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Can robots replace dogs? Comparison of temporal patterns in dog-human and robot-human interactions

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1. Introduction

Interactions with computers are part of our lives. Personal computers are common in most households, we use them for work and fun as well. This interaction became natural to most of us in the last few years. Some predict (e.g. Bartlett et al 2004) that robots will be as widespread in the not too distant future as PCs are today. Some robots are already present in our lives. Some have no or just some degree of autonomy, while others are quite autonomous. Although autonomous robots were originally designed to work independently from humans (for examples see Agah, 2001), a new generation of autonomous robots, the so-called entertainment robots, are designed specially to interact with people and to provide some kind of "entertainment" for the human, and have the characteristics to induce an emotional relationship ("attachment") (Donath 2004, Kaplan 2001). One of the most popular entertainment robots is Sony's AIBO (Pransky 2001) which is to some extent reminiscent to a dog-puppy. AIBO is equipped with a sensor for touching, it is able to hear and recognize its name and up to 50 verbal commands, and it has a limited ability to see pink objects. It produces vocalisations for expressing its 'mood', in addition it has a set of predetermined action patterns like walking, paw shaking, ball chasing etc. Although it is autonomous, the behaviour of the robot depends also on the interaction with the human partner. AIBO offers new perspectives, like clicker training (Kaplan et al. 2002), a method used widespread in dogs' training.

Based on the use of questionnaires Kahn et al (2003) suggested that people at online AIBO discussion forums describe their relationship with their AIBO to be similar to the relationship people have with live dogs. However we cannot forget that people on these kind of on-line forums are actively looking for these topics and the company of those who have similar interests. Those who participated in this survey were probably already devoted to their AIBOs.

It is also interesting how people speak about the robot. Whether they refer to AIBO as a non-living object, or as a living creature? When comparing children's attitudes towards AIBO

and other robots Bartlett et al (2004) found that children referred to AIBO as if it were a living dog, labelled it as "robotic dog" and used rather 'he' or 'she' than 'it' when talked about AIBO. Interviewing children Melson et al (2004) found that although they distinguished AIBO from a living dog, they attributed psychological, companionship and moral stance to the robot. Interviewing older adults Beck et al (2004) found that elderly people regarded AIBO much like as a family member and they attributed animal features to the robot.

Another set of studies is concerned with the observation of robot-human interactions based on ethological methods of behaviour analysis. Comparing children's interaction with AIBO and a stuffed dog Kahn et al (2004) found that children distinguished between the robot and the toy. Although they engaged in an imaginary play with both of them, they showed more exploratory behaviour and attempts for reciprocity when playing with AIBO. Turner et al (2004) described that children touched the live dog over a longer period than the robot but ball game was more frequent with AIBO than with the dog puppy.

Although these observations show that people distinguish AIBO from non-living objects, the results are somehow controversial. While questionnaires and interviews suggest that people consider AIBO as a companion and view it as a family member, their behaviour suggest that they differentiate AIBO from a living dog.

Analysis of dogs' interaction with AIBO showed that dogs distinguished AIBO from a dog puppy in a series of observations by Kubinyi et al. (2003). Those results showed that both juvenile and adult dogs differentiate between the living puppy and AIBO, although their behaviour depended on the similarity of the robot to a real dog as the appearance of the AIBO was manipulated systematically.

To investigate whether humans interact with AIBO as a robotic toy rather than real dog, one should analyze their interaction pattern in more detail. To analyse the structural differences found in the interaction between human and AIBO and human and a living dog we propose to analyze the temporal structure of these interactions.

In a previous study investigating cooperative interactions between the dog and its owner (Kerepesi et al 2005), we found that their interaction consists of highly complex patterns in time, and these patterns contain behaviour units, which are important in the completion of a given task. Analyzing temporal patterns in behaviour proved to be a useful tool to describe dog-human interaction. Based on our previous results (Kerepesi et al 2005) we assume that investigating temporal patterns cannot only provide new information about the nature of dog-human interaction but also about robot-human interaction.

In our study we investigated children's and adults' behaviour during a play session with AIBO and compared it to play with living dog puppy. The aim of this study was to analyse spontaneous play between the human and the dog/robot and to compare the temporal structure of the interaction with dog and AIBO in both children and adults.

2. Method

Twenty eight adults and 28 children were participated in the test and were divided into four experimental groups:

1. Adults playing with AIBO: 7 males and 7 females (Mean age: 21.1 years, SD= 2.0 years)
2. Children playing with AIBO: 7 males and 7 females (Mean age: 8.2 years, SD= 0.7 years)
3. Adults playing with dog: 7 males and 7 females (Mean age: 21.4 years, SD= 0.8 years)
4. Children playing with dog: 7 males and 7 females (Mean age: 8.8 years, SD= 0.8 years)

The test took place in a 3m x 3m separated area of a room. Children were recruited from elementary schools, adults were university students. The robot was Sony's AIBO ERS-210, (dimension: 154mm x 266mm x 274 mm; mass: 1.4 kg; colour: silver) that is able to recognise and approach pink objects. To generate a constant behaviour, the robot was used only in its after-booting period for the testing. After the booting period the robot was put down on the floor, and it "looked around" (turned its head), noticed the pink object, stood up and approached the ball ("approaching" meant several steps toward the pink ball). If the robot lost the pink ball it stopped and „looked around" again. When it reached the goal-object, it started to kick it. If stroked, the robot stopped and started to move its head in various directions. The dog puppy was a 5-month-old female Cairn terrier, similar size to the robot. It was friendly and playful, its behaviour was not controlled in a rigid manner during the playing session. The toy for AIBO was its pink ball, and a ball and a tug for the dog-puppy. The participants played for 5 minutes either with AIBO or the dog puppy in a spontaneous situation. None of the participants met the test partners before the playing session. At the beginning of each play we asked participants to play with the dog/AIBO for 5 minutes, and informed them that they could do whatever they wanted, in that sense the participants' behaviour were not controlled in any way. Those who played with the AIBO knew that it liked being stroked, that there was a camera in its head enabling it to see and that it liked to play with the pink ball.

The video recorded play sessions were coded by ThemeCoder, which enables detailed transcription of digitized video files. Two minutes (3000 digitized video frames) were coded for each of the five-minute-long interaction. The behaviour of AIBO, the dog and the human was described by 8, 10 and 7 behaviour units respectively. The interactions were transcribed using ThemeCoder and the transcribed records were then analysed using Theme 5.0 (see www.patternvision.com). The basic assumption of this methodological approach, embedded in the Theme 5.0 software, is that the temporal structure of a complex behavioural system is largely unknown, but may involve a set of particular type of repeated temporal patterns (T-patterns) composed of simpler directly distinguishable event-types, which are coded in terms of their beginning and end points (such as "dog begins walking" or "dog ends orienting to the toy"). The kind of behaviour record (as set of time point series or occurrence times series) that results from such coding of behaviour within a particular observation period (here called T-data) constitutes the input to the T-pattern definition and detection algorithms.

Essentially, within a given observation period, if two actions, A and B, occur repeatedly in that order or concurrently, they are said to form a minimal T-pattern (AB) if found more often than expected by chance, assuming as h_0 independent distributions for A and B, there is approximately the same time distance (called critical interval, CI) between them. Instances of A and B related by that approximate distance then constitute occurrence of the (AB) T-pattern and its occurrence times are added to the original data. More complex T-patterns are consequently gradually detected as patterns of simpler already detected patterns through a hierarchical bottom-up detection procedure. Pairs (patterns) of pairs may thus be detected, for example, ((AB)(CD)), (A(KN))(RP)), etc. Special algorithms deal with potential combinatorial explosions due to redundant and partial detection of the same patterns using an evolution algorithm (completeness competition), which compares all detected patterns and lets only the most complete patterns survive. (Fig 1). As any basic time unit may be

used, T-patterns are in principle scale-independent, while only a limited range of basic unit size is relevant in a particular study.

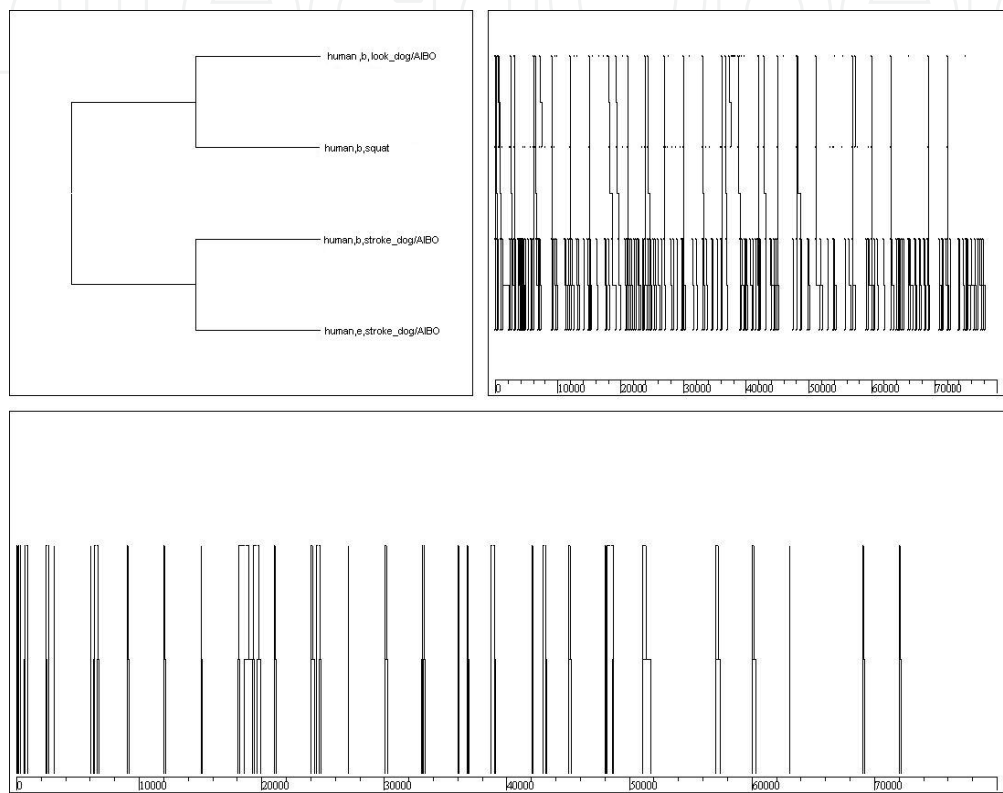


Figure 1. An example for a T-pattern. The upper left box shows the behaviour units in the pattern. The pattern starts with the behaviour unit on the top. The box at the bottom shows the occurrences of the pattern on a timeline (counted in frame numbers)

During the coding procedure we recorded the beginning and the ending point of a behaviour unit. Concerning the search for temporal patterns (T-patterns) we used, as a search criteria, minimum two occurrences in the 2 min. period for each pattern type, the tests for CI was set at $p= 0.005$, and only included interactive patterns (those T-patterns which contained both the human's and the dog's/AIBO's behaviour units) The number, length and level of interactive T-patterns were analyzed with focusing on the question whether the human or the dog/AIBO initialized and terminated the T-pattern more frequently. A T-pattern is initialized/terminated by human if the first/last behaviour unit in that pattern is human's. A comparison between the ratio of T-patterns initiated or terminated by humans, in the four groups, was carried out as well as the ratio of those T-patterns containing behaviour units listed in Table 1.

Play behaviour		Activity		Interest in partner	
abbreviation	description	abbreviation	Description	abbreviation	description
<i>Look toy</i>	Dog/ AIBO orients to toy	<i>Stand</i>	Dog/ AIBO stands	<i>Stroke</i>	Human strokes the dog/ AIBO
<i>Approach toy</i>	Dog/ AIBO approaches toy	<i>Lie</i>	Dog/ AIBO lies	<i>Look dog</i>	Human looks at dog/ AIBO
<i>Move toy</i>	Human moves the toy in front of dog/ AIBO	<i>Walk</i>	Dog/ AIBO walks (but not towards the toy)		
		<i>Approach toy</i>	Dog/ AIBO approaches toy		

Table 1. Behaviour units used in this analysis

Statistical tests were also conducted on the effect of the subjects' age (children vs. adults) and the partner type (dog puppy vs. AIBO) using two-way ANOVA.

Three aspects of the interaction were analyzed. (see Table 1).

1. *Play behaviour* consists of behaviour units referring to play or attempts to play, such as dog/ AIBO approaches toy, orientation to the toy and human moves the toy.
2. The partners' *activity during play* includes dog/ AIBO walks, stands, lies and approaches the toy.
3. *Interest in the partner* includes humans' behaviour towards the partner and can be described by their stroking behaviour and orientation to the dog/ AIBO.

We have also searched for common T-patterns that can be found minimum twice in at least 80% of the dyads. We have looked for T-patterns that were found exclusively in child-AIBO dyads, child-dog dyads, adult-AIBO dyads and adult-dog dyads. We also search for patterns that are characteristic for AIBO (can be found in at least 80% of child-AIBO and adult AIBO dyads), dog (found in child-dog and adult-dog dyads), adult (adult-AIBO and adult-dog dyads) and children (child-dog and child-AIBO dyads)

3. Results

The number of different *interactive T-patterns* was on average 7.64 in adult-AIBO dyads, 3.72 in child-AIBO dyads, 10.50 in adult-dog dyads and 18.14 in child dog-dyads. Their number did not differ significantly among the groups.

Comparing the ratio of *T-patterns initialized by humans*, we have found that adults initialized T-patterns more frequently when playing with dog than participants of the other groups ($F_{3,56}= 5.27, p= 0.003$). Both the age of the human ($F_{1,56}= 10.49, p= 0.002$) and the partner's type ($F_{1,56}= 4.51, p= 0.038$) had a significant effect, but their interaction was not significant.

The partner's type ($F_{1,56}=10.75, p=0.002$) also had a significant effect on the ratio of *T-patterns terminated by humans* ($F_{3,56}= 4.45, p= 0.007$) we have found that both children and adults terminated the T-patterns more frequently when they played with AIBO than when they played with the dog puppy (Fig. 2).

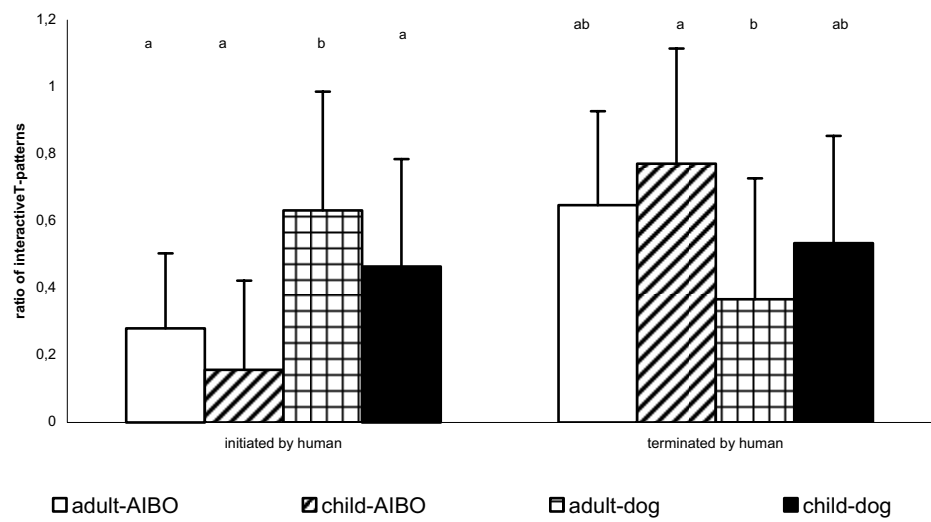


Figure 2. Mean ratio of interactive T-patterns initiated and terminated by humans (bars labelled with the same letter are not significantly different)

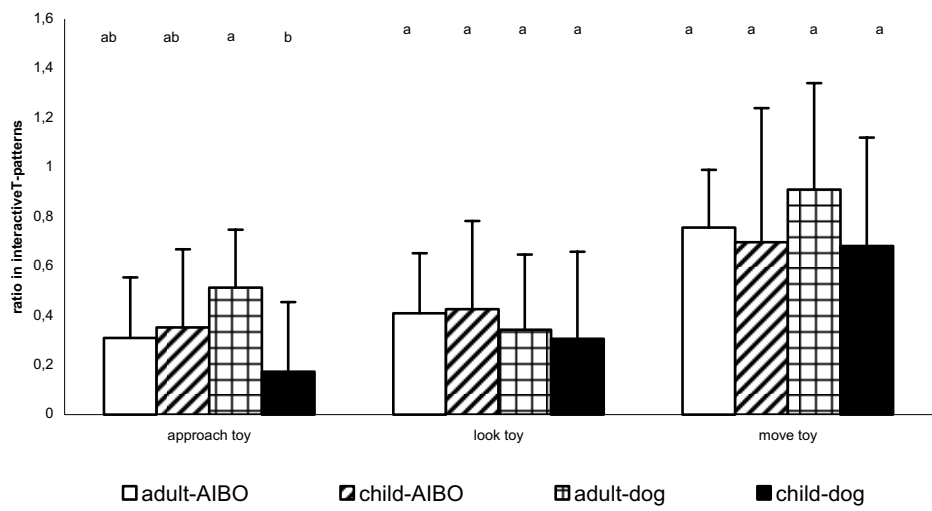


Figure 3. Mean ratio of interactive T-patterns containing the behaviour units displayed by AIBO or dog (Look toy, Approach toy) or Humans (Move toy)

The age of the human had a significant effect on the ratio of T-patterns containing *approach toy* ($F_{1,56}= 4.23$, $p= 0.045$), and the interaction with the partner’s type was significant ($F_{1,56}= 6.956$, $p= 0.011$). This behaviour unit was found more frequently in the T-patterns of adults playing with dog than in the children’s T-patterns when playing with dog. The ratio of *look toy* in T-patterns did not differ among the groups. (Fig. 3)

The ratio of the behaviour unit *stand* also varied among the groups ($F_{3,56}= 6.59$, $p< 0.001$), there was a lower frequency of such T-patterns when children were playing with dog than in any other case ($F_{1,56}= 7.10$, $p= 0.010$). However, the ratio of behaviour units *lie* and *walk* in T-patterns did not differ among the groups.

The ratio of humans’ behaviour units in T-patterns (*move toy*, *look dog* and *stroke*) did not vary among the groups.

When searching for common T-patterns we have realized that certain complex patterns were found exclusively to be produced in either child and play subject (AIBO, child-dog) or adult and play subject (AIBO, and adult-dog) interactions. Some pattern types were typical to children and found to occur in both the child-AIBO and child-dog groups (Fig 4.) and others, typical for adults were found in both adult-AIBO and adult-dog groups (Fig 5.)

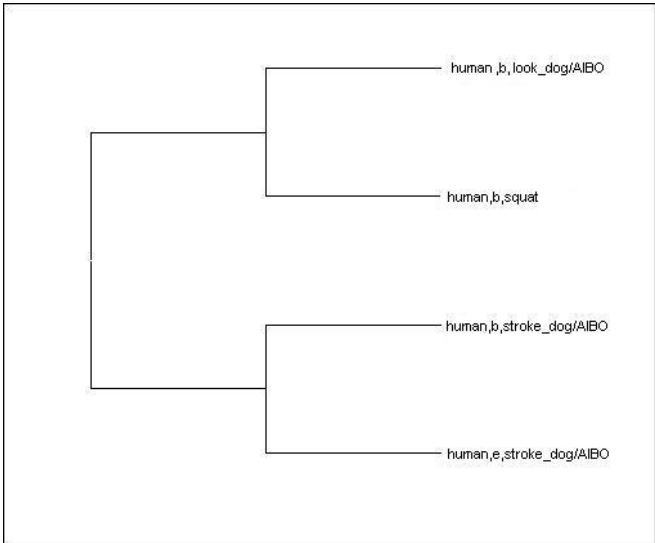


Figure 4. A T-pattern found at least 80% of adults’ dyads. The figure shows only the upper left box of the T-pattern The behaviour units in order are: (1) adult begins to look at the dog/ AIBO, (2) adult begins to stroke the dog/ AIBO, (3) adult begins to squat, (4) adult ends stroking the dog/ AIBO, (5) adult ends looking at the dog/ AIBO, (6) adult ends squatting

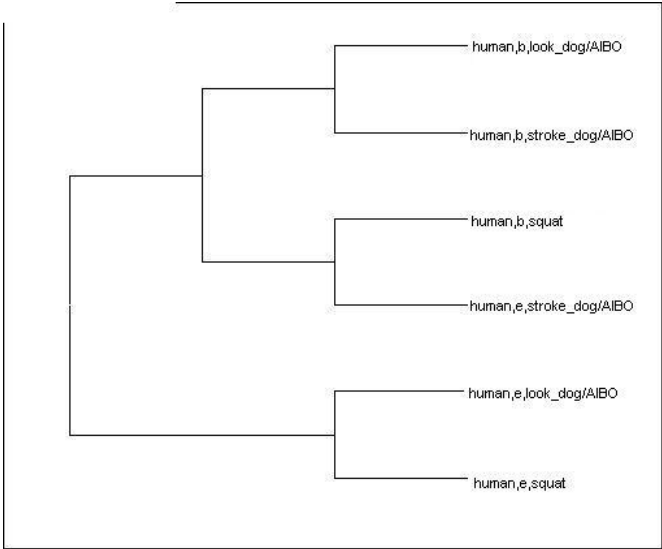


Figure 5. A T-pattern found at least 80% of children’s dyads. The figure shows only the upper left box of the T-pattern The behaviour units in order are: (1) child begins to look at the dog/ AIBO, (2) child begins to squat, (3) child begins to stroke the dog/ AIBO, (4) child ends stroking the dog/ AIBO

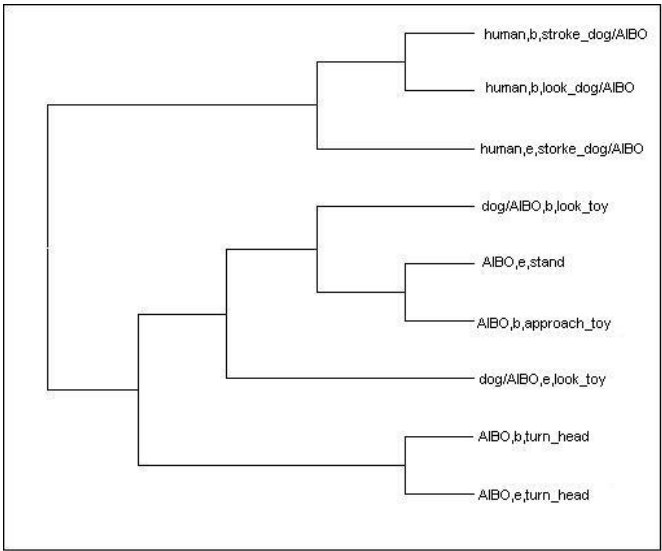


Figure 6. A T-pattern found at least 80% of AIBO’s dyads. The figure shows only the upper left box of the T-pattern The behaviour units in order are: (1) child/adult begins to stroke the dog/ AIBO (2) , child/adult begins to look at the dog/ AIBO, (3) child/adult ends stroking the dog/ AIBO (4) dog/ AIBO begins to look at the toy , (5) AIBO ends standing, (6) AIBO begins to approach the toy, (7) dog/ AIBO ends looking at the toy, (8) AIBO begins to turn around its head (9) AIBO ends turning around its head

All the common T-patterns have the same start: adult/child looks at the dog/AIBO and then starts to stroke it nearly at the same moment. The main difference is in the further part of the patterns. The T-patterns end here in case of dogs' interactions. It continues only in AIBO's dyads (Fig 6), when the robot starts to look at the toy, approach it then moving its head around. We have found that children did not start a new action when they finished stroking the AIBO.

4. Discussion

To investigate whether humans interact with AIBO as a non-living toy rather than a living dog, we have analyzed the temporal patterns of these interactions. We have found that similarly to human interactions (Borrie et al 2002, Magnusson 2000, Grammer et al 1998) and human-animal interactions (Kerepesi et al 2005), human-robot interactions also consist of complex temporal patterns. In addition the numbers of these temporal patterns are comparable to those T-patterns detected in dog-human interactions in similar contexts.

One important finding of the present study was that the type of the play partner affected the initialization and termination of T-patterns. Adults initialized T-patterns more frequently when playing with dog while T-patterns terminated by a human behaviour unit were more frequent when humans were playing with AIBO than when playing with the dog puppy. In principle this finding has two non-exclusive interpretations. In the case of humans the complexity of T-patterns can be affected by whether the participants liked their partner with whom they were interacting or not (Grammer et al 1998, Sakaguchi et al 2005). This line of arguments would suggest that the distinction is based on the differential attitude of humans toward the AIBO and the dog. Although, we cannot exclude this possibility, it seems more likely that the difference has its origin in the play partner. The observation that the AIBO interrupted the interaction more frequently than the dog suggests that the robot's actions were less likely to become part of the already established interactive temporal pattern. This observation can be explained by the robot's limited ability to recognize objects and humans in its environment. AIBO is only able to detect a pink ball and approach it. If it loses sight of ball it stops that can interrupt the playing interaction with the human. In contrast, the dog's behaviour is more flexible and it has got a wider ability to recognise human actions, thus there is an increased chance for the puppy to complement human behaviour.

From the ethological point of view it should be noted that even in natural situations dog-human interactions have their limitations. For example, analyzing dogs' behaviour towards humans, Rooney et al (2001) found that most of the owner's action trying to initialize a game remains without reaction. Both Millot et al (1986) and Filiatre et al (1986) demonstrated that in child-dog play the dog reacts only at approximately 30 percent of the child's action, while the child reacts to 60 percent of the dog's action. Although in the case of play it might not be so important, other situations in everyday life of both animals and man require some level of temporal structuring when two or more individuals interact. Such kinds of interactions have been observed in humans performing joint tasks or in the case of guide dogs and their owners. Naderi et al (2001) found that both guide dogs and their blind owners initialize actions during their walk, and sequences of initializations by the dog are interrupted by actions initialized by the owner.

Although the results of the traditional ethological analyses (e.g. Kahn et al 2004, Bartlett et al 2004) suggest that people interacting with AIBO in same ways as if it were a living dog puppy, and that playing with AIBO can provide a more complex interaction than a simple

toy or remote controlled robot, the analysis of temporal patterns revealed some significant differences, especially in the formation of T-patterns. Investigating the common T-patterns we can realize that they start the same way: adult/child looks at the dog/AIBO and then starts to stroke it nearly at the same moment. The main difference is in the further part of the patterns. The T-patterns end here if we look for common T-patterns that can be found in at least 80% of the dyads of adults, children and dog. It continues only in AIBO's T-patterns, when the robot starts to look at the toy, approaches it then moving its head around.

By looking at the recordings of the different groups we found that children did not start a new action when they finished stroking the AIBO. Interestingly when they played with the dog, they tried to initiate a play session with the dog after they stopped stroking it, however was not the case in case of AIBO. Adults tried to initiate a play with both partners, however not the same way. They initiated a tug-of-war game with the dog puppy and a ball chase game with the AIBO. These differences show that (1) AIBO has a more rigid behaviour compared to the dog puppy. For example, if it is not being stroked then it starts to look for the toy. (2) Adults can adapt to their partners play style, so they initiate a tug-of-war game with the puppy and a ball-chasing game with the robot. In both cases they chose that kind of play object which releases appropriate behaviour from the play-partner. (3) Children were not as successful to initiate a play with their partners as adults.

Although we did not investigate this in the present study, the differences in initialisation and termination of the interactions could have a significant effect on the human's attitude toward their partner, that is, in the long term humans could get "bored" or "frustrated" when interacting with a partner that has a limited capacity to being engaged in temporally structured interactions.

In summary, contrary to the findings of previous studies, it seems that at a more complex level of behavioural organisation human-AIBO interaction is different from the interactions displayed while playing with a real puppy. In the future more attention should be paid to the temporal aspects of behavioural pattern when comparing human-animal versus human-robot interaction, and this measure of temporal interaction could be a more objective way to determine the ability of robots to be engaged in interactive tasks with humans.

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Human-robot interaction research is diverse and covers a wide range of topics. All aspects of human factors and robotics are within the purview of HRI research so far as they provide insight into how to improve our understanding in developing effective tools, protocols, and systems to enhance HRI. For example, a significant research effort is being devoted to designing human-robot interface that makes it easier for the people to interact with robots. HRI is an extremely active research field where new and important work is being published at a fast pace. It is neither possible nor is it our intention to cover every important work in this important research field in one volume. However, we believe that HRI as a research field has matured enough to merit a compilation of the outstanding work in the field in the form of a book. This book, which presents outstanding work from the leading HRI researchers covering a wide spectrum of topics, is an effort to capture and present some of the important contributions in HRI in one volume. We hope that this book will benefit both experts and novice and provide a thorough understanding of the exciting field of HRI.

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