A comparative approach to dogs' <i>(Canis familiaris)</i> and human infants' comprehension of various forms of pointing gestures

Journal:	*Animal Cognition*
Manuscript ID:	AC-07-0008.R3
Type of Paper:	Original Paper
Date Submitted by the Author:	n/a
Complete List of Authors:	Lakatos, Gabriella; Eötvös Loránd University, Department of Ethology Soproni, Krisztina; Institute of Experimental Medicine, Hungarian Academy of Sciences, Department of Behavioural Neurobiology Dóka, Antal; Eötvös Loránd University, Department of Ethology Miklósi, Ádám; Eötvös Loránd University, Department of Ethology
Keywords:	dogs, children, communication, human gestures, pointing

A comparative approach to dogs' *(Canis familiaris)* and human infants' comprehension of various forms of pointing gestures

Gabriella Lakatos[1], Krisztina Soproni[2], Antal Dóka[1], Ádám Miklósi[1]

[1]: Department of Ethology
Eötvös University Budapest
Pázmány P. 1c.
1117 Hungary

[2]: Institute of Experimental Medicine, Hungarian Academy of Sciences
Department of Behavioural Neurobiology
Szigony u. 43.
1083 Hungary

Corresponding author

Gabriella Lakatos
Department of Ethology
Eötvös University Budapest
Pázmány P. sétány 1c.
1117 Hungary
e-mail: gabriella.lakatos@gmail.com
Phone: +3613812179
Fax: +3613812180

Abstract

We investigated whether dogs and 2-, and 3-year-old human infants living, in some respects, in very similar social environments are able to comprehend various forms of the human pointing gesture. In the first study we looked at their ability to comprehend different arm pointing gestures (long cross-pointing, forward cross-pointing and elbow cross-pointing) to locate a hidden object. Three-year-olds successfully used all gestures as directional cues, while younger children and dogs could not understand the elbow cross-pointing. Dogs were also unsuccessful with the forward cross-pointing.

In the second study we used unfamiliar pointing gestures i.e. using a leg as indicator (pointing with leg, leg cross-pointing, pointing with knee). All subjects were successful with leg pointing gestures, but only older children were able to comprehend the pointing with knee.

We suggest that 3-year-old children are able to rely on the direction of the index finger, and show the strongest ability to generalize to unfamiliar gestures. While some capacity to generalize is also evident in younger children and dogs, especially the latter appear biased in the use of protruding body parts as directional signals.

Keywords: dogs, children, communication, human gestures, pointing.

Introduction

Dogs' comprehension of human gestural communication including pointing, head turning and gazing has received increased interest in recent years (for a review see Miklósi and Soproni, 2006). Most studies focused on the dog's ability to comprehend human pointing gestures because it was assumed that in the course of domestication dogs might have gained some advantage in reading human communicative signals (e.g. Hare et al. 2002). Recent investigations have revealed that dogs are able to find hidden food on the basis of different human gestural cues (Miklósi et al. 1998; Hare and Tomasello, 1999; McKinley and Sambrook, 2000) in the so called two-choice task (see Anderson et al 1995, and Methods). In a series of such experiments Soproni et al. (2002) varied the form of the pointing gesture in order to determine the critical visual features of this signal. The results of this study suggest that dogs are sensitive to the relation between the hand/arm and the torso, that is, they infer the directionality of the gesture by observing the direction in which part of the arm/hand protrudes from the upper body.

Interestingly, in contrast to the many investigations of pointing in dogs there are only a few experimental studies on pointing and gazing comprehension in human children. Most of our knowledge is based on longitudinal investigations (Morisette et al. 1995) revealing that human infants are able to look in the general direction indicated by the mothers' gaze at 12 months of age, and they are able to look at the indicated target at 15 months of age if the targets are close and at 18 months of age if the targets are distant (see Morisette et al. 1995). But when gazing is accompanied by a pointing gesture children look at the indicated distant target at 15 months of age. According to Butterworth and Grover (1998) the comprehension of manual pointing develops by 12 months of age, and the exhibition of pointing for others is observed in most children at about 14 months of age (Leung and Rheingold, 1981). More recently Behne et al. (2005) found that 14 months old children are able to choose an object in an object-choice task on the basis of two different types of cues when the cues are given in a communicative way but they show very poor performance if the same cues are given in a non-communicative way.

The social environment of the human infants is often shared by pet dogs in the family. Although for many researchers this does not come as a surprise, others debate that there is a similarity between the social stimulation received by human infants and pet dogs. In any case recent experimental research has revealed some striking similarities. At the level of behavioural interaction both children and pet dogs develop an attachment relationship toward adult humans (e.g. Topál et al. 1998; Prato-Previde et al. 2006), and there are also functional similarities in their communicative behaviour especially between dogs and pre-verbal infants (Miklósi et al. 2000; 2005). Moreover pet-directed speech shares similarities with 'motherese' used to talk to infants ('doggerel' see Hirsch-Pasek and Treiman, 1981; Mitchell, 2001), and owners have complex beliefs as regards the verbal comprehension of their pets (Pongrácz et al. 2001).

Albert and Bulcroft (1987, 1988) found that pets are viewed as important family members by people who live in the city. At the psychological level dogs are often described as family members (e.g. Cain 1985), and humans perceive thinking and feeling processes in dogs to be very similar to that of preschool children where the difference lies not so much in quality but rather in quantity (Rasmussen and Rajecki, 1995). Actually, many studies on the dog-human interactions describe this relationship as an inter-specific parental contact, and there is now both behavioural and psychological evidence that the behaviour of adults toward dogs and infants shares many similarities (Hirsch-Pasek and Treiman, 1981; Mitchell, 2001; Prato-Previde et al., 2006). This gives support for the view that dogs and children have the chance to experience a similar social environment during their early socialisation in human families.

Earlier studies have shown that the comprehension of simple pointing gestures emerges already at the age of 2-4 month in dogs (Hare et al. 2002) and shows little variation over the first year of life (Gácsi et al. 2009a). There are no similar longitudinal observations in infants but studies indicate that by their first year children also comprehend pointing gestures in a communicative situations, and after this period they show a rapid development in their comprehension of human communicative gestures, which is probably facilitated by the production of similar pointing gestures in the framework of communicative behaviour including language learning (e.g. Tomasello and Camaioni, 1997). Thus the first goal of the present study was to find a period of human development in which children and dogs display similar levels of performance. Given the stable performance of dogs beyond their first year we compared adult dogs to 2 and 3 years old infants.

The second aim of this investigation was to gather comparative evidence on the ability to generalize to unfamiliar gestures in both species. It has been suggested that the use of unfamiliar signals could provide some evidence for referential understanding (Povinelli et al. 1997). Therefore we investigated whether dogs and human infants are able to generalize from familiar pointing gestures to unfamiliar ones, and whether they comprehend these unfamiliar gestures as being directional. In this regard two specific questions were investigated. First, we wanted to know whether children and dogs are able to generalize to a topographically similar gesture that is executed with a different body part (pointing with the leg) based on the assumption that subjects have been rarely (if at all) exposed to such body movements in a communicative context. Second, we asked whether dogs and children at a certain age gain the capacity to recognize the significance of the pointing finger in the communicative context.

General methods

Subjects

As testing place, we chose the most natural environment for each group so as to keep stress levels at a minimum. Therefore in the case of dogs and 2-year-old children we conducted the experiments in the home of the subjects in the presence of the owner/parent. In the case of 3-year-old children we conducted the experiments in two nursery schools in Budapest and in one kindergarten in Budaörs. In all cases we obtained the parents' permission. In addition we carried out a pilot study with five 3-year-old children tested in their homes instead of the nursery to evaluate the potential effects of setting, however no difference emerged between children tested in the two settings.

Dogs (N=15): All individuals participated in both studies (pointing with arms and pointing with legs). Eleven males, four females; the mean age of the dogs was 4.9 years, SD was 2.4 years and the range was 1 - 12 years. Eight individuals were naive, 7 individuals had participated in other studies recently, in which they had been exposed to some simpler kind of gestures (dynamic-sustained proximal and distal pointing, and momentary proximal and distal pointing gestures; Miklósi et al., 2005). The age of the owners was 24.75 + 5.2 years (mean + SD); range was 18 – 38; two men and twelve women. Previous study found that the age and other specific experiences (agility training) of the dogs do not have an effect on their ability to utilize the momentary pointing gesture (Gácsi et al. 2009a).

2-year-old children (N=13): Twelve individuals' behaviour was measured in both studies. Eleven individuals out of the thirteen children participated in both studies and 2 individuals participated only in one of the studies. Seven girls and five boys participated in both tests. Ten children were younger than 2-year-old and three children were older than 2-year-old in this group. The mean of the children's age was 21.1 months, SD was 3.7 months and the range was 16.5 - 27.5 months in the case of Study 1. The mean of the children's age was 21.1 months, SD was 3.8 months and the range was 16.5 - 27.5 months in the case of Study 2.

3-year-old children (N=11): All individuals, eight girls and three boys, participated in both studies. Ten children were older than 3-year-old and one child was younger than 3-year-old in this group. The mean of the children's age was 38.7 months, SD was 2.4 months and the range was 34 - 41 months.

Pretraining: Familiarization with the situation

In the present studies we used the same method described in earlier studies (e.g. Soproni et al. 2001, 2002; Miklósi et al. 2005). The experimenter placed two bowls (brown plastic flower pots: 13 cm in diameter, 13 cm in height) 1.3 - 1.6 metres apart, in front of her, on the floor in the case of dogs, and on two chairs in the case of children. The experimenter, in the presence of the subject, placed a reward in one of the bowls: food for the dogs and a favourite toy for the children. The subjects could witness this hiding from a distance of 2 - 2.5 m with their owner/parent standing behind them. After having the experimenter put the food/toy into the bowl, the owner/parent allowed the subject to take the reward out from the bowl. One trial lasted 30 seconds, and the procedure was repeated twice for each bowl to ensure that the subject knew that the bowls might contain some reward.

Testing

The position of the participants was the same as above, but during the testing the subject was prevented from observing the hiding. The experimenter picked up the bowls, put the reward (a piece of food in the case of dogs and a favourite toy in the case of children) into one of the bowls and after that she placed both bowls back onto the floor/chairs at the same time.

During the pointing the experimenter was standing 0.5 m back from the middle line between the two bowls, facing the subject at a distance of 2-2.5 m. The owner/parent was holding back the subject gently until the experimenter gave the cue. The experimenter drew the subject's attention to herself (any sounds, like clapping or/and the subject's name could be used) and presented the visual cue when the subject looked in the direction of her face. During pointing the experimenter was looking at the subject. If the subject did not set out at the first cue, the experimenter repeated the pointing gesture again for a maximum of three times. The subject was allowed to choose only one bowl, if it chose the incorrect one the experimenter picked up the baited bowl from the floor while the subject approached the unbaited one.

We used four types of pointing gestures in both tests (Study 1 and 2) ("Probe trial method", in which novel test treatments were presented by embedding them into a background of a very familiar gesture, the distal pointing; see below and see also Povinelli et al. 1999; Soproni et al. 2002; Miklósi et al. 2005). Apart from the pointing gesture with an extended arm and index finger ("control trials": distal pointing), we used three other kinds of pointing gestures (probe trials), which differed from each other in certain important features of the gesture (see below). Each test session consisted of 12 trials in the case of dogs, which contained 4 trials of momentary distal pointing gesture and 8 probe trials, with all three unfamiliar gestures included (3 trials of two types of the probe trials and 2 trials of the third type). Unfamiliar gestures were also displayed in a momentary manner. The presentation of the cues was in a predetermined semi-random order and was balanced for right and left side. Neither the same gesture, nor the same place for the reward was used more than two times in a row. With each dog we staged three test sessions. Overall the dogs received 8 trials for each type of the unfamiliar pointing gestures in both studies. A minimum of one day and a maximum of two weeks passed between the two test sessions in both studies.

In the case of children pilot studies have shown that they are not able to concentrate for too many trials and we also needed to take into consideration that at this age their capacities develop rapidly. Thus we decided to have fewer sessions with the children and thereby they received fewer trials overall than dogs. With each child we had one test session consisting of 18 trials, which contained 6 trials of pointing gesture and 4-4-4 trials of each probe trial in both studies (See also Table 1).

All subjects participated in Study1 for the first time, and after it was completed they participated in Study2. There were a maximum of two weeks between the two studies.

All experimental trials were recorded on video. Trials were scored in real time by the experimenter.

Study 1: Pointing with arms

In this study we wanted to test the effect of a protruding body part and the index finger on the comprehension of the pointing gesture. Therefore we systematically varied the pointing gesture by comparing gestures that either presented a protruding upper arm and elbow (elbow cross pointing), a pointing gesture when no parts of the hand appeared outside the body outline (cross-forward pointing), and a pointing gesture when the hand (including the extended index finger) protruded on one side of the body (long cross-pointing) (see Fig. 1 from left to right). If the subjects are interested only in the protruding body part (as was hypothesized earlier see Soproni et al. 2002) then they should choose the "indicated" bowl both in the elbow cross pointing and in the long cross-pointing condition (note that in the case of the former this results in incorrect choice). In parallel subjects should not be able to choose correctly in the cross-forward pointing condition. If however subjects realize the significance of the index finger as an "invariant" feature of the pointing gesture then they should be correct in all conditions.

It should be noted that in a former experiment with a smaller sample we found that dogs showed no preference in the elbow cross pointing condition but were able to find the hidden food based on the long cross-pointing gesture (Soproni et al. 2002). In this regard this study is a replication of those observations (including an additional gesture) on a new**,** larger sample of animals. Povinelli et al. (1997) used the dynamic-sustained version of our momentary elbow cross pointing gesture (for the importance of temporal structure of the gesture see Methods) with chimpanzees and children. They found that in the case of the elbow cross pointing (the only condition comparable to the gestures used in this study) the apes showed a strong preference for the unbaited container "indicated" by the "elbow", whilst children older than 2 years were looking in the bowl indicated by the index finger.

Method

Types of momentary pointing gestures used (see also Miklósi and Soproni, 2006):

1. *Distal pointing:* the experimenter pointed with extended arm and index finger in the direction of the correct location using her closer hand. After signalling (it lasted about 1 second), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Figure 1.a).

2. *Elbow cross-pointing*: the experimenter pointed with her contralateral hand, with bent arm, so her elbow stuck out to the side of the empty bowl and her extended index finger did not extend beyond the mid-line of her body. After signalling (1 sec), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Figure 1.b).

3. *Forward cross-pointing:* the experimenter stepped back about 0.5 metres from the bowls and she pointed with her contralateral hand, but her extended index finger did not protrude from her silhouette. After signalling (1 sec), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Figure 1.c).

4. *Long cross-pointing:* the experimenter pointed with her contralateral hand, with an extended arm, and her extended index finger protruded from her silhouette to the side of the rewarded bowl. After signalling (1 sec), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Figure 1.d).

Statistical analysis

The statistical analysis was based on the number of the correct choices (in percent) and non-parametric procedures (Kruskal-Wallis test, One-sample Wilcoxon signed-rank test) were used.

Results and discussion

Between-group comparisons: We compared the performance of the three experimental groups by Kruskal-Wallis test (with Dunn's post hoc tests, $p < 0.05$) separately for each gesture (Figure 2, Table 2). In the case of the "Distal pointing" we found that 3-year-old children perform significantly better than dogs. In the case of "Long cross-pointing" and the "Forward cross-pointing" we revealed that the both groups of children performed significantly better than the dogs. In the case of the "Elbow cross-pointing" we found that 3-year-old children displayed significantly better performance in choosing the correct bowl in comparison to the younger children and dogs.

We compared the performance (mean percentage) of the experimental groups to the expected chance level using One-sample Wilcoxon signed-rank tests (Table 3). Given the ceiling level of performance for 3-year-old children (which obviously differs significantly from chance level), we compared the performances to the chance level only in those cases when the mean percentages differed significantly from the data for 3-year-old children according to the Kruskal-Wallis test (see above). 2-year-old children's performance differed significantly from the 3-year-old children's performance only in the case of the "Elbow cross-pointing". According to the One-sample Wilcoxon signed-rank test their performance was at chance level in this case. In the dogs' case the Kruskal-Wallis test showed that the 3-year-old children performed better in all types of pointing gesture. If we look at the results of the One-sample Wilcoxon signed-rank tests we find that the dogs' performance is significantly above chance only in the case of the "Distal pointing" and the "Long cross-pointing", their performance does not differ from chance for the "Forward cross-pointing". In the case of the "Elbow cross-pointing" they prefer the side of the elbow (they choose the empty bowl), thus performing significantly below chance level (Figure 3).

There was no sign of learning during testing for any of the gestures in any of the experimental groups. The comparison of the performance in the first and the second half of gestures for each type revealed no significant changes (Wilcoxon matched pairs test; 3-year-old children: we could not make the statistical analysis in case of "Distal pointing" and "Long cross-pointing", because there were SD=0, and in case of the "Forward cross-pointing", because there was no any difference between the results of the two halves; "Elbow cross-pointing" (T(+)=3.0; p=0.5). 2-year-old children: "Distal pointing" (T(+)=4.0; p=0.75); "Elbow cross-pointing" (T(-)=-12.0; p=0.31); "Forward cross-pointing" (T(+)=9.0; p=0.81); "Long cross-pointing" (T(-)=-4.0; p=0.75). Dogs: "Distal pointing" (T(-)=-53.5; p=0.59); "Elbow cross-pointing" (T(-)=-43.5; p=0.73); "Forward cross-pointing" (T(+)=22.5; p=0.55);

"Long cross-pointing" (T(+)=24.0; p=0.46).

The varied age of the group of 2-year-old children allowed for a correlative analysis. We found that there was no correlation between age and performance with the "Distal pointing" and the "Forward cross-pointing" (Spearman rho = 0.10, p = 0.76 and rho = 0.15, p = 0.65) but older children were better in the case of the "Long cross pointing" and the "Elbow cross-pointing" (Spearman rho = 0.64, $p < 0.02$ and rho = 0.62; $p < 0.03$, respectively).

Supporting our hypothesis, the present study shows that dogs can choose on the basis of the "Distal pointing" and "Long cross-pointing". In addition, and contrary to earlier findings (Soproni et al. 2002) dogs also preferred the incorrect container "indicated" by the elbow of the experimenter. Whilst this tendency gives further support to our theory at the moment we have no explanation for this difference. Taken together, these findings suggest that dogs choose on the basis of a body part that protrudes from the signalling person's silhouette, and it seems that the directionality of the index finger plays a small role in influencing the choice.

Three-year-old infants' performance was significantly better in the case of the "Elbow cross-pointing" than 2-year-old infants' performance, and this was the only gesture in which younger children did not choose above chance level. The effect of age (and/or experience) was also supported by the correlation analysis. In the group of younger children we saw that they performed at chance level (at the group level), but older children in this group (older than 2 years) seemed to take into account the direction of the index finger.

Study 2: Pointing with legs

In this study we used three different kinds of pointing gestures using the leg as the signalling body part. We relied on the apparent visual similarity of the pointing arm and leg, and wanted to find out whether subjects could generalize from the hand to the leg pointing gestures. We hypothesized that if the subjects use the visual image of a protruding body part as a directional signal then they should be able to perform well in the case of leg pointing.

Method

The method used was similar to that described above. The following momentary pointing gestures were utilized:

1. *Distal pointing***:** the experimenter pointed with extended arm and index finger in the direction of the correct location using her closer hand. After signalling (1 sec), she lowered her arm to the starting position before the subject was allowed to approach the bowls (Figure 1.a.).

2. *Pointing with leg:* the experimenter pointed with an extended leg in the direction of the correct location using her closer leg. After signalling (1 sec), she lowered her leg to the starting position before the subject was allowed to approach the bowls (Figure 4.a.). The distance between the pointing leg and the baited bowl was about 15 centimetres.

3. *Cross-pointing with leg:* the experimenter pointed with an extended leg in the direction of the correct location using her contralateral leg. After signalling (1 sec), she lowered her leg to the starting position before the subject was allowed to approach the bowls (Figure 4.b.). The distance between the pointing leg and the baited bowl was about 30 centimetres.

4. *Pointing with knee:* the experimenter pointed with a bent leg, so her closer knee was signalling the baited bowl. After signalling (1 sec), she lowered her leg to the starting position before the subject was allowed to approach the bowls (Figure 4.c.). The distance between the experimenter's knee and the baited bowl was about 60 centimetres.

Results and discussion

Between-group comparisons: We compared the performance of the three experimental groups with Kruskal-Wallis test (with Dunn's post hoc tests, $p < 0.05$) in the case of each gesture separately (Figure 5, Table 2). In the case of the “Distal pointing” 3-year-old children’s performance was better than the other two experimental groups’. In the case of the “Pointing with leg” 3-year-old children performed significantly better than both the 2-year-old children and dogs. And in the case of the “Cross-pointing with leg” and the “Pointing with knee” we also found that 3-year-old children displayed a significantly better performance than the subjects in the two other experimental groups. In contrast to the previous study we found no correlation between age and performance in 2-year-olds.

We compared the performance (mean of percentage) of the experimental groups to the chance level by One-sample Wilcoxon signed-rank tests (Table 3). Given the ceiling level of performance for 3-year-old children, we compared the performances to chance level only in those cases when the mean percentages differed significantly from the data for 3-year-old children according to the Kruskal-Wallis test (see above) as we did in the Study 1. According to the Kruskal-Wallis test the 3-year-old children’s performance was better than both the 2-year-old children’s and dogs’ for each kind of pointing gesture. If we look at the results of the One-sample Wilcoxon signed-rank test we find that 2-year-old children perform significantly better, than chance in the case of the “Distal pointing”, “Pointing with leg” and “Cross-pointing with leg”, but their performance is at chance level in the case of the “Pointing with knee”. Dogs’ performance differs significantly from the chance level only in the case of the “Distal pointing”, the “Pointing with leg” and the “Cross-pointing with leg”, their performance does not differ from the chance level in the case of the “Pointing with knee”.

There was no sign of learning during testing for any of the gestures in any of the experimental groups. The comparison of performance in the first and the second half of gestures for each type revealed no significant changes (Wilcoxon matched pairs test; 3-year-old children: we could not make the statistical analysis in case of “Distal pointing”, “Pointing with leg”, and in case of “Cross-pointing with leg” because there were $SD=0$; “Pointing with knee” ($T(+)=2$; $p>0.99$). 2-year-old children: “Distal pointing” ($T(-)=-5.0$; $p=0.5$); “Pointing with leg” ($T(+)=7.0$; $p=0.62$); “Cross-pointing with leg” ($T(+)=10.5$; $p>0.99$); “Pointing with knee” ($T(+)=32.5$; $p=0.25$). Dogs: “Distal pointing” ($T(+)=18.0$; $p=0.58$); “Pointing with leg” ($T(+)=43.0$; $p=0.41$); “Cross-pointing with leg” ($T(-)=-28.5$; $p=0.92$); “Pointing with knee” ($T(-)=33.0$; $p>0.99$).

In summary the above results show that the 3-year-old infants’ performance was significantly higher in the case of all unfamiliar gestures signaled by the leg (“Pointing with leg”, “Cross-pointing with leg” and “Pointing with knee”) than the 2-year-old infants’ performance. Further it seemed that there was little difference in the performance of 2-year-old children and dogs, including the fact that neither group performed above chance level in the "knee-pointing". This suggests that to some extent subjects were able to generalize from their previous experience to a relatively novel directional gesture, and this generalization was based possibly on the similarity of the visual image, that is, the leg as well the hand provides a contrasting directional signal in which the limb protrudes from the body contour.

General discussion

We studied the behaviour of adult dogs and children of different ages in an object-choice task, in which we investigated whether they are able to use various gestural signals to locate a hidden object. The first study supported the idea that the basis for the utilization of the more and less familiar gestures was to rely on the protruding arm and/or hand. However, in older children this overall tendency was overriden by the understanding that the key feature of the pointing gesture is not the directionality of the hand or arm *per se* but the direction of the pointing index finger. This ability seems to emerge at around 2 years of age because all children in the 3-year-old group and the oldest ones in the 2-year-old group seemed to base their choice on the direction indicated by the index finger. This was revealed in the case of the "Elbow cross-pointing" condition, in which dogs preferred the (incorrect) bowl, which was located on the side of the protruding elbow, 2 years olds showed no preference whilst older children based their choice on the direction indicated by the pointing finger in front of the chest. Interestingly, in similar conditions chimpanzees also tended to prefer the bowl closer to the elbow in the case of a dynamic pointing gesture (Povinelli et al. 1997) just like dogs, however, note that the same chimpanzees were less successful in many other forms of the pointing gesture compared to dogs (see Miklósi and Soproni, 2006). This suggests that younger children and dogs do not grasp the meaning of the pointing index finger in this situation, instead, they rely on a common simple rule: follow the direction indicated by the protruding body part.

Both children and dogs showed some evidence of generalization in the presence of unfamiliar gestures i.e. when the pointing was done with the leg, and it is likely that they relied on the same rule referred to above. Interestingly, neither dogs nor 2-years olds were able to find the object when it was indicated by the "pointing" knee. Although the "pointing" knee gesture also protrudes from the body contour, its visual image is distinctly different from the "stick-like" image of a pointing limb. These results suggest that the ability to generalize is more limited in dogs and 2-year-old children than in 3-year-old children.

The results clearly indicate a ceiling effect in the case of 3-years-olds which suggests that by the age of 2-3 years marked changes have taken place in their capacity to utilize visual communicative signals. We think that the synergic effect of at least three processes could lead to this development. First, they seem to grasp the meaning of a directional signal in general terms, that is, any signal (body movement) that is displayed on one side is regarded as an indication to the location of the reward (e.g. the knee of the experimenter). We were led to this conclusion by the result that 3-year-old children's performance was very high in the case of all gestures used and, in contrast to the 2-year-old children, they were able to choose also on the basis of the "pointing with knee" gesture.

Second, 3-year-old children's performance in the case of the "Elbow cross-pointing" suggests that they are able to understand the meaning of the index finger and use it as a guiding cue. This capacity could be the result of two different processes. Children acquire the use of this gesture by 14 months of age (Leung and Rheingold, 1981; Butterworth and Grover, 1998), and by this time become proficient users of the pointing gesture (e.g. Dobrich and Scarborough, 1984). Thus they are in the position to realize the correspondence between their own pointing action and the pointing action of the experimenter (Butterworth and Grover, 1998). In addition they have been exposed to pointing gestures during language learning when the index finger has a specific role (Leavens and Hopkins, 1999), (although we note that the use of the index finger for pointing does not appear to be universal, there are reports about cross-cultural differences in the semiotics of pointing (Wilkins, 2003)). It is likely that interactions during language learning facilitate the understanding in children that the index finger has the important role of indicating objects of interest even over long distances. This suggests a feedback of referential (linguistic) communication on the understanding of pointing with the index finger. Thus children younger than 2 years of age have either too little exposure to pointing gestures or they lack the necessary cognitive structures for being able to extract the significance of the index finger. The lack of linguistic training could also explain why dogs in our study could not overcome this hurdle.

Third, the present task has been often interpreted as requiring certain capacities of cooperation. Actually, Hare et al (2000) used this argument to explain the low performance in such object choice tasks in chimpanzees. There is evidence, in children, that the cooperative ability both towards adults and especially toward peers increases markedly between 2 and 3 years of age (e.g. Brownell et al. 2006). Thus older children might be more at ease in cooperating with an unfamiliar adult in the present task, and thus are more attentive to minor behavioural signals that indicate intentional action on the part of the other (Tomasello et al. 1997). This latter ability could be enhanced by the development of complex representations of shared intention (see also Tomasello et al. 2004). Behne et al. (2005) also argued that children as young as 14 months of age can comprehend also the communicative intentions behind gestures, like gazing or pointing.

It is also important to note that although there is a quantitative difference between the performance of the dogs and the 3-years-olds in the comprehension of the pointing gesture, at the functional level dogs' performance is comparable to that of 2-year-old children. Given that dogs are not required to acquire complex linguistic forms of communication, their level of comprehension seems to be proportional to the challenges set by their natural human social environment. It remains to be shown whether, after further training, dogs may learn the significance of the directionality of the index finger including the skill to generalize to novel forms of the index gesture. On the positive side dogs have been able to learn the significance of minute directional eye movements in an object choice task (Miklósi et al. 1998).

From a broader, comparative perspective, various studies have pointed out the limitation of apes in comprehending some forms of the pointing gesture and other unfamiliar forms of pointing signals. The majority of apes tested do not perform spontaneously above chance level in object-choice tasks (Povinelli et al. 1997; Tomasello et al. 1997; Call et al. 1998; Itakura et al. 1999; Call et al. 2000; Hare et al. 2002; Bräuer et al. 2006). Although, intensive socialisation (enculturation) enhances performance in object-choice tasks when humans provide them with communicative cues such as pointing (Tomasello et al. 1997; Itakura and Tanaka, 1998), even in this case individuals did not seem to comprehend that the experimenter was attempting to communicate with them (Tomasello et al. 1997; Call et al. 2000). Results of the present study suggest that dogs are relatively flexible in their comprehension (see also Hare et al. 1999, 2002; Soproni et al. 2002; Miklósi et al. 2005), especially if we take into account that in our studies dogs are exposed to more difficult gestures. Although some studies suggest that the ability to rely on complex human pointing gestures might be present in some other species (seals: Shapiro et al. 2004; Scheumann and Call, 2004; dolphins: Tschudin et al. 2001; Herman et al. 1999), the results do not offer an easy interpretation. However, controlled experiments involving dogs and wolves socialized with humans at the same level clearly pointed at species differences. Two studies have provided evidence that in young dogs show better performance in such object choice tasks (Miklósi et al. 2003, Virányi et al. 2008) in comparison to wolves, however this difference seems to disappear in adults if subjects of the later species are socialized intensively (Gácsi et al 2009b). This suggests that at least within the Canidae domesticated dogs represent a unique species which, through their evolutionary association with humans, gained some advantages in their sensitivity to human communicative signals (Frank et al. 1980; Miklósi et al. 2004). Miklósi et al. (2003) suggested that the difference in performance could be partially explained on the basis of the dogs' preference to gaze at humans in spontaneous situations in contrast to that observed in wolves (Gácsi et al 2005).

Many researchers agree that the human pointing gesture has a referential nature (Tomasello and Camaioni, 1997), but they disagree (Povinelli et al. 1997) as to whether animals can also comprehend this aspect of the pointing action. According to Povinelli et al. (1997) and Herman et al. (1999) supporting evidence for such comprehension can be gained by showing that the subject is able to generalize (from familiar gestures to unfamiliar ones and to comprehend the familiar gestures in unfamiliar situations), and to recognize the communicative intention of the signaller. Based on the present studies we can reach some conclusion as regards the dog's generalization ability but it is difficult to determine the level of comprehension in terms of the communicative intentions behind the gestures. Children display a gradually developing capacity to grasp the referential aspect of the gesture (but this situation is made more complex by their own use of this gesturing). In the case of dogs the effect of their own utilisation can be excluded (they do not use limbs for pointing), although some assume that the dog's ability to "body point" (looking with stiff body in the direction of prey) could facilitate the emergence of such a skill. In any case a relatively simple rule leads to a flexible comprehension of the pointing gesture in dogs, which clearly suffices in everyday situations. Thus one might be tempted to refer to "functional referentiality" (Evans, 1997) in the case of dogs but the use of this terminology does not provide a solution to the problem.

Many authors draw a parallel between object choice tasks based on social cueing (when the place is signalled by a human) and experimental ("foraging") situations when the correct location of hidden target is indicated by the nearby presence of an object or visual cue ("beacon") (without the involvement of humans). According to this view both the hand/finger and the object/visual cue plays the role of a discriminative stimulus which becomes associated with the location of the hidden reward. However, importantly, there is evidence available that in choice tasks using visual beacons the distance of the signalling object and the location of the reward is critical. Neither apes (Jenkins 1943; Murphy and Miller, 1955) nor dogs (Milgram et al. 1999) are able to rely on beacons that appear further then 10-20 cm from the hidden target. In contrast in the communicative version of this task, when the "beacon" is the pointing hand, at least dogs seem to have no problem even if the distance is much greater and the "beacon" disappears at the time of choice. This difference in performance suggests that the behaviour is under different cognitive control when the search for a target takes place in an asocial or a social situation. Thus on functional grounds it might be useful to differentiate social and asocial foraging tasks. Interestingly this might suggest that human children do not use a simple rule based on discrimination learning because if this were the case even younger children should have been able to rely on all gestures presented (see Povinelli et al. 1997). Although we do not want to exclude the role of discrimination learning it seems that this process works very differently under social and asocial conditions, and on its own does not explains the observed performance. It does not mean that other types of learning cannot play a role, e.g. in the case of the human children we have seen that it takes them about three years to learn how to follow the index finger when it is presented in novel configurations, for which rule-based learning might provide a possible explanation (Allan, 1993).

In summary, the subjects' responsiveness to the variations of the pointing gesture suggests that both dogs and children (of both ages) have the ability to use rules to generalize from the pointing gesture to other similar types of gestures. Three-year-olds seem to recognize the index finger as a general directional signal. In younger children protruding body parts provide the main cue for deducing directionality. At least at the functional level dogs show a similar performance as 2 year-olds that can be explained as a joint outcome of their evolutionary history and their socialization in a human environment.

Acknowledgments

This study was supported by grants received from the Hungarian Science Fund (OTKA T049615), the Hungarian Academy of Sciences (F01/031) and an EU FP6 NEST 012787 grant. The authors are grateful to all the parents and the owners who participated in this research for their patience and support throughout the study.

The experiments delineated in this manuscript comply with the current Hungarian laws.

References

Albert A, Bulcroft K (1987) Pets and urban life. Anthrozoos 1: 9-25

Albert A, Bulcroft, K (1988) Pets, families, and the life course. J Marriage Fam 50: 543-552

Allan LG (1993) Human contingency learning: Rule based or associative? Psychol Bull 114: 435-448

Behne T, Carpenter M, Tomasello, M (2005) One-year-olds comprehend the communicative intentions behind gestures in a hiding game. Developmental Sci 8: 492-499

Bräuer J, Kaminski J, Riedel J, Call J, Tomasello M (2006) Making inferences about the location of hidden food: Social dog – causal ape. J Comp Psychol 120: 38-47

Brownell CA, Ramani GB, Zerwas S (2006) Becoming a Social Partner With Peers: Cooperation and Social Understanding in One- and Two-Year-Olds. Child Dev 77: 803–821

Butterworth GE, Grover L (1998) Joint visual attention, manual pointing, and preverbal communication in human infancy. In Jeannerod M, Hillsdale NJ (Eds.): Attention and Performance. Erlbaum.

Cain AO (1985) Pet as family members. In Sussman M (Ed.): Pets and the family. The Haworth Press.

Call J, Agnetta B, Tomasello M (2000) Cues that chimpanzees do and do not use to find hidden objects. Anim Cogn 3: 23-34

Call J, Hare B, Tomasello M (1998) Chimpanzee gaze following in an object choice task. Anim Cogn 1: 89–100

Dobrich L, Scarborough A (1984) Form and function in early communication. Language and pointing gestures. J of Exp Child Psychol 38: 475-490

Evans CS (1997) Referential signals. In Owings DH, Beecher MD, Thompson NS, (Eds.): Perspectives in Ethology, Communication. Plenum Press, New York. Vol 12: pp 99-143

Frank H (1980) Evolution of canine information processing under conditions of natural and artificial selection. Z Tierpsychol 53: 389-399

Gácsi M, Győri B, Miklósi Á, Virányi Zs, Kubinyi E, Topál J, Csányi V (2005). Species-specific differences and similarities in the behavior of hand raised dog and wolf puppies in social situations with humans. Devel Psychobiol 47:111-122.

Gácsi M, Kara E, Belényi B, Topál J, Miklósi Á (2009a) The effect of development and individual differences on pointing comprehension in. Animal Cognition (in press).

Gácsi M, Győri B, Virányi Zs,Kubinyi E, Belényi B, Miklósi Á (2009b) Selection for developmental shift explains dog-wolf difference in comprehension of human gestural signals (submitted)

Hare B, Tomasello M (1999) Domestic dogs *(Canis familiaris)* use human and conspecific social cues to locate hidden food. J Comp Psychol 113: 173-177

Hare B, Brown M, Williamson C, Tomasello M (2002) The domestication of social cognition in dogs. Science 298: 1634-1636

Herman LM, Abichandani SL, Elhajj AN, Herman EYK, Sanchez JL, Pack AA (1999) Dolphins *(Tursiops truncatus)* comprehend the referential character of the human pointing gesture. J Comp Psychol 113: 347-364

Hirsch-Pasek K, Treiman R (1981) Doggerel: motherese in a new context. J Child Lang 9: 229-237

Itakura S, Tanaka M (1998) Use of experimenter-given cues during object-choice tasks by chimpanzees *(Pan troglodytes)*, an orangutan *(Pongo pygmaeus)*, and human infants *(Homo sapiens)*. J Comp Psychol 112: 119-126

Jenkins WO (1943) A spatial factor in chimpanzee learning. J Comp Psychol 35: 81–84

Leavens DA, Hopkins WD (1999) The whole-hand pointing: The structure and function of pointing from a comparative perspective. J Comp Psychol 113: 417-425

Leung EHL, Rheingold HL (1981) Development of pointing as a social gesture. Dev Psychol 17: 215-220

McKinley J, Sambrook TD (2000) Use of human-given cues by domestic dogs *(Canis familiaris)* and horses *(Equus caballus)* Anim Cogn 3: 13-22

Miklósi Á, Polgárdi R, Topál J, Csányi V (1998) Use of experimenter-given cues in dogs. Anim Cogn 1: 113-121

Miklósi Á, Kubinyi E, Topál J, Gácsi M, Virányi Zs, Csányi V (2003) A simple reason for a big difference: wolves do not look back at humans but dogs do. Curr Biol 13: 763-766

Miklósi Á, Topál J, Csányi V (2004) Comparative social cognition: What can dogs teach us? Anim Behav 67: 995-1004

Miklósi Á, Pongrácz P, Lakatos G, Topál J, Csányi V (2005) A comparative study of the use of visual comminicative signals in interactions between dogs *(Canis familiaris)* and humans and cats *(Felis catus)* and humans. J Comp Psychol 119: 179-186

Miklósi Á, Soproni K (2006) A comparative analysis of the animals' understanding of the human pointing gesture. Anim Cogn 9: 81-93

Milgram NW, Adams B, Callahan H, Head E, Mackay B, Thirlwell C, Cotman CW (1999) Landmark discrimination learning in the dog. Learn Memory 6: 54-61

Mitchell RW (2001) Americans' talk to dogs: Similarities and differences with talk to infants. Res Lang Soc Interac 34: 183–210

Morisette P, Ricard M, Decarie TG (1995) Joint visual attention and pointing in infancy: A longitudinal study of comprehension. Brit J Dev Ps 13: 163-175

Murphy JV, Miller RE (1955) The effect of spatial contiguity of cue and reward in the object-quality learning of rhesus monkeys. J comp Physiol Psychol 48: 221-224

Povinelli DJ, Reaux JE, Bierschwale DT, Allain AD, Simon BB (1997) Exploitation of pointing as a referential gesture in young children, but not adolescent chimpanzees. Cognitive Dev 12: 423-461

Povinelli DJ, Bierschwale DT, Cech CG (1999) Comprehension of seeing as a referential act in young children, but not juvenile chimpanzees. Brit J Dev Ps 17: 37-60

Prato-Previde E, Fallani G, Valsecchi P (2006) Gender differences in owners interacting with pet dogs: An observational study. Ethology 112: 64-73

Rasmussen JL, Rajecki DW (1995) Differences and similarities in humans' perceptions of the thinking and feeling of a dog and a boy. Soc Anim 3: 117-137

Shapiro AD, Janik VM, Slater PJB (2004) A grey seal's *(Halichoerus grypus)* responses to experimenter-given pointing and directional cues. J Comp Psychol 117: 355-362

Scheumann M, Call J (2004) The use of experimenter-given cues by South African fur seals (*Arctocephalus pusillus*). Anim Cogn 7: 224-230

Soproni K, Miklósi Á, Topál J, Csányi V (2001) Comprehension of human communicative signs in pet dogs *(Canis familiaris)*. J Comp Psychol 115: 122-126

Soproni K, Miklósi Á, Topál J, Csányi V (2002) Dogs' (*Canis familiaris*) responsiveness to human pointing gestures. J Comp Psychol 116: 27-34

Tomasello M, Camaioni L (1997) A comparison of the gestural communication of apes and human infants. Hum Dev 40: 7-24

Tomasello M, Call J, Gluckman A (1997) Comprehension of novel communicative signs by apes and human children. Child Dev 68: 1067-1080

Tschudin A, Call J, Dunbar RIM, Harris G, van der Elst C (2001) Comprehension of signs by dolphins *(Tursiops truncatus)*. J Comp Psychol 115: 100–105

Virányi Zs, Gácsi M, Kubinyi E, Topál J, Belényi B, Ujfalussy D, Miklósi Á (2008) Comprehension of human pointing gestures in young human-reared wolves and dogs. Anim Cogn 11: 373-387.

Wilkins D (2003) Why pointing with the index finger is not a universal (in sociocultural and semiotic terms). In S. Kita (Ed.): Pointing: Where Language, Culture, and Cognition Meet, 171-215. Hillsdale, NJ: Erlbaum.

Figure legends

Figure 1. a. Distal pointing b. Elbow cross-pointing c. Forward cross- pointing, d. Long cross-pointing

Figure 2. The comparison of the group performance in Experiment 1 ("Pointing with arm") (Mean + SE). Line represents chance level. Different letters label significant differences by Kruskal-Wallis test among the three experimental groups.

Figure 3. Dogs' performance in the Experiment 1 ("Pointing with arm") (Mean + SE). Dotted line represents chance level. The asterisks over the bars refer to the significant differences (One-sample Wilcoxon signed-rank test) from the chance level (** $p < 0.01$, *** $p < 0.001$).

Figure 4. a. Pointing with leg b. Cross-pointing with leg c. Pointing with knee

Figure 5. Comparison of group performance in Experiment 2 ("Pointing with leg") (Mean + SE). Line represents chance level. Different letters label significant difference by Kruskal-Wallis test between the three experimental groups.

Table 1. The experimental procedure for the different groups. In the case of dogs each test session consisted of 12 trials, which contained 4 trials of momentary distal pointing gesture

(control trials) and 8 probe trials, with all three unfamiliar gestures included (3 trials of two types of the probe trials and 2 trials of the third type of the probe trials in). With each dog we staged three test sessions. At the end the dogs got 8 trials of each type of the unfamiliar pointing gestures in both studies. In the case of children in both age-groups we had one test session consisting of 18 trials with each child, which contained 6 trials of momentary distal pointing gesture (control trials) and 4-4-4 trials of each probe trial in both studies.

Table 2. Results of the Kruskal-Wallis tests (with Dunn's post hoc tests, $p < 0.05$) separately for each gesture.

Table 3. Results of the One-sample Wilcoxon signed-rank tests (in those cases when the mean of percentages differed significantly from the 3-year-old children's performance according to the Kruskal-Wallis test).

Figure 1.

1/a. 1/b. 1/c.

1/d.

Figure 2.

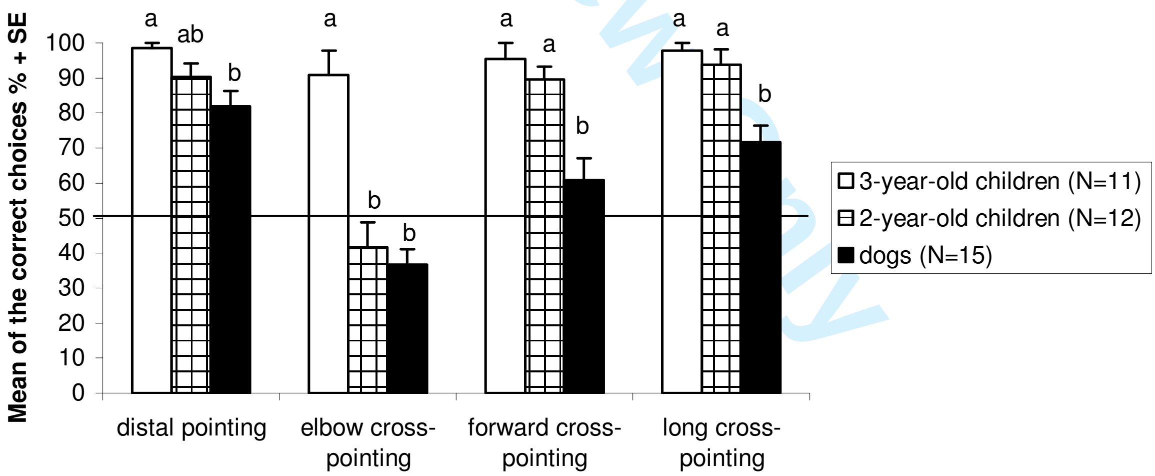


Figure 3.

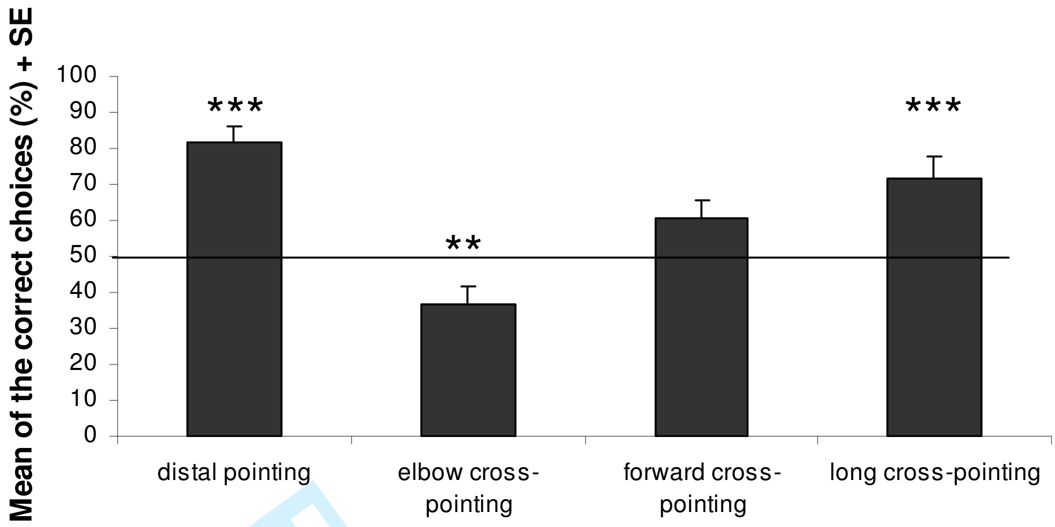
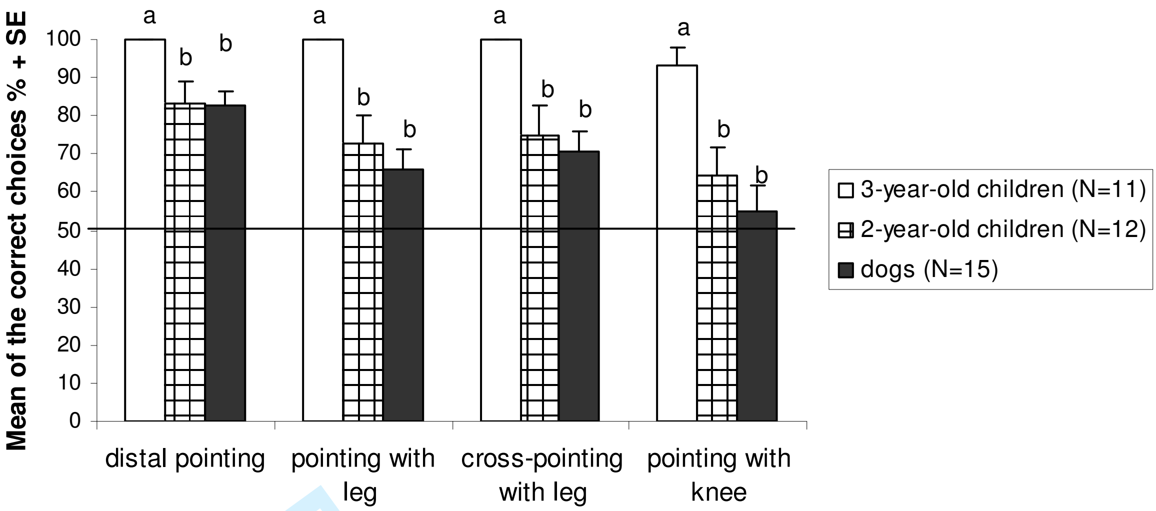


Figure 4.

4/a. 4/b. 4/c.

Figure 5.


Mean of the correct choices % + SE
100
90
80
70
60
50
40
30
20
10
0
a
b
b
a
b
b
a
b
b
a
b
b
distal pointing
pointing with leg
cross-pointing with leg
pointing with knee
3-year-old children (N=11)
2-year-old children (N=12)
dogs (N=15)

753 Table 1. The experimental procedure for the different groups.

	Subjects	
1. Pointing with arm test	**Dogs**	**Children (in both age-groups)**
1. Session	12 mixed trials: 4 control trials, 3-3-2 probe trials	18 mixed trials: 6 control trials, 4-4-4 probe trials
2. Session	12 mixed trials: 4 control trials, 3-2-3 probe trials	
3. Session	12 mixed trials: 4 control trials, 2-3-3 probe trials	
2. Pointing with leg test		
1. Session	12 mixed trials: 4 control trials, 3-3-2 probe trials	18 mixed trials: 6 control trials, 4-4-4 probe trials
2. Session	12 mixed trials: 4 control trials, 3-2-3 probe trials	
3. Session	12 mixed trials: 4 control trials, 2-3-3 probe trials	

Table 2. Results of the Kruskal-Wallis tests (with Dunn's post hoc tests, $p < 0.05$) separately for each gesture.

Type of the pointing gesture	Kruskal-Wallis test		Dunn's posthoc test ($p < .05$)
	χ^2	p	
Distal pointing (Study 1)	13.37	0.01	3 year-old-children > dogs
Elbow cross-pointing	17.87	0.001	3-year-old children > 2-year-old children 3-year-old children > dogs
Forward cross-pointing	18.52	0.001	3 year-old-children > dogs 2-year-old-children > dogs
Long cross-pointing	16.24	0.001	3 year-old-children > dogs 2-year-old-children > dogs
Distal pointing (Study 2)	11.16	0.01	3-year-old children > 2-year-old children 3-year-old children > dogs
Pointing with leg	17.60	0.001	3-year-old children > 2-year-old children 3-year-old children > dogs
Cross-pointing with leg	14.90	0.001	3-year-old children > 2-year-old children 3-year-old children > dogs
Pointing with knee	13.82	0.001	3-year-old children > 2-year-old children 3-year-old children > dogs

Table 3. Results of the One-sample Wilcoxon signed-rank tests (in those cases when the mean of percentages differed significantly from the 3-year-old children's performance according to the Kruskal-Wallis test)

	One-sample Wilcoxon signed-rank test			
Type of the pointing gesture	2-year-old children		dogs	
	T	p	T	p
Distal pointing (Study 1)			104.0	0.001
Elbow cross-pointing	-32.0	0.30	-61.0	0.01
Forward cross-pointing			50.0	0.15
Long cross-pointing			88.5	0.001
Distal pointing (Study 2)	66.0	0.001	105.0	0.001
Pointing with leg	21.0	0.05	77.5	0.05
Cross-pointing with leg	42.5	0.05	75.5	0.01
Pointing with knee	37.5	0.09	59.0	0.37