Anim Cogn
DOI 10.1007/s10071-013-0606-2

ORIGINAL PAPER

Eighteen-month-old human infants show intensive development in comprehension of different types of pointing gestures

Edina Pfandler · Gabriella Lakatos · Ádám Miklósi

Received: 20 October 2011 / Revised: 28 January 2013 / Accepted: 28 January 2013

Abstract This study explored children's development in comprehending four types of pointing gestures with different familiarity. Our aim was to highlight human infants' pointing comprehension abilities under the same conditions used for various animal species. Sixteen children were tested longitudinally in a two-choice task from 1 year of age. At the age of 12 and 14 months, infants did not exceed chance level with either of the gestures used. Infants were successful with distal pointing and long cross-pointing at the age of 16 months. By the age of 18 months, infants showed a high success rate with the less familiar gestures (forward cross-pointing and far pointing) as well. Their skills at this older age show close similarity with those demonstrated previously by dogs when using exactly the same testing procedures. Our longitudinal studies also revealed that in a few infants, the ability to comprehend pointing gestures is already apparent before 16 months of age. In general, we found large individual variation. This has been described for a variety of cognitive skills in human development and seems to be typical for pointing comprehension as well.

Keywords Pointing · Gesture · Communication · Development · Comparative · Infant

Introduction

Comparative investigation of the comprehension of human gestural cues is widely believed to provide useful information on the evolutionary origin of human gestural communication. Thus, the performance of infants and children in such tasks is often taken as a reference in human–animal comparisons.

There is a great deal of interest in studying mother/adult–child gestural interaction that occurs early in development. Most of these studies have investigated how a mother directs the attention of their child to locations and targets in the environment, and how this ability develops in the infant (Butterworth and Grover 1998; Butterworth and Itakura 2000; Deák et al. 2000; Lempers 1979; Leung and Rheingold 1981; Morisette et al. 1995; Murphy and Messer 1977). At 6 months of age, infants are able to look at the indicated side (Butterworth and Grover 1998), but both at this age and at 9 months of age they often fail to follow the pointing gesture, and their gaze is stuck and fixated on the pointing hand (Butterworth and Grover 1998; Murphy and Messer 1977). The majority of human infants, however, do follow pointing gestures toward distal targets by 12 months of age (Butterworth and Grover 1998; Butterworth and Itakura 2000; Deák et al. 2000; Leung and Rheingold 1981; Morisette et al. 1995; Murphy and Messer 1977). Butterworth attributed this skill to a 'geometric mechanism' that allows the infants to extrapolate an invisible line between the outstretched hand and the target object, but only if it is within the infants' visual field. The next phase emerges at the age of 18 months when infants are able to follow an adult's gaze to locations out of the current field of view, for which Butterworth and Grover (1998) hypothesized a 'representational mechanism'. However, others assume that this emerges earlier and that even 12-month-olds possess some kind of representation of invisible space.

In the above studies, infants sat in their mother's lap during the entire test and were expected to look at the object to which their attention was directed. However, in a

E. Pfandler (✉) · G. Lakatos · Á. Miklósi
Department of Ethology, Eötvös Loránd University,
Pázmány P. 1c., Budapest 1117, Hungary
e-mail: edina.pfandler@gmail.com; edina.pfandler@ceva.com

natural situation, it often happens that the addressee (the subject) moves toward the object(s) and makes a choice that is based on the indicative gesturing. In line with this, most animal studies (including comparative investigations) on the comprehension of human gestures use such a context for testing (Anderson et al. 1995; Itakura and Anderson 1996; Itakura and Tanaka 1998; Lakatos et al. 2009; Povinelli et al. 1997; Tomasello et al. 1997). Applying this natural situation to infants, it has been found that 14-month-olds (Behne et al. 2005; Gräfenhain et al. 2009) and also 12-month-olds (Behne et al. 2011) reliably choose the correct location of the hidden toy when the experimenter signals it by gazing and pointing in a communicative way.

Comparative investigations of the understanding of pointing have revealed variable performance results depending on animal species, developmental skills, environment and testing context (see Miklósi and Soproni 2006 for a review). In contrast, at 2–3 years of age, children invariably show outstanding success in locating hidden rewards with this paradigm (Povinelli et al. 1997; Tomasello et al. 1997; Lakatos et al. 2009).

It is important to note, however, that a realistic comparison of animal and human studies is jeopardized due to several methodical differences between the two types of study. For example, in the case of infants many authors (e.g. Behne et al. 2005) have utilized dynamic (sustained) pointing gestures together with gaze turning (ostensive gazing/gaze alternations) and/or proximate pointing gestures, which were often accompanied with complex verbal communication. In other cases the experimenter left the room before the infant could perform a choice (Herrmann and Tomasello 2006).

These issues become especially significant if the study is interested in the mental abilities controlling these skills. The question of whether humans and non-human animals share at least some cognitive mechanisms employed in pointing comprehension can be answered only if there is a common procedural basis. Furthermore, investigating the development of both physical (e.g. spatial and temporal aspects) and cognitive components (e.g. referentiality, familiarity) of the cognitive mechanisms behind pointing comprehension may be of crucial importance. At the moment theories range from some type of mental attribution (Anderson et al. 1995) to associative discrimination learning (Povinelli et al. 1999). In addition, it is assumed that ability to generalize from familiar signals to unfamiliar ones is a sign for referential understanding (Povinelli et al. 1997; Herman et al. 1999).

In the planning of this study, we placed emphasis on three main factors. First, we aimed to provide infant data that can be compared to the results of experiments with different animal species, especially dogs. This is why we applied pointing gestures of momentary nature (in order to reduce the influence of local enhancement: Miklósi and Soproni 2006) and avoided any other parallel signalling (gaze alternation and verbal communication). This allows finding an age range in human infants in which their performance is most comparable to that of dogs, or other animals.

Second, we wanted to cover a relatively long period in development beginning at the time when the geometrical attention directing role of pointing becomes available (Butterworth and Grover 1998). Lakatos et al. (2009), using simple and less familiar (cross-pointing, forward cross-pointing) gestures, found that children between 2 and 3 years of age display a gradual improvement in comprehending the referential aspect of the pointing gesture. However, younger infants are able to rely on some unfamiliar gestures, so the basic skill presumably develops earlier than 2 years of age. Thus, the cognitive development between 12 and 18 months could be of special interest with regard to pointing comprehension.

Third, we used a set of pointing gestures which were thought to represent challenging communicative signals to different degrees (Lakatos et al. 2009; Soproni et al. 2002) and have been tested earlier in cross-sectional developmental studies. The main variable feature was the distance of the index finger from the rewarded location which, to some extent, corresponded to the novelty of the gesture. While in principle all gestures could be decoded by a simple extrapolating mechanism, understanding all forms of the pointing signal may reflect the presence of referential understanding (Tomasello 2008). We predicted that infants will be more successful with gestures that are either familiar to them or refer more directly to the target (e.g. smaller distance between target and pointing hand) and only at a later age (18 months) will infants be successful with other types of pointing gestures when referential understanding is becoming available to them. More importantly, an added benefit of a longitudinal study is that it offers some insight into individual variation in the emergence of such a cognitive skill.

Methods

Subjects

Twenty infants (10 boys, 10 girls) and their mothers participated in our longitudinal study. They were tested at the age of 12 (mean 12.5 months ± 2 weeks), 14 (mean 14.5 months ± 2 weeks), 16 (mean 16.5 months ± 2 weeks) and 18 months (mean 18.5 months ± 2 weeks). Four infants out of the 20 enrolled in this study were excluded from the final sample because the children lost interest and did not complete the experimental trials ($N = 2$) or did not participate in tests at all ages ($N = 2$). Another group of ten 18-month-old infants (5 boys, 5 girls) and their mothers participated in our non-longitudinal test as naive control (not tested before the age of 18 months).

Hungarian infants were recruited from families with a middle-class background whose parents had agreed to participate in studies of infant development. All of the infants were full term and participated from the age of 12 months.

Procedure

The observations were carried out at the infants' apartments between September 2004 and July 2005. The same experimenter (Edina Pfandler) conducted every session. The child and mother both participated in the trial, but in some cases other close relatives (sisters, brothers, father or grandparents) were also present. Two bowls (yellow plastic flower pots: 15 cm in diameter, 15 cm in height) were used to hide the reward which could be a little toy or a small piece of food.

Pretraining

The experimenter knelt on the floor 0.5 m back from the middle of the line between the two bowls, which were 1.2–1.5 m apart. The mother sat on the floor, faced the experimenter at a distance of 1.5–2 m and allowed the child to move freely between them. The experimenter showed the child the reward and placed it visibly into one of the containers. Then the experimenter encouraged the child to get it out from the pot. If the child was successful, he/she could eat (food reward) or play with it (toy reward) and was also praised verbally. Otherwise, the experimenter showed the child the reward again and asked him/her to get it, until he/she was successful. The pretraining was useful for helping the child become familiar with the situation (e.g. the reward is in one of the bowls). It was continued until four successful trials occurred (two left- and two right-side trials in turns).

Pointing sessions

During the test, the arrangement of the bowls, the experimenter and the mother was the same as above, but the child was sitting in the mother's lap, faced the experimenter and he/she was prevented from observing the placement of the reward into the bowl. The experimenter picked up the bowls and turned away from the subject while she put the reward into one of the bowls. The experimenter placed both bowls onto the floor at the same time in front of her. After the reward was hidden, the experimenter called the child by name, gained his/her attention by establishing eye contact and presented a pointing gesture that was maintained for approximately 1 s. If the child did not set out at the first gesture, the experimenter repeated it once again. The child was allowed to choose only one pot. In the case of an incorrect choice (the child did not find the hidden object), the experimenter showed the child the content of the other container, but did not let him/her retrieve it.

If the child chose neither container, the trial was repeated once more. The second refusal to choose in a row was considered as loss of interest. When the subject lost interest (e.g. did not come to their mother's call), a 10-min break with free play was introduced before continuing further. If necessary, this process was repeated until the completion of the trial. If an infant did not complete the trial, he/she was excluded from the analysis ($N = 2$).

In the experiments, four types of momentary distal pointing gestures were used (see below). Each test session consisted of 16 trials that consisted of four probe trials with four different types of pointing gestures. The gestures were presented in a predetermined, semi-random order and were balanced to the right and left side. Neither the same gesture, nor the same location, was used more than two times in a row. After the 16 experimental trials, a set consisting of four control trials was conducted without showing any pointing gesture. The location of the reward was predetermined in semi-random order and balanced for right and left side.

In a longitudinal design, children received four test sessions (visits) each consisting of 16 trials and four controls, carried out at different ages (12, 14, 16 and 18 months of age). Naive controls (tested first time at the age of 18 months) received one test session (visit) consisting of the same 16 trials and four controls. All experimental sessions were recorded on video.

The following types of momentary pointing gestures ('conditions') were utilized (see also Miklósi and Soproni 2006; Lakatos et al. 2009):

1. Distal pointing (DP): The experimenter pointed with extended arm and index finger in the direction of the correct location with her ipsilateral hand. After signalling (for about 1 s), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Fig. 1a).
2. Long cross-pointing (LCP): The experimenter pointed with her contralateral hand, with extended arm, and her extended index finger protruded from her silhouette to the side of the rewarded bowl. After signalling (1 s), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Fig. 1b).

3. Forward cross-pointing (FCP): The experimenter stepped back about 0.5 m from the bowls, and she pointed with her contralateral hand, but her extended index finger did not protrude from her silhouette. After signalling (1 s), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Fig. 1c).
4. Far pointing (FP): The experimenter stepped behind the non-rewarded bowl at a distance of 0.5 m from the bowl. Next, she pointed at the correct location with extended arm and index finger with her ipsilateral hand. After signalling (1 s), she lowered her arm to the starting position beside her body before the subject was allowed to approach the bowls (Fig. 1d).

Statistical analysis

The statistical analysis was based on the number of correct choices. A response was considered correct if a child chose the container that the experimenter pointed at. Choosing the other container was scored as an incorrect response. A child's choice was considered as the first container he/she took hold of or looked into (Fig. 2).

Effects of age, gestures and the potential interaction of these factors were analysed by generalized linear mixed model for performance data (%) after transformation of the data (SPSS, version 17).

Binomial tests were used for checking the age group's performance at the very first trial with any of the gesture types (two-tailed binomial test, 13 out of 16 individuals were significant at $P = 0.021$), and for analysing performance at the individual level when we pulled together all gesture types within an age group for analysis (one-tailed binomial test, 13 out of 16 trials were significant at $P = 0.038$). It should be noted that the comparisons of the performance with the first gesture of any type do not take into account the effect of the preceding gestures.

A Mann–Whitney U test was used to compare the performance of infants tested on the fourth visit at 18 months of age (longitudinal design) and the control group tested on the first visit at the age of 18 months.

Fig. 1 Visual perspective of pointing gestures as seen by the infant. The hands were lowered before the child was allowed to make a choice. Distal pointing (**a**); long cross-pointing (**b**); forward cross-pointing (**c**); far pointing (**d**)

Fig. 2 Looking behaviour of the infant that was considered to be a choice

To assess inter-observer reliability, data from four randomly chosen children in each age group (i.e. 20 % of all trials) were independently coded from tape by a second person. For all four age groups, there was 100 % agreement between the two coders on whether or not children chose the correct container.

Results

Effect of age and gesture

The generalized linear mixed model was used to assess the effect of age and gesture types on children's performance. In the model, performance data (in percentage) were taken as the dependent variable after arcsin transformation, gesture types (four point types and controls) were taken as a fixed factor, while age was set as a covariate and name of the infant was set as random effect. According to the model that explains the data best (AIC = 198.83), both age and gesture type affected the success of finding the indicated object, but there was no interaction between the two factors. Age had a gesture-independent increasing effect on children's performance (parameter estimate = 0.12, SE = 0.015, $df = 299$, $t = 8.13$, $P < 0.001$). Also, each pointing type had significant effect on infants' search performance relative to the control condition, as follows: distal pointing (parameter estimate = 0.34, SE = 0.054, $df = 299$, $t = 6.31$, $P < 0.001$), long cross-pointing (parameter estimate = 0.28, SE = 0.054, $df = 299$, $t = 5.25$, $P < 0.001$), forward cross-pointing (parameter estimate = 0.21, SE = 0.054, $df = 299$, $t = 5.25$, $P < 0.001$) and far pointing (parameter estimate = 0.21, SE = 0.054, $df = 299$, $t = 5.17$, $P < 0.001$).

Analysis of the first choices

At 12 months of age, search performance of the first choices did not differ significantly from chance in distal pointing, long cross-pointing or forward cross-pointing conditions, but interestingly, infants tended to choose the non-correct bowl in far pointing (4 correct out of 16 children) when they observed this type of gesture for the first time in the test series. Two months later at 14 months of age, their performance in the first trials still did not differ from chance with any type of gesture.

At the age of 16 months in the distal pointing conditions, 14 infants out of 16 searched correctly in the first trial, and in the long cross-pointing conditions and the forward cross-pointing conditions, 13 out of 16 children searched correctly in the first trial (two-tailed binominal tests, $P < 0.05$ for all 3 conditions). However, in this age group their search performance in the far pointing task (11 out of 16) did not differ significantly from the chance level. At 18 months of age they were successful in three conditions (distal pointing 15 ($P < 0.001$), forward cross-pointing 14 ($P < 0.01$) and far pointing conditions 15 ($P < 0.001$) out of 16 children correct) and tended to search correctly also in the long cross-pointing condition (12 out of 16 children correct).

Signal utilization at the individual level

In order to analyse individual performance, we pulled together the performance results of each individual in all four types of probe trials (=16 trials) in order to obtain the necessary number of trials for calculating the two-tailed binomial test (at least 13 correct out of 16 trials, $P \leq 0.021$). At 12 and 14 months of age, only 12.5 and 25 % of the infants chose significantly above chance at the individual level. By the age of 16 months, this proportion reached 56 %, and by the age of 18 months it was 87.5 % (Fig. 3). Interestingly, several infants who performed below the chance level at the ages of 12 and 14 months showed side preference (10 out of 14 at 12 months and 6 out of 12 at 14 months of age, binomial test).

Although the overall achievements of the infants suggest a gradual development in this ability, we found large individual variation. Two infants were able to comprehend most of the gestures from the start (at the age of 12 months), two others never seemed to get above the chance level during the whole study, and a variable number of infants performed over chance between 14 and 18 months of age (Table 1).

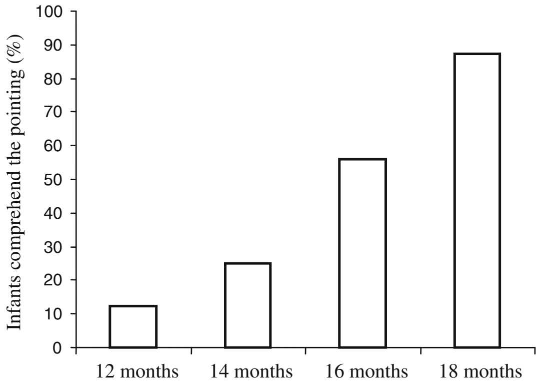

Fig. 3 The number of infants utilizing pointing gestures shows a steady increase between 14 and 18 months of age. The percentage of infants who were choosing over the chance level at a given age is shown (binomial test, $P < 0.05$) (see also Table 1)

Effect of experience

There was no significant difference in the number of correct choices for any of the four conditions between the subjects who received the trials at the fourth visit (longitudinal design) or at the first visit (naive controls) at the age of 18 months (Mann–Whitney U test, $P = 0.81$ for distal pointing, $P = 0.98$ for long cross-pointing, $P > 0.99$ for forward cross-pointing and $P = 0.30$ for far pointing condition). In fact, 18-month-old infants without any earlier experience with the trials showed similarly high success rates with each gesture (87.5 % for distal pointing, 87.5 % for long cross-pointing, 85 % for forward cross-pointing and 80 % for far pointing condition) as the longitudinally tested infants of the same age (89, 84.4, 81.25 and 87.5 %, respectively).

Discussion

During their first year, human infants rapidly develop various physical (e.g. object permanence), social and cognitive skills (e.g. gestural and vocal imitation) (e.g. Uzgiris and Hunt 1980; Carpenter et al. 1998). Earlier research has shown that infants are able to follow pointing at this age (Butterworth and Grover 1998; Butterworth and Itakura 2000; Deák et al. 2000; Leung and Rheingold 1981; Morisette et al. 1995; Murphy and Messer 1977). However, in the present study we found that most of the infants were not able to rely on this gesture when performing a two-way object-choice task. While the following ability of pointing is based on mechanisms (ecological and geometric) that are already available at this age (Butterworth and Grover 1998), relying on the pointing gesture is a decision-making act that is based on the comprehension of the referential aspect of the pointing gesture.

The ability to rely on human distal pointing gestures is considered to be present in some species such as seals

Table 1 Individual performance (percentage of correct choices) at each age

ID	Gender	Age				Mean	SD
		12 m	14 m	16 m	18 m		
Cs	Girl	100*	94*	100*	100*	98	3.00
Ma	Boy	81*	88*	81*	94*	86	6.27
Sz	Boy	38	81*	100*	100*	80	29.24
Gr	Girl	38	88*	69	100*	74	27.03
Pa	Girl	63	44	81*	88*	69	19.72
Vi	Boy	50	56	81*	88*	69	18.57
Mt	Boy	44	63	94*	94*	74	24.64
Bl	Girl	63	63	75*	81*	70	9.00
Ád	Boy	50	63	75*	75*	66	11.93
Mi	Girl	63	69	69	94*	74	13.79
Em	Girl	56	56	50	75*	59	10.87
Es	Girl	50	69	56	81*	64	13.83
Le	Boy	50	44	50	94*	59	23.17
Be	Boy	50	56	63	100*	67	22.47
Mc	Boy	50	50	75*	44	55	13.79
Ha	Girl	44	31	56	63	48	7.03
Mean		56	63	73	86		
SD		16.04	17.64	16.06	15.56		

* Indicates significant differences from the chance level (binomial tests)

(Shapiro et al. 2004), dolphins (Herman et al. 1999) and certainly dogs (Miklósi et al. 1998; Hare and Tomasello 1999), but not evident for others such as horses (Maros et al. 2008), wolves (e.g. Gácsi et al. 2009b) or surprisingly great apes (Povinelli et al. 1997; Tomasello et al. 1997; Call et al. 2000). We found that under similar conditions, most of the infants utilized simpler momentary pointing gestures at 16 months of age. Two months later they were also successful with a less familiar gesture (far pointing), thereby showing some ability of generalization, which could be considered as a sign of referential understanding (Povinelli et al. 1997; Herman et al. 1999). However, we found that only a few of the infants could comprehend pointing gestures under the age of 16 months. This result is in contrast to earlier studies by Behne et al. (2005, 2011) and Gräfenhain et al. (2009), although in these developmental studies the pointing gesture was also accompanied by gaze alternations and/or complex verbal communication which could provide significant assistance for the infants.

At 12–14 months of age, as the pointing comprehension ability is not available yet, the most frequent searching strategy was to choose exclusively the pot on a particular side. Side bias developed even though the same side was rewarded no more than twice in a row. The same tendency for developing side preference has also been observed in dogs (Gácsi et al. 2009a), wolves (Virányi et al. 2008) and chimpanzees (Hare and Tomasello 2004), suggesting that side bias is a universal optimizing strategy with its 50 % effectiveness. As infants mature, this side bias becomes less prevalent in the pointing sessions but continues to occur in control trials, indicating that it remains a favoured strategy when no signal is available.

Another interesting feature of the 1-year-olds' searching behaviour was that they often followed the pointing gesture and looked toward the indicated container, but then chose the other container. This phenomenon, also found in chimpanzees (Call et al. 2000) and dogs (Gácsi et al. 2009a), suggests that there is substantial separation of the point following and decision-making acts, made on the basis of the gesture.

According to the results of the present study, infants had more difficulty in the far pointing and forward cross-pointing conditions, than in distal pointing and cross-pointing conditions, as these gestures had the smallest effect on infants' performance according to the model. In the case of far pointing gesture, this could be explained by seeing the pointer's body closer to a potential hiding location. In everyday situations, the pointer is usually closer to the object he/she is indicating than to other potential objects. Thus, the actual position of the pointer's body could become a local cue for indicating locations. If there was no pointing cue given, several non-human species including chimpanzees (Itakura et al. 1999), dogs (Hare and Tomasello 1999) and socialized wolves (Miklósi et al. 2003) showed a preference for the bowl which the human was standing next to. This indicates that the body position could serve as an alternative cue for choice. Our analysis of the first trial performance shows that 12-month-olds preferred to choose the bowl closer to the pointer, as was the case with chimpanzees (Povinelli et al. 1997).

The forward cross-pointing condition, when the extended hand and index finger do not protrude from the silhouette, is possibly visually ambiguous for younger infants. Their relatively lower performance with this gesture can presumably be explained by the lack of the protruding pointing hand and index finger which possibly makes the perception of this gesture more difficult. However, by the age of 16 months, most of the infants were able to respond correctly when they saw the gesture for the very first time in the session. Interestingly, dogs were also found to be inferior with this gesture (Lakatos et al. 2007, 2009), but they became superior when the gesture was made visually more conspicuous (Lakatos et al. 2007).

Lakatos et al. (2009) suggested that at the functional level, dogs' performance in pointing comprehension can be compared to that of 2-year-old children. Dogs, like 2-year-old children, are able to rely on distal pointing and long cross-pointing, but not on elbow cross-pointing. Although, according to that study's results, dogs do not comprehend forward cross-pointing gesture, while 2-year-olds do (Lakatos et al. 2009). In the present study, the model which described infants' performance the best showed that there was a significant improvement with age for each gesture, suggesting a gradual improvement in pointing comprehension. Lakatos et al. (2009) showed further improvement of comprehension with regard to some types of pointing gestures such as elbow cross-pointing or pointing with knee from 2 to 3 years of age. This suggests that there is a continuing development in comprehension until at least the age of 3, at which time children reach a high level of understanding of the pointing gesture and they are ready to generalize from earlier experiences and rely flexibly on novel forms of pointing gestures.

Our small sample size limits the discussion of some findings, but the 6-month difference in children's ability to perform successfully in this task cautions against a straight forward interpretational view narrowed to effect learning and experience. The performance of children at 18 months of age tested in the longitudinal design corresponds well with the performance of naive 18-month-olds tested with the same set of gestures and under the same conditions for the first time in their life. However, we cannot exclude the role of environmental influence (learning) on performance, as well as other cognitive influences and neurodevelopmental changes, including genetic predisposition, that underpin the improvement of pointing comprehension.

In summary, the ability to respond correctly to pointing gestures emerges only in a restricted extent, before the age of 16–18 months. However, at this age infants show development in comprehension of the referential aspect of the pointing gesture. In a frame of similar methodological conditions, these outcomes can be a reference point for the interpretation of pointing comprehension in different animal species. Moreover, in reflection of dogs' responsiveness to human communicative gestures, including their generalization ability similar to that of 16-month-old infants, our present results represent a baseline for this behavioural analogy between dogs and humans, supporting the hypothesis of convergent evolution.

Acknowledgments This study was supported by grants received from the Hungarian Science Fund (OTKA 049615), the Hungarian Academy of Sciences (F01/031) and an EU FP6 NEST 012787 grant. We are grateful to all of the infants and their parents for their participation, patience and support throughout the study. We are also very grateful to C. P. West for correcting the English of the manuscript. An ESF Research Networking Program titled 'The Evolution of Social Cognition: Comparisons and integration across a wide range of human and non-human animal species' (COMPCOG) also supported this research.

References

Anderson JR, Sallaberry P, Barbier H (1995) Use of experimenter-given cues during object-choice tasks by capuchin monkeys. Anim Behav 49:201–208

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

Behne T, Liszkowski U, Carpenter M, Tomasello M (2011) Twelve-month-olds' comprehension and production of pointing. Br J Dev Psychol. doi:10.1111/j.2044-835X.2011.02043.x

Butterworth GE, Grover L (1998) Joint visual attention, manual pointing, and preverbal communication in human infancy. In: Hillsdale NJ, Jeannerod M (eds) Attention and performance. Erlbaum, Hillsdale, pp 605–623

Butterworth GE, Itakura S (2000) How the eyes, head and hand serve definite reference. Br J Dev Psychol 18:25–50

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

Carpenter M, Nagell K, Tomasello M (1998) Social cognition, joint attention, and communicative competence from 9 to 15 months of age. Monographs of the Society for Research in Child Development. Society for Research in Child Develpoment, Washington, p 255

Deák GO, Flom RA, Pick AD (2000) Effects of gesture and target on 12- and 18-month-olds' joint visual attention to objects in front of or behind them. Dev Psychol 36:511–523

Gácsi M, Kara E, Belényi B, Topál J, Miklósi Á (2009a) The effect of development and individual differences in pointing comprehension of dogs. Anim Cogn 12:471–479

Gácsi M, Győri B, Virányi Z, Kubinyi E, Kubinyi E, Range F, Belényi B, Miklósi Á (2009b) Explaining dog wolf differences in utilizing human pointing gestures: selection for synergistic shifts in the development of some social skills. PLoS One 4(8):e6584. doi:10.1371/journal.pone.0006584

Gräfenhain M, Behne T, Carpenter M, Tomasello M (2009) One-year olds' understanding of non-verbal gestures directed to a third person. Cogn Dev 24:23–33

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, Tomasello M (2004) Chimpanzees are more skilful in competitive than cooperative cognitive tasks. Anim Behav 68:571–581

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

Herrmann E, Tomasello M (2006) Apes' and children's understanding of cooperative and competitive motives in communicative situation. Dev Sci 9:518–529

Itakura S, Anderson JR (1996) Learning to use experimenter-given cues during object-choice tasks by a capuchin monkey. Cur Psychol Cogn 15:103–112

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 120:119–126

Itakura S, Agnetta B, Hare B, Tomasello M (1999) Chimpanzee use of human and conspecific social cues to locate hidden food. Dev Sci 2:48–456

Lakatos G, Dóka A, Miklósi Á (2007) The role of visual cues in the comprehension of the human pointing signals in dogs. Int J Comp Psychol 20:341–350

Lakatos G, Soproni K, Dóka A, Miklósi Á (2009) A comparative approach to dogs' (*Canis familiaris)* and human infants' comprehension of various forms of pointing gestures. Anim Cogn 12:621–631

Lempers JD (1979) Young children's production and comprehension of nonverbal deictic behaviours. J Gen Psychol 135:93–102

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

Maros K, Gácsi M, Miklósi Á (2008) Comprehension of human pointing gestures in horses *(Equus caballus)*. Anim Cogn 11:457–466

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

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 Z, Csányi V (2003) A simple reason for a big difference: wolves do not look back at humans but dogs do. Cur Biol 13:763–766

Morisette P, Ricard M, Decarie TG (1995) Joint visual attention and pointing in infancy: a longitudinal study of comprehension. Br J Dev Psychol 13:163–175

Murphy CM, Messer DJ (1977) Mothers, infants and pointing: a study of a gesture. In: Schaffer HR (ed) Studies in mother-infant interaction. Academic Press, London, pp 325–354

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. Cogn 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. Br J Dev Psychol 17:37–60

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

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

Tomasello M (2008) Origins of communication. MIT Press, Cambridge

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

Uzgiris IC, Hunt J (1980) Assessment in infancy: ordinal scales of psychological development, 4th edn. University of Illinois Press, Urbana

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