spot and stopped, the experimenter waited for 15 s, and than turned the robot to face the bowl again.) When the robot reached the goal-object, it started to kick it (as if it were a ball). The average latency of standing up and starting to move towards the bowl was $13.5 \pm 2.1$ s, and the average number of kicks with one of the front legs during the 1-min tests was $3.3 \pm 0.3$ in 12 randomly chosen experimental trials. Its audio output was switched off during the experiment.

#### *2.2.3. Furry robot*

The same robot as described in Section 2.2.2 was used. Thirteen pieces of a brown-coloured artificial fur were put on the body of the robot. The fur was scented in the puppy's sleeping box on the day before the testing. The pieces covered the body of the robot completely, only the ears and the aperture of the camera were visible from the original cover. Two black plastic "eye spots" (diameter 8 mm) were attached on the head.

#### *2.2.4. Remote controlled car*

The 4WD, grey and green-coloured toy car was approximately 300 mm × 180 mm × 120 mm. Its movement was controlled by the experimenter. Ten to thirty centimetres long forward-back movements were made towards the bowl continuously with 2–6 s pauses.

### *2.3. Procedure*

A 4 m × 4 m closed arena of a 30 m$^2$ wooden house was used for testing. At the edge of the arena there were two cupboards, shelves and a desk. Only the experimenter (E.K.), the owner and a cameraman were present during the trials. Subjects were habituated for 2 min to the experimental arena before the start of the first test, while the experimenter was explaining the task to the owner. After 2 min had elapsed, and the experimenter finished the explanation, the owner was asked to sit down in a chair in the arena, at 2.5 m from the entrance. He was asked to call the dog next to him/her, and hold the collar of the dog. Then the experimenter put a red bowl (30 cm in diameter) in the middle of the arena, which was filled with food in the feeding situation. The owner was asked not to talk to the dog during the testing.

#### *2.3.1. Neutral situation*

The owner called the dog next to him/her. The experimenter placed the empty bowl and one of the partners in front of the dog. At this moment the owner let the dog go free. After 1 min had elapsed the test was terminated. The owner called the dog to him/her, and in the meantime the experimenter changed the test-partner. The same process was repeated with each test-partner one after the other (Fig. 1).

#### *2.3.2. Feeding situation*

The situation was similar as described above the only difference being that the red bowl was now filled with food (food-pellets, bones and meat). At the start of the test the owner made the dog eat from the bowl. While the dog was eating, the experimenter placed the test-partner on the other side of the bowl. After 1 min had elapsed the experimenter changed the test-partner. The test was terminated earlier if the dog started to attack the test-partner (Fig. 1).

### *2.4. Data collection and analysis*

All tests were videotaped and used later for the behavioural analysis. The following behavioural variables have been defined:

- *Approach*: The time elapsed from the beginning of the session until the first approach toward the test-partner (s).
- *Orientation at partner*: The total amount of time that the subject spent looking toward the test-partner (s).
- *Sniffing at front*: The total amount of time during which the subject kept its nose (within 1 cm) close

to the test-partner's front part, including face, ear, shoulder, front leg (s).

- *Sniffing at rear*: The total amount of time during which the subject kept its nose (within 1 cm) close to the test-partner's rear part, including anus, inguinal, hind leg (s).
- *Distance*: We compared the initial position of the dog and his position in the 15th second of the testing in relation to the test-partner. The following scoring system was used: 0, the dog did not change its position; +1, the dog changed its posture towards the partner, but did not move towards it; +2, the dog moved towards the partner; −1, the dog turned away from the partner, but did not change its place; −2, the dog moved away from the partner.
- *Barking*: The number of barks was noted.
- *Growling*: A score of 1 was assigned if the dog growled during the test. The lack of growling resulted in a score of 0.

For statistical analysis we used a multi-way repeated measures analysis of variances (SPSS, version 6.1.2). 'Age' (adult/juvenile), 'Sex' (male/female) and the 'Type' of the first partner (puppy/robot/car/furry robot) and 'Order' of the partners in testing were chosen as between-subject variables; 'Situation' (neutral/feeding) and 'Partner' (puppy/robot/car/furry robot) were chosen as within-subject variables. Durations were normalised in those cases when we had to terminate the tests before 60 s. For group comparisons (see "Effect of 'Partner' on adults and juveniles during the two situations" in the following) repeated measures ANOVA with Student–Neuman–Keul post hoc tests was used ($P < 0.05$).

## 3. Results

The main results of the repeated measures of ANOVA are presented in Table 1. As expected, both

Table 1
The ANOVA table (three-way repeated measures ANOVA) for the behavioural variables tested in two situations (neutral vs. feeding) and in two ages of dogs (juveniles vs. adults)

| | Behavioural situation | | Age | | Sex | |
|---|---|---|---|---|---|---|
| | Neutral | Feeding | Adult | Juvenile | Male | Female |
| Approach | 22.9 | 41.3 | 36.4 | 25.7 | 31.5 | 32.8 |
| S.E. | 2.2 | 2.0 | 1.97 | 2.5 | 2.15 | 2.3 |
| ANOVA | $F = 48.8$; $P < 0.001$ | | $F = 6.6$; $p < 0.05$ | | n.s. | |
| Orientation at partner | 21.7 | 14.9 | 11.6 | 28.4 | 15.7 | 21.2 |
| S.E. | 1.6 | 1.4 | 1.1 | 1.8 | 1.3 | 1.6 |
| ANOVA | $F = 10.3$; $P < 0.01$ | | $F = 55.4$; $P < 0.001$ | | $F = 11.6$; $P < 0.01$ | |
| Sniffing at front | 3.1 | 1.6 | 1.2 | 4.2 | 2.5 | 2.3 |
| S.E. | 0.5 | 0.4 | 0.2 | 0.7 | 0.4 | 0.4 |
| ANOVA | $F = 9.91$; $P < 0.01$ | | $F = 20.69$; $P < 0.001$ | | n.s. | |
| Sniffing at rear | 2.0 | 0.5 | 0.8 | 2.0 | 1.4 | 1.1 |
| S.E. | 0.4 | 0.2 | 0.2 | 0.5 | 0.3 | 0.3 |
| ANOVA | $F = 15.2$; $P < 0.001$ | | $F = 11.6$; $P < 0.01$ | | n.s. | |
| Distance | −0.2 | −0.5 | −0.2 | −0.7 | −0.3 | −0.4 |
| S.E. | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 | 0.1 |
| ANOVA | $F = 17.8$; $P < 0.001$ | | $F = 7.6$; $P < 0.01$ | | n.s. | |
| Barking | 2.2 | 1.8 | 0.1 | 4.9 | 2.3 | 1.7 |
| S.E. | 0.9 | 0.6 | 0.03 | 1.3 | 0.9 | 0.4 |
| ANOVA | n.s. | | $F = 7.0$; $P < 0.01$ | | n.s. | |
| Growling | 0.1 | 0.2 | 0.1 | 0.2 | 0.1 | 0.2 |
| S.E. | 0.03 | 0.03 | 0.02 | 0.04 | 0.02 | 0.03 |
| ANOVA | $F = 8.6$; $P < 0.01$ | | $F = 6.04$; $P < 0.05$ | | $F = 11.5$; $P < 0.01$ | |

Table 2
Behaviour of adults and juveniles with the partners in both experimental situations

| | Adult | | | | Juvenile | | | |
|---|---|---|---|---|---|---|---|---|
| | Puppy | Furry robot | Robot | Car | Puppy | Furry robot | Robot | Car |
| Neutral situation | | | | | | | | |
| Approach | 15.4 (4.8) | 11.9 (4.7) | 31.2 (5.8) | 45.1(4.8) | 0.5 (0.15) | 23.8 (7.13) | 19.6 (7.6) | 29.6 (7.1) |
| SNK test | a | ab | bc | c | a | b | ab | b |
| One-way ANOVA | $F = 10.56$; $P < 0.001$ | | | | $F = 5.84$; $P < 0.002$ | | | |
| Orientation at partner | 19.5 (3.6) | 22.2 (3.4) | 10.3 (2.3) | 3.7 (0.9) | 51.9 (3.2) | 33.5 (4.5) | 28.2 (4.9) | 20 (4.4) |
| SNK test | a | ab | bc | c | a | b | bc | c |
| One-way ANOVA | $F = 10.74$; $P < 0.001$ | | | | $F = 23.84$; $P < 0.001$ | | | |
| Sniffing at front | 4.4 (1.0) | 2.0 (0.7) | 1.0 (0.4) | 0.2 (0.1) | 15.3 (2.5) | 2.9 (1.0) | 12 (0.5) | 0.8 (0.7) |
| SNK test | a | b | b | b | a | b | b | b |
| One-way ANOVA | $F = 11.26$; $P < 0.001$ | | | | $F = 30.29$; $P < 0.001$ | | | |
| Sniffing at rear | 4.2 (1.2) | 1.1 (0.4) | 0.3 (0.2) | 0.1 (0.0) | 9.9 (2.2) | 0.8 (0.4) | 0.4 (0.3) | 0.2 (0.2) |
| SNK test | a | b | b | b | a | b | b | b |
| One-way ANOVA | $F = 8.6$; $P < 0.01$ | | | | $F = 16.68$; $P < 0.001$ | | | |
| Distance | 0.8 (0.3) | −0.7 (0.3) | −0.3 (0.2) | −0.3 (0.2) | 1.7 (0.3) | −1.2 (0.4) | −1.1 (0.3) | −0.75 (0.2) |
| SNK test | a | b | b | b | a | b | b | b |
| One-way ANOVA | $F = 6.081$; $P < 0.001$ | | | | $F = 22.57$; $P < 0.001$ | | | |
| Barking | 0.5 (0.3) | 0 | 0 | 0.04 (0.04) | 8,3 (6.5) | 0.1 (0.1) | 7.5 (4.2) | 4.9 (4.2) |
| SNK test | | | | | | | | |
| One-way ANOVA | n.s. | | | | n.s. | | | |
| Growling | 0.1 (0.01) | 0.2 (0.01) | 0 | 0 | 0.3 (0.1) | 0.2 (0.1) | 0.3 (0.1) | 0 |
| SNK test | | | | | | | | |
| One-way ANOVA | n.s. | | | | n.s. | | | |
| Feeding situation | | | | | | | | |
| Approach | 39.9 (5.3) | 39.8 (5.3) | 49.3 (4.0) | 58.2 (1.8) | 11.4 (5.2) | 29.4 (6.7) | 41.7 (6.7) | 49.6 (5.3) |
| SNK test | a | a | ab | b | a | ab | b | b |
| ANOVA | $F = 4.97$; $P < 0.01$ | | | | $F = 8.91$; $P < 0.001$ | | | |
| Orientation at partner | 13.3 (3.4) | 11.5 (3.4) | 8.8 (2.1) | 3.4 (1.7) | 28.9 (5.2) | 26.8 (5.3) | 21.4 (5.2) | 16.5 (4.3) |
| SNK test | a | a | ab | b | | | | |
| ANOVA | $F = 4.41$; $P < 0.007$ | | | | n.s. | | | |
| Sniffing at front | 0.3 (0.2) | 1.5 (0.5) | 0.3 (0.1) | 0.03 (0.02) | 10.4 (2.6) | 2.2 (1.4) | 0.5 (0.2) | 0.1 (0.1) |
| SNK test | ab | a | ab | b | a | b | b | b |
| ANOVA | $F = 4.90$; $P < 0.055$ | | | | $F = 11.05$; $P < 0.001$ | | | |
| Sniffing at rear | 0.4 (0.4) | 0.1 (0.1) | 0.1 (0.1) | 0.0 (0.0) | 4.1 (1.8) | 0.2 (0.1) | 0.0 (0.0) | 0.0 (0.0) |
| SNK test | | | | | a | b | b | b |
| ANOVA | n.s. | | | | $F = 5.16$; $P < 0.01$ | | | |
| Distance | −0.1 (0.1) | −0.1 (0.1) | −0.3 (0.2) | −0.3 (0.1) | −1.1 (0.3) | −1.1 (0.2) | −1.1 (0.2) | −0.9 (0.2) |
| SNK test | | | | | | | | |
| ANOVA | n.s. | | | | n.s. | | | |
| Barking | 0.04 (0.04) | 0.1 (0.1) | 0 | 0 | 0.7 (0.5) | 11.5 (4.3) | 3.6 (1.9) | 2.4 (1.6) |
| SNK test | | | | | a | b | ab | ab |
| ANOVA | n.s. | | | | $F = 3.87$; $P < 0.05$ | | | |
| Growling | 0.7 (0.1) | 0.04 (0.04) | 0.04 (0.04) | 0 | 0.4 (0.1) | 0.34 (0.1) | 0.2 (0.1) | 0.2 (0.1) |
| SNK test | a | b | b | b | | | | |
| ANOVA | $F = 36.68$; $P < 0.001$ | | | | n.s. | | | |

Student–Neuman–Keul (SNK) post hoc test was used to reveal the differences. In the SNK-test rows ‘a’, ‘b’ and ‘c’ represents significant ($P < 0.05$) differences (e.g. ‘ab’ does not differ from ‘a’, but does from ‘c’). Data are represented as means with S.E. in brackets.

‘age’ and ‘situation’ affected the behaviour of the subjects (see the following). ‘Sex’ had also some effects. Beginning with one of the situations (‘Order’) and ‘Type’ of the first partner did not affect any of the variables; therefore these were omitted from the further analysis.

### *3.1. Effect of ‘Situation’*

In general, dogs approached the partners later, orientated and sniffed at them less in the feeding situation. They barked more, growled more frequently and distanced themselves farther from the partners in the feeding situation than in the neutral one.

### *3.2. Effect of ‘Age’*

Juveniles approached the test-partners sooner, oriented and sniffed at them for longer durations. On average they kept greater distance from the partners during the situations. They barked more, and growled more frequently than the adults.

### *3.3. Effect of ‘Sex’*

Female dogs growled more frequently and spent more time with orientation toward the test-partner. In neutral situations males spent more time with sniffing the rear parts of the partner than females. In feeding situation it was the opposite: females kept more interest in sniffing the rear part of the partner than males.

### *3.4. Effect of ‘Partner’ on adults and juveniles during the two situations*

Because both ‘Age’ and ’Situation’ influenced the dogs’ behaviour, for further statistical analysis we divided the data into four groups for further analysis: adults/juveniles in neutral situation, adults/juveniles in feeding situation (Table 2). In the ‘neutral situation’ adults approached the furry robot and the puppy sooner than the robot and the car, and spent more time with orienting toward the former than the latter. On the contrary, juveniles approached the puppy almost at once at the beginning of the neutral episodes, while the latency of approach was on average approximately 20 s in case of the other three test-partners. In juveniles the duration of time that they spent with looking at the puppy differed significantly from at the other three test-partners, although the furry robot evoked more attention than the car. It seems that with regard to the approach latency and duration of orientation the covering of the AIBO with fur had some restricted effect on the dogs’ behaviour. However, in the case of sniffing and maintenance of distance we found that all subjects discriminated only the puppy from all the others since in both juveniles and adults sniffed the puppy more, and maintained their proximity if it moved away during the neutral episodes.

In the feeding situation adult dogs no longer seemed to discriminate the robot and the puppy as revealed by the similar latency of ‘approach’ and duration of ‘orientation’. In this case the main difference emerged between the ‘legged’ creatures and the remote controlled car. However, with regard to growling, adult dogs showed evidence of discriminating the puppy from the other partners because they growled more frequently in the presence of the puppy than when confronted with any other test-partner (67% of the adults growled at the puppy, while almost none of them growled at the other test-partners). There was no difference in the amount of orientation toward any of the test-partners in juveniles although they approached the puppy and the furry robot sooner. Younger dogs also preferentially sniffed at the puppy, however, interestingly the presence of the furry robot evoked the most frequent barking in juveniles.

## 4. Discussion

In this study we allowed dogs to interact with a commercially available four-legged autonomous robot (AIBO ERS-210) in two different behavioural contexts in order to observe their behaviour toward the dog-shaped object. A puppy and a toy car served as controls. An interesting aspect of this study is that the behaviour of the subjects seems to depend mainly on the testing situation where the interaction takes place and to some extent on their age. Juveniles were more active in the neutral tests: they approached the partners sooner, they orientated more toward them, barked more, and growled more often. Adults spent approximately only one-third of the test orientating towards the puppy and the furry robot. Juveniles usually surpassed them in time orienting. In the feeding tests the adult dogs approached the partners somewhat sooner, spent less time with orientation toward them and sniffing at them but growled more frequently. Juveniles approached non-living partners later, but spent more time with orientation compared to adults.

Dogs seemed to be more sensitive to the identity of their partners in the neutral situation. Considering the latency of approach and time spent with orientation we found that adult dogs show similar response to the puppy and to the furry robot. However, in sniffing and keeping distance dogs seem to discriminate the puppy from all non-living partners. It is very likely that the preference to stay near the partner (positive distance scores) is associated with the inclination to orient and sniff at the partner, which is especially obvious in the case of the puppy. This might indicate that the appearance of the partners was more balanced with regard to visual stimuli displayed, in contrast the smell of the puppy was superior (more attractive) to that provided by all other partners.

To some extent the opposite effect can be observed in the feeding encounters. Here, adult dogs show a tendency to discriminate those stimulus objects that had four legs from the car by orientation, approaching and sniffing, suggesting that mobility in itself plays little role in this situation. The only sign for the presence of finer discrimination was the frequent occurrence of growling in the presence of the puppy showing that it was able to release aggressive behaviour from the adults. This might indicate that adults regarded only the puppy as a potential competitor. (We have observed only one adult dog, which growled at the furry robot during competition. In contrast, 16 out of 24 adults growled at the puppy.)

Contrary to adults, juveniles growled in similar numbers at the test-partners in the feeding situation, which could be due to the testing situation that provoked a high level of excitement independent from the partner present. (It is worth to mention that there were two juveniles, that seriously attacked the furry robot.) However, juveniles still sniffed the puppy much longer than the non-living partners.

During feeding, the females sniffed the partners' rear parts longer than the males. In the neutral situation the case was the reverse: males spent almost twice as much time as females in sniffing at these body parts. The case of the latter seems to support an earlier observation by Bradshaw and Lea (1993) who found that male dogs sniffed more than females at rear parts of strange conspecifics during walking encounters.

In summary the social behaviour of the adults and juveniles toward the different test-partners seemed to correspond to the similarity of the stimulus to a living dog, therefore the values followed each other in the puppy, furry robot, robot, toy car order. In adults, the approach and the orientation evoked by the puppy and the furry robot did not differ in any situations. Both age groups orientated more toward the furry robot than the car in the neutral situation. However, we should keep in mind that the order mentioned above could be due to other effects than the similarity to a dog. The fact that both adults and juveniles have kept at a larger distance (after initial approach of the partner) from the furry robot than any other of the stimulus objects suggests that this object was "strange" for them and perhaps evoked fear to a certain extent.

A social partner is not only the carrier of species-specific characters to evoke behaviour on the part of the subject but also actively reacts to the actions of the other. In order to mimic interactive situations, the robot has to be able to detect and react to, at least, some elements of the environment that it shares with the tested animal. In our case this was achieved by using a red bowl for the food, which was a salient object both for the subject (it contained food) and the robot (given its built-in character to approach red objects) but this single common dimension of the environment is significantly less than in the case of encountering a real conspecific. Nevertheless, dogs reacted more extensively to the robot-dummies than to life-sized drawings as reported earlier (Fox, 1971). Being predators, dogs are naturally more sensitive to moving three-dimensional objects than to two-dimensional stationary pictures.

It seems that at present there are some serious limitations in using AIBO robots for behavioural tests with dogs. Although differences between the duration of orientation and latency of approach make it likely that in a choice-test AIBO would be a more salient stimulus than a remote controlled toy car, the effect is significantly different from that of a conspecific. It is likely that at present the main limit is the speed of the robot. Dogs react much faster than the robot, and also seem to expect rapid reactions on the part of the other. Most interactions, like play, will not be possible until the robot's reactions are speeded up.

A further interesting question is whether puppies with experience restricted only to the robot (AIBO "raised" dog-litters) would consider the robot as a social partner. Such experiments could give some insight in the flexibility of the sensitive period and the mechanisms of social recognition in dogs when they learn about conspecifics (Fox, 1970). For example, chicks follow relatively indiscriminately objects presented to them at the beginning of their sensitive period but they also have a clear innate preference to objects that resemble conspecifics (Bolhuis, 1991; Gottlieb, 1971).

Our results support that age and context influence the process of social behaviour in animals, and proposes a method of using robots in animal behavioural studies. Although this time AIBO did not turn out to be a 'real' social partner for the dogs in all respects, but the change of its appearance, the improvement of its movements and speed could make this possible.

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