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Behavioural Processes 73 (2006) 92–99
BEHAVIOURAL PROCESSES
www.elsevier.com/locate/behavproc

Behavioural comparison of human–animal (dog) and human–robot (AIBO) interactions

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Received 24 October 2005; received in revised form 27 March 2006; accepted 1 April 2006

Abstract

The behavioural analysis of human–robot interactions can help in developing socially interactive robots. The current study analyzes human–robot interaction with Theme software and the corresponding pattern detection algorithm. The method is based on the analysis of the temporal structure of the interactions by detecting T-patterns in the behaviour. We have compared humans' (children and adults) play behaviour interacting either with an AIBO or a living dog puppy.

The analysis based on measuring latencies and frequencies of behavioural units suggested limited differences, e.g. the latency of humans touching the dog/AIBO was similar. In addition other differences could be accounted for by the limited abilities of the robot to interact with objects.

Although the number of interactive T-patterns did not significantly differ among the groups but the partner's type (whether humans were playing with dog or AIBO) had a significant effect on the structure of the patterns. Both children and adults terminated T-patterns more frequently when playing with AIBO than when playing with the dog puppy, which suggest that the robot has a limited ability to engage in temporally structured behavioural interactions with humans.

As other human studies suggest that the temporal complexity of the interaction is good measure of the partner's attitude, we suggest that more attention should be paid in the future to the robots' ability to engage in cooperative interaction with humans.

Keywords: Human–animal interaction; Human–robot interaction; Temporal patterns

1. Introduction

People interact with computers and computerized machines, and such systems are part of our everyday life. Personal computers are common in most households, and some predict (e.g. Bartlett et al., 2004) that robots will be as widespread in the not too distant future as PCs are today. While some robotic systems have no or just some degree of autonomy, others are able to work without the presence of a human (for examples see Agah, 2001). Although autonomous robots were originally designed to work independently from humans, nowadays many such robots are around us and we are interacting with them. A new generation of autonomous robots, the so-called entertainment robots, are designed specially to interact with people. Some of them are functioning as physical aids for elderly people (Pineau et al., 2003), as museum-guide robots (Nourbakhsh et al., 1999; Burgard et al., 1999), as educational instruments (Billard, 2003), or as therapeutic tools (Dautenhahn and Werry, 2002).

Other types of such autonomous robots are designed 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 is able to learn and can be trained with "clicker training" (Kaplan et al., 2002).

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doi:10.1016/j.beproc.2006.04.001

To investigate humans' interaction with entertainment robots two different approaches have been preferred. Based on surveys some researchers are trying to find out whether humans perceive AIBO as similar to a dog and what kind of emotions they ascribe to the robot. A content analysis of online postings to a chatroom for AIBO owners focused on describing owners' perceived relationship with their AIBOs (Kahn et al., 2003). About 42% of the participants spoke of AIBO having feeling while 26% of them spoke of AIBO as a companion. Kahn et al. (2003) suggested that the relationship between people and their AIBO appeared to be similar to the relationship people have with live dogs. 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.

The second line 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 imaginary play with both of them, they showed more exploratory behaviour and attempts at reciprocity when playing with AIBO. Turner et al. (2004) found that children touched the live dog over a longer period than the robot but ball game playing 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.

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 analyze 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. The THEME program (PatternVision Ltd.) allows the analyst to detect complex repeated temporal patterns even when a multitude of unrelated events occur in between components of the patterns, which typically makes them undetectable for currently available statistical methods (for theoretical foundation and explanation of the model and method see Magnusson, 1996, 2000; Anolli et al., 2005, and see also www.hbl.hi.is). The production and perceptual detection of such patterns may well constitute important social skills to be considered in studies of, for example, human social handicaps and "social" robotics (Magnusson, 2004).

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 can not only provide new information about the nature of dog–human interaction but also robot–human interaction.

In our study we investigated children's and adults' behaviour during a play session with AIBO and compared it to playing with a living dog puppy. Our focus was on analyzing spontaneous play between the human and the dog–robot. We wanted to: (1) analyze and compare the temporal structure of the interaction with dog and AIBO in both children and adults, and (2) to investigate whether there are any differences in their play behaviour.

2. Methods

2.1. Subjects

Twenty-eight adults and 28 children were divided into four experimental groups:

1. Adults playing with AIBO: seven males and seven females (mean age: 21.1 years, S.D. = 2.0 years), eight of them has or had a dog before, six of them never had a dog.
2. Children playing with AIBO: seven males and seven females (mean age: 8.2 years, S.D. = 0.7 years), four of them has or had a dog before, five of them never had a dog, five of them did not answer this question.
3. Adults playing with dog: seven males and seven females (mean age: 21.4 years, S.D. = 0.8 years), nine of them has or had a dog before, five of them never had a dog.
4. Children playing with dog: seven males and seven females (mean age: 8.8 years, S.D. = 0.8 years), six of them has or had a dog before, eight of them never had a dog.
5. The number of dog owners in a group did not differ significantly.

2.2. Procedure

The test took place in a 3 m × 3 m separated area of a room. Children were recruited from elementary schools, and the tests were in their schools in a familiar room but not their classroom. Adults were university students, and the tests were carried out either in a familiar room at their dormitory (adult-AIBO dyads) or a familiar room at the university (adult-dog dyads). The robot was Sony's AIBO ERS-210 (dimension: 154 mm × 266 mm × 274 mm; mass: 1.4 kg; colour: silver) that is able to recognize and approach pink objects. To generate a constant behaviour, the robot was used only in its after-booting period for the testing. During the booting period the robot was lying and wiggled its head. The robot's booting behaviour was the same in each case, neither the latency of standing up nor the behaviour units recorded during the booting differed in children-AIBO and adult-AIBO dyads 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 accustomed to interacting with both children and adults, furthermore, its owner's age was similar to the children participating in the test. It was playful and its behaviour was not controlled in rigid manner during the playing session. When the dog seemed to be exhausted we stopped the test and continued next day.

The toy for AIBO was its pink ball, and a ball and a tug for the dog puppy. The tug was introduced in this situation in order to motivate the dog puppy for more play.

The participants played for 5 min either with AIBO or the dog puppy in a spontaneous situation. None of the participants had 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 min, and informed them that they could do whatever they wanted, in the sense that the participants' behaviour were not controlled in any way. All participants were told that AIBO was designed to like being stroked and playing with a pink ball. However, they were not told where the sensors were. About the dog puppy the experimenter said that she can be stroked and likes playing with either the ball or the tug.

2.3. Analysis of behaviour

The video recorded play sessions were coded by ThemeCoder, which enables detailed transcription of digitized video files. All the behaviour of AIBO, the dog and the human was described by 8, 10 and 7 behaviour units, respectively (for the list of the behaviour units see Appendix A). Only those behaviour units were included in this study that were present in all groups, and (due to statistical reasons) occurred at least in two dyads in each group (see Table 1).

Three aspects of the interaction were analyzed. 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. The partners' activity during play includes dog/AIBO walks, stands, lies and approaches the toy. 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 noted the latency of the first human tactile contact (touch) with the dog/AIBO. (This was also the starting point of the 2-min long observation period, transcribed by ThemeCoder, as we expected interactive behaviour elements to occur more frequently after the humans first touched the dog/robot.) Previous work has shown that 2 min (3000 digitized video frames) provides sufficient duration for time pattern analysis.

2.4. Theme software

The interactions were transcribed using ThemeCoder and the transcribed records were then analyzed 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 h0 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. As any basic time unit may be used, T-patterns are in principle scale-

Table 1
Behaviour units used in this analysis

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

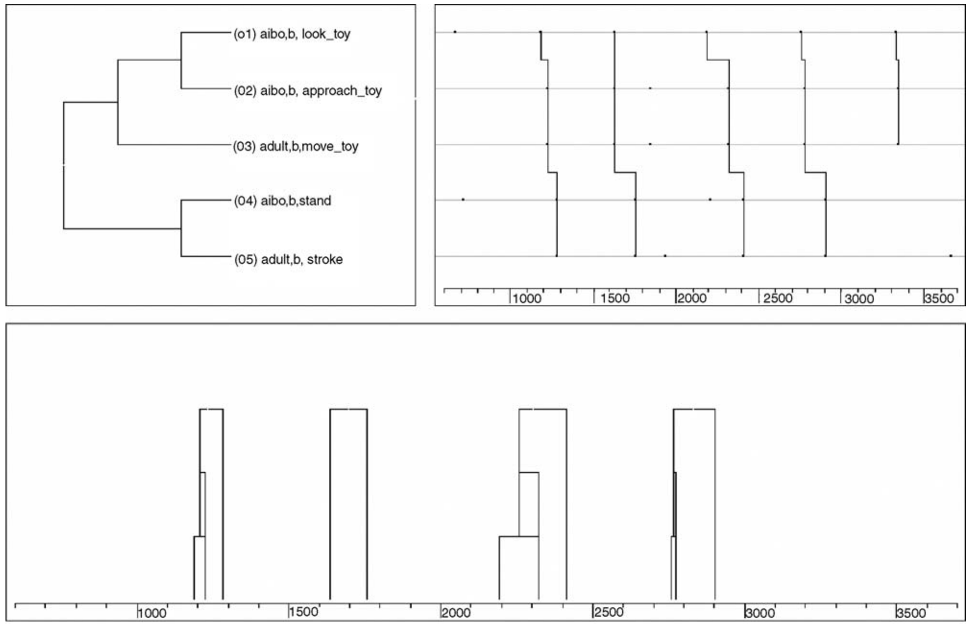

Fig. 1. An example for an interactive T-pattern. This pattern was detected in an adult-AIBO dyad. The upper left box shows the events occurring within the pattern, listed in the order in which they occur within the pattern. The first event in the pattern appears at the top and the last at the bottom. The upper right box shows the frequency of events within the pattern, each dot means that an event has been coded. The pattern diagram (the lines connecting the dots) shows the connection between events. The number of pattern diagrams illustrates how often the pattern occurs. Subpatterns also occur when some of the events within the pattern occur without the whole of the pattern occurring. The lower box illustrates the real-time of the pattern. The lines show the connections between events, when they take place and how much time passes between each event.

independent, while only a limited range of basic unit size is relevant in each concrete study.

2.5. Data analysis

During the coding procedure we recorded the frequency and the duration of behavioural units. We have also transcribed the latency of the first human tactile contact with the dog/AIBO (this was also the starting point of the 2-min long coding with Theme-Coder). Concerning the search for temporal patterns (T-patterns) we used, as a search criterion a 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 contain both the human's and the dog's/AIBO's behaviour units; for example of a T-pattern see Fig. 1). The number, length and level of interactive T-patterns were analyzed with a special focus on 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 the 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. Tests were also conducted on the effect of the subjects' age (children versus adults) and the partner type (dog puppy versus AIBO) using two-way ANOVA.

3. Results

The overall difference in the latency of the first touch of the dog/AIBO among the four groups was not significant ($F_{3,56} = 2.24$, $p = 0.095$). Similarly the overall difference in the duration of behaviour units referring to humans' interest in the partner was not significant. The time spent stroking and looking to the dog/AIBO did not differ among the groups.

Comparing the duration of the behaviour units associated with playing we have found that the overall duration of approach toy differed among the groups ($F_{3,56} = 7.44$, $p < 0.001$) with the significant effect of the partner's type ($F_{1,56} = 17.43$, $p < 0.001$). AIBO spent more time approaching the toy, when playing with children, while no such difference was found when adults played with the dog puppy or AIBO. Humans' age had an effect on the duration of look at toy ($F_{3,56} = 5.21$, $p = 0.003$, effect of age: $F_{1,56} = 10.96$, $p = 0.002$). Both the dog and AIBO spent more time orienting to the toy when playing with children. The duration of move toy varied significantly among the groups ($F_{3,56} = 8.83$, $p < 0.001$), with the significant effect of participants' age. Adults also spent more time moving the ball in front of the dog/AIBO than children did when playing with either AIBO or dog ($F_{1,56} = 4.35$, $p = 0.042$). However, both children and adults spent more time moving the toy if they were playing with AIBO ($F_{1,56} = 21.92$, $p < 0.001$). No significant interaction was found between the effect of humans' age and the partner's type (Fig. 2).

Humans' age also had a significant effect on the dog/AIBO's activity during the playing session. The dog puppy spent more time with lying on the floor ($F_{3,56} = 5.89$, $p = 0.002$, 'human age' $F_{1,56} = 4.73$, $p = 0.002$), and less time with standing and walking than AIBO ($F_{3,56} = 8.94$, $p < 0.001$, 'human age' $F_{1,56} = 21.167$, $p < 0.001$ and $F_{3,56} = 7.86$, $p < 0.001$, 'human age' $F_{1,56} = 4.75$, $p < 0.001$, respectively).

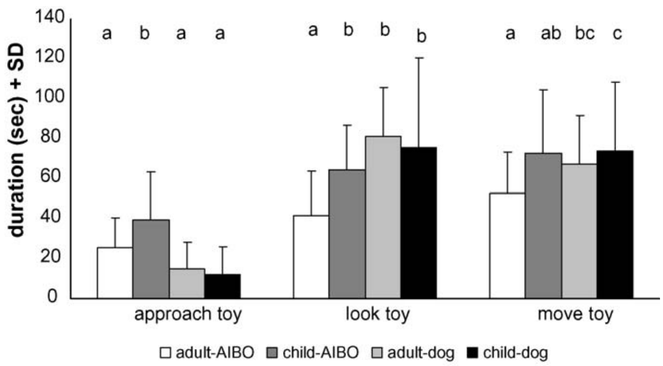

Fig. 2. Mean duration of behaviour units displayed by AIBO or dog (look toy, approach toy) or humans (move toy) (letters ‘a’, ‘b’ and ‘c’ are indicating whether the groups differ significantly. Bars marked by the same letter indicate no differences between those groups).

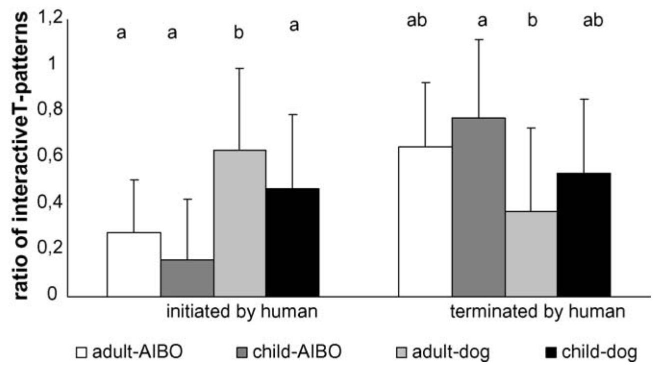

Fig. 4. Mean ratio of interactive T-patterns initiated and terminated by humans (letters ‘a’ ‘b’ and ‘c’ are indicating whether the groups differ significantly. Bars marked by the same letter show that those groups do not differ significantly).

The frequency of the behaviour units describing playing behaviour also differed. Approach toy occurred more frequently when adults played with the dog puppy than in any other case ($F_{3,56} = 6.65$, $p = 0.001$). Both the age of the humans ($F_{1,56} = 4.70$, $p = 0.035$) and the partner ($F_{1,56} = 6.18$, $p = 0.016$) had significant effects and the interaction between them was also significant ($F_{1,56} = 9.09$, $p = 0.004$). However the frequency of look toy did not vary among the groups.

Humans’ age also had an effect on the activity of the play. The frequency of lie ($F_{3,56} = 2.91$, $p = 0.043$, effect of age: $F_{1,56} = 4.73$, $p = 0.034$) and walk ($F_{3,56} = 5.99$, $p = 0.001$, effect of age: $F_{1,56} = 12.25$, $p < 0.001$), were higher in children’s play (Fig. 3). Both AIBO and the dog lay down and started to walk around in the room more frequently when playing with children then when playing with adults.

None of the human’s behaviour (move toy, look dog and stroke) differed in frequency among the groups.

The number of different interactive T-patterns was on an average 7.64 (S.D. = 4.94) in adult-AIBO dyads, 3.72 (S.D. = 1.89) in child-AIBO dyads, 10.50 (S.D. = 10.02) in adult-dog dyads and 18.14 (S.D. = 25.22) in child dog-dyads. Their number did not differ significantly among the groups.

Comparing the ratio of T-patterns initialized by humans among the groups, 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. 4).

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. 5).

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.

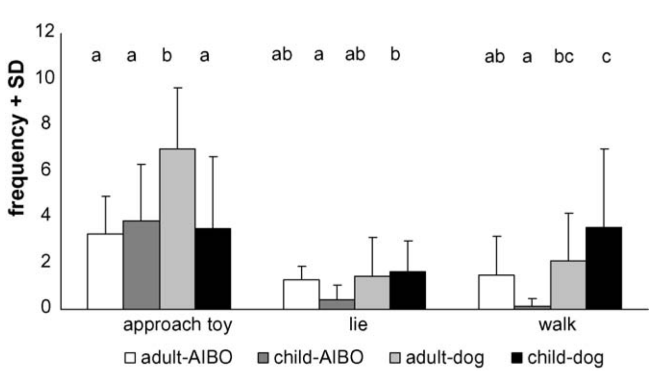

Fig. 3. Mean frequency of behaviour units displayed by AIBO or dog (letters ‘a’, ‘b’ and ‘c’ are indicating whether the groups differ significantly. Bars marked by the same letter show that those groups do not differ significantly).

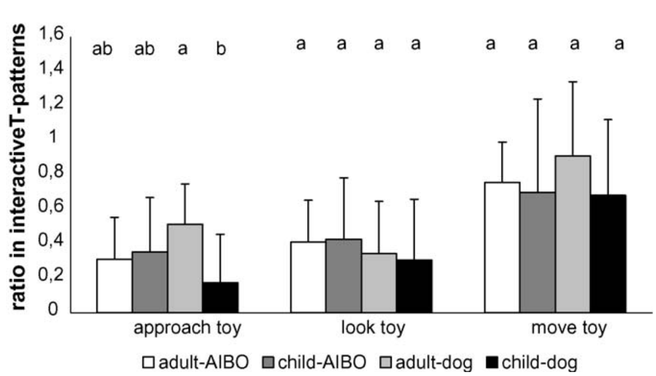

Fig. 5. Mean ratio of interactive T-patterns containing the behaviour units displayed by AIBO or dog (look toy, approach toy) or humans (move toy) (letters ‘a’, ‘b’ and ‘c’ are indicating whether the groups differ significantly. Bars marked by the same letter show that those groups do not differ significantly).

4. Discussion

Previous questionnaire studies on human–robot interaction showed that people describe their relationship with AIBO similar to a relationship with dog puppy (Kahn et al., 2003), attribute animal characteristics to the robot and view it as a family member (Beck et al., 2004). However, the analysis of their behaviour tended to show that in parallel they also behave differently toward the AIBO and a living dog puppy (Turner et al., 2004).

Considering the behavioural pattern of the humans our results show that neither the latency of the first tactile contact between humans and the dog/AIBO nor the duration of stroking the dog/AIBO differed significantly among the groups. This suggests that under the present conditions the robot was as an affective playing partner for both children and adults as the dog puppy. Comparing the play behaviour during the interactions we have found that the only difference between behaviour units performed by humans was the amount of time spent moving the toy in front of the partner. Both children and adults moved the toy in front of AIBO for longer duration. This can be explained on the basis of behavioural difference between the dog and the robot. The dog spent less time approaching the toy compared to AIBO because it was faster to get to the toy, and thus there was no need for the human participants to move the toy so long in front of the dog puppy in order to get its attention as in front of AIBO. So the only difference in humans' behaviour caused by the partner's type can be easily explained by AIBO's much slower movements compared to the dog puppy. This finding is interesting because living dogs distinguished AIBO from a dog puppy in a series of observations by Kubinyi et al. (2004). 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.

Considering the behavioural patterns of the play partners both the dog and the AIBO oriented to the toy more often when playing with children. The dog puppy lay down more often and for longer periods when playing with children, and it was less active during the play with children than with adults. The dog puppy also started to walk around in the room more frequently during the interaction with adults, while no such difference was found when adults or children played with AIBO. These findings suggest that children were less successful in motivating the dog puppy to play than adults.

The results of the traditional ethological analysis showed that both the subjects' age and the partner's type have a significant effect on the interaction. The behaviour of the dog and AIBO (their activity and playing behaviour) were different depending on their type (dog or AIBO) and the age of the subjects' with whom they were playing (children or adults). However, the only difference we have found in humans' behaviour caused by the partner can be explained by the faster speed of movements in the dog puppy compared to the AIBO and not on the basis of the difference between the robot and the living dog puppy.

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 the partner with whom they were interacting or not (Grammer et al., 1998; Sakaguchi et al., 2005). This line of argument 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 losses sight of ball it stops and that can interrupt the playing interaction with the human. In contrast, the dog's behaviour is more flexible and it has a wider ability to recognize 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 and Filiâtre (1986); Millot et al. (1988) and Filiâtre et al. (1986) demonstrated that in child–dog play the dog reacts only at approximately 30% of the child's actions, while the child reacts to 60% of the dog's actions. Although in the case of play it might not be so important, other situations in the 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 and 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 analysis both in our own and other studies (e.g. Kahn et al., 2004; Bartlett et al., 2004) suggest that people interact with AIBO in some 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 differences. Although we did not investigated this in the present study the differences in initialization 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 still different from the interactions displayed while playing with a real puppy, and in the future more attention should be paid to the temporal aspects of behavioural pattern when comparing human–animal versus human–robot interaction.

Acknowledgements

This work has been supported by OTKA (T043763), and a grant from the HAS (F01/031). We would like to thank Frederic Kaplan for providing the AIBO for this study and Márta Gácsi one of the owners of the dog puppy (Nudli) for her help in collecting of the data.

Appendix A

List of the coded behaviour units. Behaviour units written in italics are part of this analysis

(a) Behaviour units in AIBO
- *Orientation to toy (look toy)*
- *Stand*
- Sit
- *Lie*
- Move its head
- *Walk (but not towards the toy)*
- *Approach toy*
- Raise its paw

(b) Behaviour units in dog puppy
- Orientation to human
- *Orientation to toy (look toy)*
- *Stand*
- Sit
- *Lie*
- *Walk (but not towards the toy)*
- *Approach toy*
- Try to leave the room
- Chew toy
- Chew human

(c) Behaviour units in humans
- Orientation to toy
- *Orientation to dog (look dog)*
- Stand
- Sit or squat
- *Move the toy in front of the dog/AIBO (move toy)*
- *Stroke the dog/AIBO (stroke)*
- Flinch back
- Speaking to the dog/AIBO

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