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The effect of development and individual differences in pointing comprehension of dogs

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Abstract In spite of the rather different procedures actually used in comparative studies to test the ability of different species to rely on the human pointing gesture, there is no debate on the high performance of dogs in such tasks. Very little is known, however, on the course through which they acquire this ability or the probable factors influencing the process. Important developmental questions have remained unsolved and also some methodological concerns should be addressed before we can convincingly argue for one interpretation or another. In this study we tested 180 dogs of different age (from 2 months to adults) to investigate their performance in the human distal momentary pointing gesture. The results, analyzed at both the group and the individual levels, showed no difference in the performance according to age, indicating that in dogs the comprehension of the human pointing may require only very limited and rapid early learning to fully develop. Interestingly, neither the keeping conditions nor the time spent in active interaction with the owner, and not even some special (agility) training for using human visual cues, had significant effect on the success and explained individual differences. The performance of the dogs was rather stable over time: during the 20 trials within a session and even when subsamples of different age were repeatedly tested. Considering that in spite of the general success at the group level, more than half of the dogs were not successful at the individual level, we revealed alternative "decision-making rules" other than following the pointing gesture of the experimenter.

Keywords Abstract · Interspecific communication · Dog · Human pointing · Two-way object choice test · Developmental effects · Individual differences

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Introduction

Comparative investigation of the comprehension of human gestural cues is widely believed to provide useful information on the flexibility of the communication skills of different animal species. Investigation of the ability to learn about other species' signals and the factors that affect interspecific communication can help us to understand other cognitive aspects of their behavior as well (for a review see Miklósi and Soproni 2006). While such tests have by now been applied to a wide range of species, their present value can be questioned on the basis of both theoretical and methodological grounds.

It has been suggested that domesticated species (Kaminski et al. 2005), especially dogs, are predisposed to comprehending human communicative signals, because the process of domestication might have selected for such capabilities (Hare et al. 2002; Miklósi et al. 1998). This argument was supported further by showing that foxes selected for many generations for tameness show somewhat better performance in comparison to non-selected ones (Hare et al. 2005), and young hand-reared wolves cannot rely on human pointing (Virányi et al. 2008).

The studies cited above and many others utilized the so-called two-way object choice task (Anderson et al. 1995), in which the subject can find the target at one of two similar locations if he pays attention to the gestural signals provided by the human. Unfortunately, the lack of standardization of the methods inevitably influenced the interpretation of the results. Recently, there have been some arguments that the communicative nature of the gesture can be enhanced if the subject is presented with distal momentary pointing (Miklósi and Soproni 2006). This type of gesture is demanding for both infants (Lakatos et al. 2008) and different domestic species (cats and dogs: Miklósi et al. 2005; horses: Maros et al. 2008) even when the cuing context is explicitly communicative. The superior performance of dogs and children to other species, however, underlines the notion that distal momentary pointing can be used to compare the subjects' comprehension of the communicative aspect of this human gesture. Further, this type of pointing gesture minimizes the effect of local enhancement and makes the subject rely on memory when making the choice.

The comparative analysis of these studies, however, seems to be problematic because of the variance in the procedure and the different ways of analysis used. The evolutionary interpretation of the results is also arguable because most studies did not (fully) account for the developmental and/or environmental effects. In the case of the dog (for which most data are available) there are observations suggesting that comprehension of pointing improves with both age and experience. Using a small sample Hare and Tomasello (1999) found that older dogs are better at utilizing the human pointing signal. However, 4-month-old puppies raised in kennels with limited human contact were able to rely on the proximal static pointing gesture (Hare et al. 2002), thus maturation (and social experience) after this age was claimed to play only a minor role in dogs. However, as the success with this type of gesture can be best explained by local or stimulus enhancement, the results of Riedel et al. (2007) on puppies provide a better support for the hypothesis that domestication played a critical role in shaping this ability in dogs. They found that 6, 8, 16 and 24-week-old puppies could rely on different communicative cues provided, and that their success increased with age only in using the marker cue. Miklósi et al. (2003) reported on the successful performance of 4-month-old dogs in distal momentary pointing tests, but without the systematic study of developmental and environmental effects.

Although by testing natural populations of dogs one cannot separate clearly the effect of maturation and experience, in this study we look for the effect of maturity by testing dogs of different ages across a wide time range (between 2 and 14 months and also adults). These dogs lived with human families. We also addressed the question of potential gender differences or possible gender–age interactions.

It has been assumed that living conditions (e.g., dogs kept in the garden or inside) might influence communicative interactions between dogs and humans (Topál et al. 1997). McKinley and Sambrook (2000) reported that gundog training may improve the comprehension of the human pointing gesture. Thus, in the present study the effect of social experience was tested at two different levels. In order to find out whether the richness of social interaction with humans influences the performance of dogs, we asked owners both about their living conditions and the extent of interaction with their companion.

To test for the specific effect of communication-related training, we compared dogs with and without advanced agility training in which humans control the dog by using both gestural and vocal communicative signals.[1]

Apart from the effects of maturation and experience, there are no data in earlier research, which show that the performance of the subject is consistent. This is important if the two-way object choice task is to be used as a standard method of testing inter-species communication, and also if one assumes that it reflects reliably the ability of the animal to utilize human communicative signals on a regular basis. In this study, we evaluate whether puppies and adult dogs show stable performance over a short or long period of time.

Although many previous studies have failed to show that within-task learning plays a role in success, we controlled this factor in our investigation, because some critics repeatedly argue that the superior performance of dogs (or other species) can be explained by rapid learning during a test. According to them, the subjects can learn rules solely from the different reinforcements during the test session. According to this view, repeated testing is not a valid way of revealing an ability that was present before, because the skill emerges actually during the experiment. If the performance of the subject improves by the end of the test session, then one could argue that a relatively short (but systematic) human interaction could lead to learning about human gestures.

Due to practical and statistical considerations, subjects are usually provided with several (16–20) trials in succession in the two-way object choice tasks, although their choices in these trials cannot be regarded as being independent. A successful first choice to the left, for example, can obviously bias the animal to the left at the second trial

[1] Agility is a canine version of the horse show jumping competition, in which a dog and a human work together so that the dog successfully navigates a series of obstacles arranged in a random course. The goal is to complete the course with the least number of faults and at the fastest time. The handler's job is to help the dog overcome all the obstacles in the sequence, prescribed by the judge. As the dog runs the course off-lead, the success of the team depends greatly on the ability of the dog to rely on the communicative signals of the handler.

(place learning), regardless of the actual gesture of the human (who points to the right). However, the strength of such a bias could depend on both the developmental stage of the individual and/or the ecological environment of the species. Thus, difference in performance may be independent of the cognitive or communicative capabilities of the species. In the present sample, we looked for the effects of first and second choices, and whether place learning or other simple tactics used by the subjects can explain the observed performance.

Importantly, the usual evaluation of the two-way choice test is not in line with the assumptions of communication. Communication is said to occur between two individuals, when the signal is followed reliably by a change in behavior of the receiver. Thus, in order to establish that communication has taken place, that is, that the signal has been "transmitted", one has to show that the behavioral change in the receiver occurred more often than by chance after a signal was emitted. However, the present way of evaluating the subjects' performance is to compare only the mean percentage of correct choices of the group to the chance level. This method, though informative, can result in significant effects at the group level when none of the subjects performs actually better than chance at the individual level (e.g. Maros et al. 2008). The "trick" is that very few subjects perform below 50% because even if they utilize other decision-making rules than relying on the human gestural signal, subjects still find the target at least in half of the trials. Thus, we will also evaluate to what extent dogs use the human's cue on the individual level.

In sum, in the present paper we aim at clarifying some important issues that concern the effect of development, social experience and training on the performance of dogs, and also the reliability of the test. We suggest also new ways of analyzing the results.

Method

The two-way object choice tests took place in an unfamiliar room at three locations: the Department of Ethology, ELTE Budapest, a summer dog camp, and the Top Mancs dog training center. The protocol was basically the same as in the comparative study of Virányi et al. (2008) on wolves and dogs.

The experimenter (E) who presented the pointing gesture was always a trained woman. Most of the tests were video recorded and analyzed later, but in some cases the choices of the dogs were only recorded in notes.

After the test, we asked the owners to fill in a short questionnaire and used their answers as a grouping variable later in the analysis (we got the questionnaires back from 138 owners). In addition to the age, gender, breed and training of the adult dog, its keeping condition (whether kept inside or outside the house) as well as its handling condition were recorded [whether he/she spends less or more than 1 h daily in active interaction (playing, training, walking) with the owner, and whether rarely or often initiates communication with the owner (vocalization, gaze alternation, nudge, catching hand/cloth)]. We analyzed the data continuously and checked the balance in the age groups for the independent variables. In a few cases, it was necessary to look for the last subjects with the environmental or gender/breed specifity required for the balanced samples. However, in most cases the different groups proved to be balanced anyway.

Subjects

Altogether, 180 pet dogs (90 males and 90 females) from 46 breeds (and 33 mongrels) were tested in this study. Subjects were acquired from dog schools and from volunteers of our Family Dog Project.

The possible changes in the performance during ontogeny were tested on 2–14-month-old puppies and juveniles, and also on adult (>1.5-year-old) dogs. We determined the youngest age category on the basis of our pilot studies, in which most of the puppies younger than 8 weeks showed perceptional or attentional difficulties in distal momentary pointing trials.

We defined six age groups of puppies and juveniles: 2–4, 4–6, 6–8, 8–10, 10–12 and 12–14 months. In each group, 20 dogs of different breeds (and mongrels) were tested. The groups were balanced for gender and also for keeping and handling conditions based on the questionnaire information. Additionally, 20 adult pet dogs (9 males and 11 females, mean age 3.88) and 20 adult dogs with agility training (9 males and 11 females, mean age 3.85) of different breeds (and mongrels) were tested. To control for any effect of breed differences in our samples with and without agility training, we also tested a smaller sample of one single breed, 20 Belgian shepherds, 10 dogs without agility training (4 males and 6 females, mean age 5.45) and 10 agility dogs (4 males and 6 females, mean age 5.48; see Table 1).

From the tested subjects, 36 dogs of different breeds (and mongrels) were retested sometime after the first test. In the Puppy-Puppy (PP) group, 12 individuals were retested within 1–12 weeks (6 males and 6 females, 3–7-month-old puppies, mean age 4.9 months). In the Puppy-Adult (PA) group, 12 individuals (6 males and 6 females, 3–7 month-old puppies, mean age 4.9 months) were retested as adults within 8–18 months. In the Adult-Adult (AA) group, 12 individuals (5 males and 7 females, mean age 3.5 years) were retested within 1 week–6 months. The individuals participating in the repeated trials were selected from the

Table 1 Gender and breed of the tested subjects listed by age group

Group	Male/female	Breeds
2–4 Months	12/8	Four mongrels, three border collies, three Belgian shepherds, German shepherd, bichon frise, cavalier King Charles, mudi, pumi, puli, sheltie, vizsla, rough collie, Czech wolfdog
4–6 Months	11/9	Three mongrels, border collie, Belgian shepherd, four golden retrievers, German shepherd, pumi, two Labradors, great dane, rough collie, Rhodesian ridgeback, Airedale terrier, west highland white terrier, giant schnauzer, bull terrier
6–8 Months	9/11	One mongrel, two huskies, border collie, two Belgian shepherds, two golden retrievers, German shepherd, pumi, Labrador, rough collie, west highland white terrier, two giant schnauzers, middle schnauzer, two hovawarts, cocker spaniel, cairn terrier
8–10 Months	8/12	Five mongrels, Belgian shepherd, two golden retrievers, two German shepherds, Labrador, Yorkshire terrier, Airedale terrier, two parson Russel terriers, Welsh terrier, Magyar vizsla, spitz, Saint Bernard, Chinese crested
10–12 Months	9/11	Two mongrels, border collie, Belgian shepherd, two golden retrievers, pumi, Magyar vizsla, three Labradors, great dane, poodle, three beagles, middle schnauzer, staffordshire bull terrier, kuvasz, Russian black terrier
12–14 Months	7/13	Five mongrels, two Belgian shepherds, three German shepherds, three golden retrievers, puli, Labrador, two pugs, two beagles, parson Russel
Adult pet	9/11	Seven mongrels, three golden retrievers, three Labradors, two pugs, beagle, pug, wolfspitz, dachshund, cavalier King Charles, American staffordshire terrier, cocker spaniel
Adult agility	9/11	Six mongrels, four border collies, two Belgian shepherds, Magyar vizsla, golden retriever, Airedale terrier, boxer, mudi, parson Russel terrier, hovawart, schipperke
Belgian shepherd pet	4/6	
Belgian shepherd agility	4/6	

relevant age groups of the original sample on a random basis.

Procedure

Two plastic bowls (measures, depending on the size of the dog, 10–25 cm in diameter, 10–25 cm height) were used to hide the bait. We hid small pieces of cold cut or the favourite food of the dog as bait. Both bowls were extensively scented with the food before the experiment.

In the pretraining, E placed the two bowls 1.5–1.6 m apart in front of herself and stood 20–30 cm behind them in the middle. She dropped a piece of food into one of the bowls while the subject was held by the owner at a distance of 2–2.5 m from E. When the food fell into the bowl, the owner released the subject and it was allowed to eat the food. This procedure was repeated twice for each bowl to ensure that the subject learned that the bowls might contain food. After a 1-minute break, the test sessions began.

During the test, the positions of the bowls, E, the subject and the owner were the same as described above, but the dogs were prevented from observing the baiting. E picked up the bowls and turned away from the subject while she put a piece of food into one of the bowls. The owner made the subject sit or stand facing E, while E placed both bowls onto the floor at the same time in front of her. During the pointing, E stood facing the subject at a distance of 2–2.5 m with hands bent in front of her chest and tried to establish eye contact with the subject prior to signaling (see Fig. 1). In case of a few dogs, whose eyes were lower than 30 cm, E presented the pointing gesture in a kneeling position (in this case the elbow was pressed to the waist so as to have the same distance between the pointing finger and the bowl).

The owner stood behind the dog and held its collar until E gave the cue. If the subject did not gaze at E's face, she called it by its name or produced some sounds (i.e., clapping with hands) to direct the dog's attention. As soon as eye contact was achieved, E enacted a momentary distal pointing gesture (see also Virányi et al. 2008; Maros et al. 2008). This was a short, definite pointing toward the baited bowl with the outstretched index finger about 60–80 cm from the bowl. E's arm was in a pointing position for only less than 1 s, and then her hand was placed back to her chest. The subject was released only after the hand had been taken back to its starting position. Throughout the trial, E looked at the subject. If the subject did not leave the starting point within 3 s after being released, E would repeat the pointing gesture. The bowl that was first approached by the subject within 10 cm was considered as being chosen. After choosing the baited bowl, the subject could eat the food and would be praised verbally. If it chose the empty bowl, it failed to get the food (the baited bowl was picked up).

The test session included 20 trials for each subject, except the youngest dogs (2–4 months group) that were

Fig. 1 Distal momentary pointing: the dog was released to make a choice only when the experimenter placed her pointing hand back to her chest

tested in two sessions of 10 trials, and 1 day–3 weeks elapsed between the two sessions. In half of the trials, the baited bowl was placed on the right side, in the other half it was on the left. The order of baiting was defined randomly with the restrictions that one side could be rewarded for only two times in a row and this could not happen at the very beginning of the trial.

Data analysis

We calculated the percent of correct choices from the 20 trials for each individual. For this variable, inter-observer reliability was not assessed because the subjects' choices could be determined without ambiguity.

As all data did not differ significantly from a normal distribution (Kolgomorov–Smirnov test), two-way ANOVAs (gender x age group) were used to compare the six age groups' performance and one-sample *t* tests were applied to compare the results against chance performance (50%). We applied two-way ANOVA (gender x training) and independent samples *t* tests to analyze the effect of agility training. We used repeated measures ANOVA when comparing the first and second ten trials of the same dogs by age group (age group x repeat) and paired samples *t* tests to analyze the consistency of the results in the repeated tests. The relationship between age and performance in adult dogs was checked with Pearson correlation.

In order to get a more complete analysis, the individual performances were also analyzed statistically with binomial test (according to the binomial distribution, 5 errors out of 20 trials result in a P value of 0.041, so a subject can be reported as relying on the pointing gesture over chance if it achieved 15 or more correct choices). We applied Pearson χ^2 test to compare the rate of the successful individuals in different groups.

Result

First, we investigated the potential independent variables and environmental factors such as age, gender and experiences that may influence the performance of pet dogs in this test. As a second aspect, we studied whether the characteristics of the applied paradigm can have any effect on the results or explain some of the individual differences.

The development of pointing utilization

The mean performance in all age groups was significantly above random choice (2–4 months; $t_{19} = 4.815$, $P < 0.001$, 4–6 months; $t_{19} = 4.483$, $P < 0.001$, 6–8 months; $t_{19} = 5.051$, $P < 0.001$, 8–10 months; $t_{19} = 6.276$, $P < 0.001$, 10–12 months; $t_{19} = 3.359$, $P = 0.003$, 12–14 months; $t_{19} = 4.554$, $P < 0.001$). The two-way ANOVA (age group x gender) did not reveal any difference in the mean performance among the six age groups in the 2–14-month-old sample ($F_{5,108} = 1.28$, $P = 0.28$). Gender also did not have an effect on the success ($F_{1,108} = 0.13$, $P = 0.72$), and there was also no interaction between gender and age ($F_{5,108} = 2.02$, $P = 0.08$). The subjects' success counted at the individual level did not depend on age ($\chi^2_5 = 2.64$, $P = 0.756$). Notwithstanding, considering the individual results, we found some decline in the dogs' performance during the period of 10–12 months because the significant majority of this age group (16 individuals out of 20) did not base their choices on the human gesture (binomial test: $P = 0.041$).

In none of the groups, significantly more dogs relied on the human signal than on other influential factors (no group with 15 or more successful individuals; Fig. 2).

Moreover, at the individual level less than half of the dogs were successful (with more than 15 correct choices). None of the dogs performed significantly below chance level (five or less correct choices). Actually, the worst result was eight successful choices ($n = 2$).

On comparing the two groups of adult dogs with and without advanced agility training (two-way ANOVA: agility training x gender), we found that there was no effect of training ($F_{1,36} = 0.49$; $P = 0.49$), gender ($F_{1,36} = 0.81$, $P = 0.37$) or interaction in them ($F_{1,36} = 1.93$, $P = 0.17$).

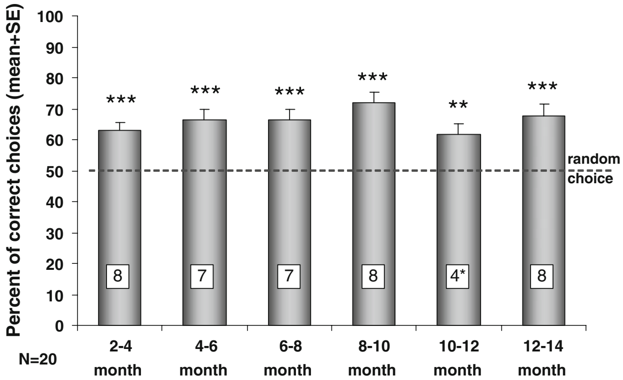

Fig. 2 The performance of the six age groups ($n = 20$ each) in relying on the human distal momentary pointing gesture in a two-way object choice test. *Asterisks* indicate the significant differences from chance (50%) level. *Double asterisks*, $P < 0.01$, *triple asterisks*, $P < 0.001$. *Numbers* in the *columns* indicate the number of successful dogs in an age group when evaluating the data at the individual level. *Single asterisk*, $P < 0.05$

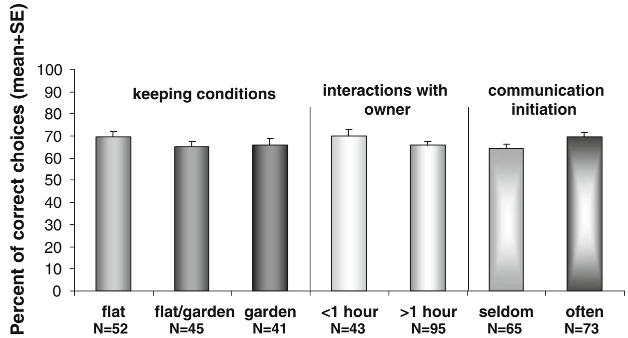

Fig. 3 The performance of the dogs grouped according to (1) keeping conditions, (2) the duration of daily active interaction with the owner and (3) the tendency to initiate communication with the owner

We checked for correlation between the age and performance of these adult dogs as well, but could not find any relationship ($r_{40} = 0.01$, $P = 0.99$). In order to exclude any occasional non-controlled breed effect in our mixed breed sample, we tested a smaller sample of Belgian shepherds, both trained and untrained, for agility. Even in this case, no effect of training could be shown ($t_{18} = 0.27$, $P = 0.79$). The number of successful individuals (with 15 or more correct choices; binomial test: $P = 0.041$) in the trained and untrained groups was actually the same (half of the total sample) in the case of both the mixed group (10–10) and the Belgian shepherds (5–5).

We also analyzed the effects of two presumably important environmental factors (keeping conditions and the average time the owner spends in active interaction with the dog) and the possible relationship between the performance of the dogs and their tendency for initiating communication with humans. Based on the answers of the owners, we could conclude that neither of the above factors had significant relationship with the success of the dogs (three-way ANOVA; keeping conditions: $F_{2,126} = 0.8$, $P = 0.43$; time spent in active interaction: $F_{1,126} = 1.56$, $P = 0.21$; initiating communication: $F_{1,126} = 1.77$, $P = 0.19$, without any interaction effect; Fig. 3).

Stability of performance

In order to study the consistency in the performance of dogs of different age, we compared the results in a first and a repeated test of the three groups (PP, PA, AA). The performance of all three age categories seemed to be rather consistent on analysis by two-way repeated measures ANOVA (age x repetition) at the group level. There was no significant effect of repetition ($F_{1,33} = 1.11$, $P = 0.3$), the age when the tests had been run ($F_{2,33} = 0.31$, $P = 0.97$) or their interaction ($F_{2,33} = 1.17$, $P = 0.32$). On comparing the dogs' individual success in the two tests (15 or more correct choices), there were a few changes over time, mainly in group PA (tested first in puppyhood and later in adulthood; see Table 2).

Within-task learning

To control for within-task learning, we compared the results in the first and second ten trials. A two-way repeated measure ANOVA (age x trials) was applied in order to exclude the possibility of two counteracting effects being involved in dogs of different ages. For example, the performance of young individuals might decrease because of getting tired during the test, while older dogs could learn to use the cue provided by the human and thus achieve increasing success. On comparing the results of the dogs of different age groups (2–14 months), we did not find any evidence for the effect of learning or fatigue ($F_{1,100} = 0.21$, $P = 0.64$), age ($F_{5,100} = 0.71$, $P = 0.62$) or their interaction ($F_{5,100} = 1.80$, $P = 0.12$). Similarly, no change in the performance in time could be revealed in case of the adult dogs ($t_{55} = -1.62$, $P = 0.11$).

Side bias and interference of trials

We searched the whole sample for "decision-making" rules, other than following the pointing gesture of the experimenter. We found that 53% of the dogs that were not successful at the individual level developed side preference. Irrespective of the human gesture, they preferred to visit one side significantly more times (binomial test: $P = 0.041$). Interestingly, from this subgroup, about the same number of dogs preferred the side which was baited in the first (49%) or second trial (51%). All 49%, which later preferred the firstly baited side, were successful in the first trial, while only less than one-third of the 51%, which later

Table 2 Individual results of the same dogs tested twice

Puppy–Puppy (*n* = 12)		Puppy–Adult (*n* = 12)		Adult–Adult (*n* = 12)	
First test	Second test	First test	Second test	First test	Second test
100	**85**	**100**	**90**	**100**	**100**
95	**80**	**80**	**100**	**90**	**90**
85	**95**	**80**[a]	60[a]	**80**	**100**
85	**90**	**75**	**85**	**90**[a]	70[a]
75[a]	45[a]	**75**	**80**	**75**	**75**
70[a]	**75**[a]	70	50	65	60
70	70	60[a]	**100**[a]	60[a]	**80**[a]
70	50	60	50	60	55
60	55	55	55	55	60
55	50	55	50	55	60
50	50	50[a]	**85**[a]	55	60
45	80	45	50	50	60
71.7%	**68.8%**	**67.1%**	**71.3%**	**69.6%**	**72.5%**

In the Puppy–Puppy group both tests were run in puppyhood, in the Puppy–Adult group dogs were first tested as puppies and secondly as adults, and in the Adult–Adult group both tests were done in adulthood. In all three age categories the percentage of the subjects' correct choices in the first and second tests are listed. The numbers in bold indicate the individual performances that are significantly above chance level

[a] Different performances at the individual level (once successful, once not)

preferred the other (secondly baited) side, found the bait at the first time. Thus, success in the first two trials seemed to influence the dogs' later behavior.

Moreover, we supposed that the success of the first choice had a general effect on the next one (and so on). The performances experienced in the first (70%) and second (69%) trials or in sum in the 20 trials (68%) did not seem to support this concept. However, when we analyzed the second choices depending on the success of the first ones, a special pattern was unfolded. Most of the individuals that could not find the bait at the very first trial had a successful second choice (90%). We must note that, because of the always alternated baiting order in the first two trials, this necessarily meant visiting the same, previously unrewarded side. In the case of the dogs that were successful at first, however, we experienced a different tendency. Although more than half of them correctly switched to the other side pointed at by the experimenter (60%), still many (40%) stuck at the previously rewarded side in spite of the directing human gesture. Thus, an unsuccessful first choice may increase the probability of using the pointing cue; however, in case of a successful first choice the dogs either stuck to following the cue or to the place the bait had been found previously.

Discussion

In the present study, we investigated the extent to which (1) the selection process during domestication and/or rapid learning during early ontogeny, (2) exposure to complex social experiences, (3) specific communicational interactions and (4) fast learning during the experiment contribute to the skilful performance of dogs in using the human pointing gesture. Furthermore, we detected some aspects of the widely utilized procedure and analysis of the two-way choice test, which could be responsible for biased data in comparative analyses.

The development of pointing utilization

The comparison of the performances in the different age groups of dogs did not unfold significant differences from 2 to 14 months. A slight drop in the performance at the age of 10–12 months might indicate the influence of hormonal and/or behavioral changes associated with adolescence. Even in the case of adults, age did not affect success; so accumulating experiences in the human environment did not seem to play a major role in improving this ability. This was also supported by the questionnaire data indicating that individuals with more intense human contact did not show better performance. Neither living inside in close proximity to humans nor more intensive daily interaction with the dog could be related to increased performance.

Interestingly, we found that agility training also did not have an effect on the performance of the dogs. This is even more surprising because during the training and the competitions, dogs are oriented towards target obstacles by the use of arm/hand signals, and our subjects, being experienced contestants, can definitely rely on these signals on the agility course. Having been trained to communicate and cooperate effectively, one would have expected them to be able to rely on the human pointing in a two-way object choice situation as well. As in this comparison we controlled for age, gender, breed and the major environmental influences, these results provided convincing evidence that even specific training did not improve the performance in this type of two-way object choice test. We conclude that the ability of dogs to rely on the human pointing gesture is relatively a robust characteristic and relatively resistant to environmental influences after the age of 2–4 months. To some extent, these results support the view that there might be some selected capacity behind the success in these tests, and under natural circumstances the effect of learning might play a rather minor role (Hare et al. 2002, Miklósi et al. 2003, Riedel et al. 2007).

Though in popular dog literature, females are widely reported to be more attentive and cooperative and some observations suggest that female dogs might learn faster

Range et al. (2007), in this test our results did not support this differentiation. Neither in the case of the young dogs nor in the adult group did success depend on gender.

Stability of performance

Testing a subsample of dogs, we found little change in performance at repeated testing. In contrast to the relatively high individual variability in the performance of wolves (Virányi et al. 2008) and chimpanzees (Call et al. 2000) when presented with the same cues, both young and older dogs seemed to show rather stable responses in repeated tests, which supports further the relatively little environmental influence on this ability.

Within-task learning

Critics of the two-way choice procedure often assume that successful performance can be explained by prior learning by associating the human hand with food, and/or rapid learning during the test where differential reinforcement is used. First, there are many observations that such distal momentary cues are unlikely to support place learning or utilize local enhancement. Even chimpanzees that can rely on locally enhanced gestures (e.g., proximate sustained-dynamic pointing) do not seem to be able to grasp the communicative aspect of the distal pointing gestures (Itakura et al. 1999). Secondly, we failed to find any sign of improvement during the testing trials in the performance. This observation parallels those of earlier findings on dogs (Lakatos et al. 2008), cats (Miklósi et al. 2005) and wolves (Virányi et al. 2008). Importantly, opposite tendencies were reported in goats (Kaminski et al. 2005) and horses (Maros et al. 2008), in which cases the performance of the subjects decreased significantly in the second part of the test session. The explanation for the contradictory evidence in the above species could be related to their differential ability to attend, which might be related to frustration, differences in motivation or social experiences with humans. Thus, researchers need to control such factors in comparative studies.

Side bias and within-session interference

We assumed that the choice of dogs in such tests is affected by other decision-making rules, partly in addition to the ability of comprehending the pointing cue. One of these could be the "choose the bowl, which was baited last time". In spite of the fact that in order to avoid the development of a side bias no more than two rewards were hidden on the same side in subsequent trials, the most frequent searching rule other than following the human gesture was to choose the pot on the same side. Interestingly, a similar response was observed in young wolves (unpublished data cited in Virányi et al. 2008), as eight out of nine pups developed a characteristic tendency for side preference in their first distal momentary pointing tests. Moreover, the use of the same decision-making rule and "first-trial interference effect" was observed in 3-year-old children (Ma and Lillard 2006). The decreasing success in case of domestic goats in distal pointing trials was also explained by the effect of side preference developed by the second part of the test (Kaminski et al. 2005). Horses, on the contrary, did not show side preference in similar tests, even though they were not successful in relying on the human distal momentary pointing (Maros et al. 2008).

We may well suppose that if the subjects are able to use the given cue and see it as relevant, they would not develop a bias. However, the applied test design (non-independent trials) can facilitate the manifestation of other searching rules. For example, another decision-making rule resulting in relatively weak performance might be the mixed tendency of following the gesture and/or trying to find the bait on the same place where it previously was ("win–stay strategy" or "sticking to the winning side of Trial 1" in child psychology). The detailed analysis of the performance in the first two trials revealed a connection between the success of the first choice and the decision-making rule in the second one. Thus, our results suggest that we cannot exclude the interference of the successive trials or gesture types during a session. When different decision-making rules confront, due to lack of understanding, the animal may develop biases. As the tendency to develop side preference in a two-way object choice test when faced with a complex task might depend on species-specific features, it can influence comparative results depending on whether one includes these animals in the analyses (see above studies) or excludes them (e.g., West and Young 2002). An interesting aspect of the behavior of some dogs with side preference was reported by E, who was pointing. The dogs followed the gesture and looked at the baited pot, but then still chose the preferred one. Similar response was experienced in some unsuccessful dogs that stared at one pot before the eye contact and the pointing, and then followed the pointing gesture gazing towards the baited pot, but chose the originally fixated one. Although this behavior could be seen by E, unfortunately it could not always be coded later without ambiguity from the video records and so we could not analyze it any further. (see Video S1).

Individual and group performance

Even in the present sample of well-socialized and partly specially trained dogs, we have found a fair number of subjects (more than half of the dogs) that did not base their choice on the human pointing cue. This raises the question on the source of significant individual differences. Considering the minor role of environmental factors on this ability, the aimed study of dog breeds selected for strikingly different purposes could also help to determine the effect of the potential of genetically based traits on the performance of dogs.

Since we cannot exclude other important factors (i.e., success of previous trial) influencing the choice of the individuals, low performance might not necessarily mean the inability to use the human gesture as a communicational signal. This is of vital importance because in the case of other species, weak performance is commonly regarded as negative evidence for the given capacity.

We suggest that to fully unfold the differences and similarities in comparative studies we should separate two different aspects to answer our final questions whether: (1) the animal is able or not to comprehend the communicative meaning of such signals, or (2) to what degree it is influenced by other (non-communicative/non-social) factors when making a choice (e.g., previous success or the place the bait was last seen).

A further important point is that the task-relevant cognitive abilities can be shaded/masked by species-specific characteristics (or individual "temperament/personality" traits) such as the tendency to pay attention to humans (Miklósi et al. 2003), undiscerning reliance on human cues (Erdőhegyi et al. 2007) or tendency to make decisions on their own based on previous success. We propose the more detailed analysis of object choice tasks, for example, also coding the subjects' gaze orientation right after the pointing besides counting correct choices.

Summary

In summary, we have provided unambiguous evidence that in dogs the ability to rely on subtle human pointing must be strongly facilitated by inherited factors that may require very rapid early learning to fully develop. Moreover, environmental factors seem to exert only little influence on this ability and, if analyzed at the individual level, dogs are not as successful as it is widely believed. Finally, in the case of comparative investigations several influencing factors, which arise from the applied paradigm and related species-specific differences, should be taken into account.

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