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Dogs are able to solve a means-end task

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Abstract

Dogs, although very skilled in social communicative tasks, have shown limited abilities in the domain of physical cognition. Consequently, several researchers hypothesized that domestication enhanced dogs' cognitive abilities in the social realm, but relaxed selection on the physical one. For instance, dogs failed to demonstrate means-end understanding, an important form of relying on physical causal connection, when tested in a string-pulling task. Here, we tested dogs in an 'on/off' task using a novel approach. Thirty-two dogs were confronted with four different conditions in which they could choose between two boards one with a reward 'on' and another one with a reward 'off' (reward was placed next to the board). The dogs chose the correct board when 1) both rewards were placed at the same distance from the dog, when 2) the reward placed 'on' the board was closer to the dog, and 3) even when the reward placed 'off' the board was much closer to the dog and was food. Interestingly, in the latter case dogs did not perform above chance, if instead of a direct reward, the dogs had to retrieve an object placed on the board to get a food reward. In contrast to previous string pulling studies, our results show that dogs are able to solve a means-end task even if proximity of the unsupported reward is a confounding factor.

Keywords

support problem; on/off problem; means-end understanding; dogs; clicker training; reward type

Introduction

Humans as well as non-human animals often encounter problems that force them to progress through a series of mediating actions in order to reach a certain goal at the end. When performing a goal-directed behaviour, understanding this series of progressing steps as the means to an end can be of great advantage for any individual (Schmidt & Cook 2006). Consequently, means-end understanding is considered to be a key step in the cognitive development of humans, since without it, organisms will be unable to transform an intention into a plan and, arguably, form an intention at all (Bratman 1981; Osthaus et al. 2005).

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In order to understand the evolution and mechanisms of this capacity, researchers investigate how nonhuman animals perceive and conceptualize various kinds of means–end relations. Usually, means-end understanding is studied by offering a choice of two options, one of which is in physical connection to an out-of-reach object of desire. Examples include the ‘string-pulling task’, originally introduced by Köhler (1927), where a string within reach of the subject is attached to a piece of food out of reach of the subject as well as the ‘support problem’, originally employed by Piaget (1952). Piaget’s ‘support problem’ involves a goal object (toy or food) that is out of a subject’s reach, but is resting on a support (a blanket) that is within the subject’s reach. The question is whether the subject appreciates that the goal object can be obtained by pulling on the support. Both tasks – the string pulling as well as the support problem - are based on the assumption that subjects that do not understand that pulling the string or the cloth is the ‘means’ for achieving the desired ‘ends’ of bringing the toy or food within reach, will only be able to succeed through repeated exposure allowing for associative learning (Thorndike 1898). Nevertheless, solving either of the tasks still does not necessarily imply the understanding of the underlying physical concept of connectivity but may also be solely based on perceptual features such as the contact between the ‘means’ and the ‘end’ (Tomasello & Call 1997).

So far, a number of non-human primate species (e.g. tamarins, *Saguinus oedipus oedipus*, (Hauser et al. 1999), great apes (Herrmann et al. 2008)), birds (ravens, *Corvus corax*, (Heinrich 1995); keas, N*estor notabilis* (Auersperg et al. 2009; Werdenich & Huber 2006), blue-fronted amazon, *Amazona aestiva* (de Mendonca-Furtado & Ottoni 2008)) and elephants (Irie-Sugimoto et al. 2008) have solved the string pulling task and/or the support problem. Interestingly, dogs as well as domestic cats (*Felis catus*), although able to learn to retrieve food that is out of reach by means of an attached string, have failed to show understanding of means-end relationships when tested in a 2-choice paradigm involving crossed strings or strings with varying angle orientations (Osthaus et al. 2005; Whitt et al. 2009).

Poor performance of dogs has also been reported for other physical cognition tasks such as the invisible displacement task in object permanence studies (Fiset et al. 2000; Fiset & LeBlanc 2007), where dogs rather rely on simple spatial relationship rules, like the adjacency rule (Collier-Baker et al. 2004; Watson et al. 2001). Similarly, dogs fail to infer the location of food if only physical, causal information is available (Bräuer et al. 2006). On the other hand, dogs perform extremely well in object choice tasks if they can locate the hidden food based on social cues, e.g. human communicate signals (Bräuer et al. 2006; Hare & Tomasello 2005; Miklósi et al. 1998; Virányi et al. 2008). They can comprehend the referential nature of human pointing (Miklósi & Soproni 2006; Soproni et al. 2001), as well as recognize and follow social rules (Topal et al. 2005). Based on these advanced cognitive abilities in the social domain and the poor performance in the physical domain, it has been proposed that the domestication process might have increased the social cognitive skills of dogs (Hare et al. 2002; Miklósi et al. 2003; Udell et al. 2010) (see also Wynne et al. 2008 for a different view) but had a detrimental effect on their physical cognition (Frank 1980). Since in dogs (and in other domesticated species) environmental effects on feeding and mating are buffered by humans, natural selection might have relaxed in these species on their individual problem solving (Frank 1980; Hemmer 1990). The fact that dogs have smaller relative brain sizes than wolves (Herre & Röhrs 1973) may support this conclusion.

Alternatively, a factor that might have accounted for the poor performance of the dogs in the string-pulling tasks is a lack in inhibitory control (defined as blocking an impulsive or prepotent response in favor of a more appropriate alternative when it is advantageous to do so (Wobber & Hare 2009)). The main reason for the failure of the dogs in these tasks was a proximity error; i.e. the dogs pawed or mouthed at a location closest in line to the treat. This predisposition of dogs to approach a reward in the direct, shortest way was apparent also in a detour task, when most dogs showed severe difficulties to walk away from the visible reward in order to detour a fence and thus reach the reward from the other side (Pongracz et al. 2001). Thus, this error could be due to insufficient inhibitory control in regard to the closer reward (see also Wobber & Hare 2009 for an example of a lack of inhibitory control in a social task in dogs). Inhibition has been shown to compromise problem solving abilities in several animal species as well as in children (Deacon 1997; Diamond 1990). Interestingly, several studies using the reversed contingency task to study inhibitory control have found that chimpanzees (*Pan troglodytes*) and tamarins, perform significantly better when Arabic numerals are used instead of food arrays (Boysen et al. 1999), when the food is invisible (Vlamings et al. 2006), or when color associations representing rewards are used instead of food (Kralik et al. 2002). These results suggest that the poor performance with food rewards may be attributable to an interfering non-associative disposition toward the direct perceptual and/or incentive features of the reward (Boysen et al. 1999).

Thirdly, dogs might be capable of efficient problem solving but it is overshadowed by other behavioral strategies (Topal et al. 1997). In a study examining dogs' choice based on exclusion (choosing the baited container in a two-way object choice task when being shown which container is empty) the dogs' behavior could be described by a set of hierarchically ordered decision rules (Erdohegyi et al. 2007). The dogs preferentially chose based on social-communicative cues (experimenter touching and looking at a container) or simple discriminative stimuli (movement of a container), and chose based on exclusion only when choice following the preferred cues was not possible.

Finally, also the former training history of dogs seems to influence their problem solving performance. For instance, clicker trained dogs were found to learn faster to pull on a string in order to reach a reward fixed to it, and committed the proximity error more rarely than dogs that had no experience with the clicker (Osthaus et al. 2003). Using the clicker – similarly to other secondary reinforcers – produces more specific learning in comparison to primarily reinforced training (Pryor 2009, p. 204). The animals establish not only positive associations with the training location where they were rewarded but learn specifically about the exact behaviour that pays off. For example, in an experimental comparison of two groups of horses, animals that were trained with secondary reinforcement showed more flexible performance and learnt a new task faster at the same location of a former training task than horses that were trained with primary reinforcement (McCall & Burgin 2002). Animals that are used to such action-specific learning may have an advantage in object choice tasks in which manipulating one of the objects leads to a reward but making the other choice remains unrewarded.

Taking these interfering processes into account it is less surprising that dogs' problem solving shows high inter-individual variability and appears to depend on various factors. In order to test whether the dogs used a set of hierarchically arranged rules to make their choice and in contrast to previous studies (Osthaus et al. 2005), we tested explicitly 1) to what extent proximity bias can either override or support choice based on physical connection and 2) what dogs choose when decision based on proximity is not possible (Figure 1). Moreover, to test whether a lack in inhibitory control might have been responsible for the proximity error in previous studies, we tested half of the dogs with an object that they had to retrieve in order to get a food reward from the owner (e.g. the object probably functioned like a token), while the other half of the dogs could obtain the food reward directly. Finally, to investigate whether training history would influence the problem solving skills, we tested 2 groups of dogs that were either clicker trained or not counterbalanced with the different rewards. As a further difference to earlier dog studies, we tested dogs' means-end understanding using the 'support' problem. More specifically, we used an apparatus with two movable boards that

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functioned as the ‘support’. During the test sessions, one of two identical rewards was placed ‘on’ (i.e. on top of) the board, whereas the second reward was placed ‘off’ (i.e. next to) the board. In order to reach a reward, the subject had to pull out the board with the reward/object on top with its paws. However, our aim in this study was not to investigate the underlying cognitive mechanisms that dogs use to solve the support problem, but first to investigate whether or not they can solve it at all and to what degree proximity governs their choice behavior.

In condition 1 (“Same distance”), we placed both rewards/objects at the same distance from the dog, so that proximity could not play any role when solving the problem. In condition 2 (“Weak proximity + support”), the reward/object that was placed ‘on’ the board was slightly closer to the dogs than the reward/object placed ‘off’ the board, thus choosing based on proximity would lead to success. In condition 3 (“Strong proximity + support”), we increased the distance between the reward/object placed ‘off’ the board and the one placed ‘on’ the board with the latter being even much closer to the dog than in condition 2. This condition was designed to examine the effect of proximity on the dogs’ success. In condition 4 (“Proximity against support”), the closer reward/object was placed ‘off’ the board, thus, in contrast with conditions 2 and 3, choosing based on proximity would lead to failure in this condition.

Methods

Subjects

Dogs (N = 68) and their owners were recruited to participate in this study between August and October 2009. Participation in the tests was voluntary. Only dogs older than 12 months were tested and various breeds were included. Thirty-six dogs had to be excluded since they never learned to manipulate the apparatus (N= 23) or because the owners did not follow the instructions of the experimenter (N= 13). Thus, data from 15 males and 17 females with a mean age of 6 years (range: 1.5-10.5) were included in the analyses. 16 dogs were clicker trained and 16 non-clicker trained dogs. Dogs were defined as clicker trained if the owners reported in a questionnaire that they use the clicker regularly for training or shaping behaviors. Using the clicker just once every 6 months did not qualify for being clicker trained.

Seventeen dogs were tested with an object (a red rubber toy) that they had to retrieve and bring back to the owner in order to get a food reward, whereas 14 dogs could directly retrieve a food reward (pieces of sausage) (see procedure for assessing which reward to use). One of the dogs started with the object retrieval, but then had to be switched to the food reward due to a lack motivation. In all analyses testing for the effect of the reward, this dog was excluded.

Test Apparatus

The apparatus used for the experiment consisted of a black wooden board (80 × 65 cm) with two yellow colored wooden boards (each 60 × 10 cm) mounted on top (see Figure 2). Each of the two boards was fixed between wooden rails constructed from drawer extensions so that a dog could move them forward and backward with its paws. Three rounded wood strips were fixed on the proximal end of each board as well as one in the middle to enhance the grip of the paws on the board, thus facilitating the moving of the boards. The distance between the two boards was 45 cm.

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Experimental set-up

All tests were conducted in the experimental room (4 × 5 m) of the ‘Clever Dog Lab’ (http://cogbio.univie.ac.at/labs/clever-dog-lab/). In order to control the access of the dogs to the apparatus, a small square area (1,2 × 1,5 m) of the testing room, which contained the apparatus and also provided sufficient place for the experimenter, was fenced in (Figure 2). The fence was constructed from aluminum bars and consisted of a gate in the front, the two sides and the wall of the experimental room. The spacing of the metal bars allowed complete visual access to the apparatus from the front and the two sides. During the experiments, the apparatus was positioned between the experimenter and the gate. An eight-centimeter gap between the floor and the gate allowed for pushing the boards back and forward underneath the gate. An opaque screen (50 cm * 100 cm) was used by the experimenter to hide the baiting process from the dog.

Procedure

Before the start of the experiment, the dogs were given time to familiarize with the test room, the experimenter, the fence and the apparatus until they stopped exploring the room (approx. 5 minutes).

Training phase

To train the dogs how to physically pull out the boards with the paw, we placed the board underneath the gate in reach of the dog and used a shaping method to train the dogs to pull out the yellow boards with the paw. Importantly, we first called the attention of each dog towards one of the two boards. Only if the dog was focused on the board, the reward was put down so that no discrimination training was conducted. Accordantly, none of the dogs pulled out the unbaited board in any of the training trials. In the first training trials, the reward was put down just out of reach of the dog, so that not much action was required to pull the board out and reach the reward. Once they reliably pulled out the board, the reward was placed at a greater distance to the dog so that it had to be pulled out further. The distance was increased until the dogs successfully pulled out the entire boards. Both boards were used alternately for the training, so that the dogs had the same experience in pulling out both boards. The owners were allowed to reward the dogs verbally for a successful action.

Although the dogs needed to pull out the entire board 5 times in a row in order to proceed to the test session (mean ± SD = 21.94 ± 8.72), this criterion was not based on a discrimination performance (e.g. they did not learn to discriminate between the baited and non-baited board), but on their physical ability to pull out the board. Nevertheless, it is possible, that the dogs associated the reward with pulling out a board that had a target on top. This association, however, should get stronger the more often the dogs pulled out a board with a piece of food on it, which would predict that a higher number of training trials would lead to a better performance in the test trials (Dickinson 1980; Call 2006). No such effect was found in either of the four test conditions (spearman rank: Condition 1: $r=0.038$, $N= 31$; $p = 0.837$; Condition 2: $r=0.255$, $N= 31$; $p = 0.167$; Condition 3: $r=0.167$, $N= 31$; $p = 0.371$; Condition 4: $r= -0.011$, $N= 31$; $p = 0.954$).

Assessing motivation

During this break the experimenter asked the dogs to retrieve the object from a random place in the testing room (not the apparatus) to get a food reward. The owners were also allowed to verbally praise their dogs when they retrieved the object. Dogs that successfully retrieved the object five times in a row were assigned to the object reward group, otherwise they were assigned to the food reward group.

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Test phase

The test phase started shortly after the training was completed. In each of four different experimental conditions, one board was presented with a reward/object on the surface (ON) whereas an identical reward/object was presented to the side of the other board (OFF) (see Figure 1). To obtain the reward/object, the dog had to pull out the board with the reward/object on its surface. At the beginning of each trial, the owner was asked to sit down on a chair at a distance of three meters to the apparatus (see Figure 2) holding the dog on the collar. While preparing the experimental arrangement, the dog was prevented from watching the experimenter by an opaque barrier. Once the rewards were in place, the opaque barrier was removed, the owner released the dog and the experimenter called the attention of the subject towards the arrangement by calling its name. Once the subject had approached the fence within 50 cm, looking at the layout, the experimenter waited for 3 consecutive seconds, and then moved the boards forward, so that the end of the boards could be reached by the subject from the other side of the gate. During the presentation, the experimenters' hands were placed at each end of the two boards. The experimenter never looked directly at the dog but over its head. Once the dog had started to pull out a board for at least 2 cm with its paws, the dog was considered to have made a choice. If the dog did not pull out the chosen board entirely, the experimenter pushed it out. If the dog tried to change between the boards after a choice was made, the experimenter pulled the apparatus back out of reach of the dog. A trial ended when the dog investigated the board being outside and took the reward/object if it was there. In case of the object, the dog was called back by the owner and got a food reward in exchange for the object. Then the next trial followed.

The owner remained sitting on the chair during the entire experimental trial, but was allowed to encourage the dog by giving commands like 'bring', 'search', and 'go'. The owner was not allowed to say 'no' or to praise the dog before the board was completely pulled out. The dogs who's owner did not adhere to the rules were excluded from the analyses.

We conducted 12 trials per condition per subject pseudo-randomizing the side of baiting so that, for each condition, 6 times the left and 6 times the right board were baited but never more than 2 times on the same board in a row. The conditions were randomly intermixed. Dogs were tested once per week. The maximum of trials per session were six, but if the dog started to walk around the room instead of approaching the apparatus, the session was terminated earlier. After a break of approximately 10 minutes, the dogs were tested in the next session. Since we were interested in the dogs' cognitive performance, the number of trials and sessions conducted per testing day varied between dogs according to their individual attentiveness and motivation e.g. we stopped when the dog started to wander around in the room and/or the performance dropped (mean number of trials: 19, range: 2-24 within 2-6 sessions). All dogs completed the tests within 4 weeks. The minimum number of sessions was 2 the maximum was 5 per day.

All trials were videotaped using a set-up of 4 digital video cameras (2× Sony Exwave HAD, 2× Sony DCR-TRV 25). The cameras were connected to a video station outside of the testing room.

Data analyses

Videos were analysed using Solomon Coder beta 090626. In all four conditions, we coded the number of dogs' correct choices. Statistical analyses were performed in R 2.10.1 (R Development Core 2009) and Instat 3. To determine whether sex, type of reward, clicker training and learning over the experiment influenced the performance of the dogs in each of the four different test conditions, we fitted the number of correct trials as the binomial response term in a general linear mixed model with the total number of trials as the denominator. The dog's sex, type of reward (object or food), training (being clicker-trained or not) and learning (first six trials vs. last six trials) were fitted as fixed factors and dog identity as random factor. According to the Kolmogorov–Smirnov test, the data were not normally distributed. Consequently, we used non-parametric statistics to compare the performance of dogs to the chance level or to certain other conditions. All tests were two-tailed and alpha was set at 0.05. When we conducted multiple comparisons with the same data, probabilities were corrected with the Bonferroni procedure.

Results

In condition 1 ("Same distance"), where both rewards/objects were placed at an equal distance from the dog, according to the general linear mixed model analysis none of the fixed factors influenced the performance of dogs (Table 1). Further analyses revealed that the dogs chose the reward/object placed 'on' the board significantly more often than expected by chance (Wilcoxon signed rank test: $N = 31$, $T^+ = 397.0$, $p = 0.0001$, adjusted α-value = 0.017). Furthermore, four dogs performed significantly above chance at the individual level withh 10 or more correct choices out of 12 trials (Binomial test, $p < 0.05$).

In condition 2 ("Weak proximity + support"), where both rewards/objects were placed at the far end of the boards but the reward/object placed 'on' the board was slightly closer to the dog, none of the fixed factors influenced the performance of dogs (Table 1). Further analyses showed that the overall performance of the dogs was again significantly above chance (Wilcoxon signed rank test: $N = 31$, $T^+= 322$, $p < 0.0001$; adjusted α-value = 0.017). Again four dogs performed significantly above chance at the individual level with 10 or more correct choices out of 12 trials (Binomial test, $p < 0.05$). The performance of dogs in condition 1 and 2 did not differ significantly from each other (Wilcoxon matched-pairs signed-ranks test: N=27 (4 ties), $T^+= 169.0$, $p = 0.644$).

In condition 3 (Strong proximity + support"), when the much closer reward/object was placed on the board, the fixed factor "learning" had a significant influence on the performance of dogs (Table 1). However, further analyses showed that the performance of the dogs was significantly above chance already in the first 6 trials (Wilcoxen signed rank test: $N = 31$, $T^+=371.00$, $p < 0.0001$; adjusted α-value = 0.025), suggesting that although the dogs increased in their performance in this condition from the first to the last six trials, they could solve the task from the beginning on. This is supported also by the individual data, since the majority of the dogs (17 of 32) performed significantly above chance with 10 or more correct choices out of 12 trials (Binomial test, $p < 0.05$). Condition 2 and 3 only differed in the fact that in condition 3 the on-reward/object was even closer to the dogs than in condition 2; this difference in distance significantly increased the performance of the dogs in condition 3 compared to condition 2 (Wilcoxon matched-pairs signed-ranks test: N= 29 (2 ties), $T^+= -275.0$, $p = 0.002$, adjusted α-value = 0.025).

In condition 4 ("Proximity against support"), where the reward/object closer to the dogs was placed 'off' the board, the fixed effect 'type of reward' significantly influenced the performance of dogs (Table 1). Interestingly, the dogs rewarded with food performed better than dogs that had to retrieve the object to get a food reward (Figure 3). Further analyses revealed that, while the dogs rewarded with food chose the reward placed 'on' the board significantly more often than chance (Wilcoxon signed rank test: N = 9 (5 ties), $T^+= 42.5$, $p = 0.012$; adjusted α-value = 0.025), the dogs in the object group did not (Wilcoxon signed rank test: $N = 16$, $T^+= 9.5$, $p = 0.129$). Two out of the 14 dogs rewarded with food performed significantly above chance also on the individual level, with one dog choosing correctly on all 12 trials and one dog making a single mistake (Binomial test, $p < 0.05$). None of the dogs was individually significant in the object group.

Comparing condition 4, where proximity of the off-reward was a confounding factor, with condition 1, where proximity played no role, we found that dogs in the object group were significantly better in condition 1 than condition 4 (Wilcoxon matched-pairs signed-ranks test: N= 16, T^+= 122.0, p = 0.0034; adjusted α-value = 0.025), whereas the performance of the dogs rewarded with a food reward did not differ in the two conditions (Wilcoxon matched-pairs signed-ranks test: N= 13 (1 tie), T^+= 50.0, p = 0.787).

Discussion

Our findings demonstrate that dogs possess the ability to consider means–end relationships in the support problem even if proximity is a confounding factor. The dogs were not only successful if the reward/object that was placed 'on' the board was closer to the dog than the reward/object placed 'off' the board (condition 3, 2), but also when both rewards/objects were placed at an equal distance from the dogs (condition 1) or when the reward/object placed 'off' the board was much closer (condition 4). Moreover, our study highlights the importance of the reward type and possibly of inhibitory control in the study of dogs' physical understanding. Namely, the performance in condition 4 depended on whether a food or an object was used, with dogs choosing significantly above chance when food was placed on the board, but not when the dogs had to retrieve an object in order to get a food reward from their owners. Nevertheless, one has to note that only few dogs performed significantly above chance on the individual level in all conditions but condition 3. Per condition, we conducted only 12 trials, which might be responsible for the low number of individuals who succeeded in the difficult conditions on an individual level. To reach significance in the binomial test, an individual could not make more than 2 mistakes in the 12 trials, requiring great concentration at all times especially since the different conditions were randomly intermixed. Altogether, the group level results demonstrate that dogs can be successful also in the physical domain, and argue against Frank's (1980) hypothesis that the domestication process had a detrimental effect on dogs' cognitive abilities.

The low number of trials and the randomization of the test conditions, made it very difficult for the dogs to learn how to solve the task by associative learning. More importantly, it might be argued that our training influenced the performance of the dogs in the test trials. Although we did not use discrimination training, but rather were concerned with the physical abilities of the dogs to pull out the boards, it is still possible that the animals associated the reward with pulling a board out that had the target on. We think that this is unlikely due to two reasons: 1) we found no relationship between the number of training trials and the animals' performance in the test trials which would be expected based on an associative account (Dickinson 1980, Call 2006) and 2) Osthaus et al. (2003) trained half of the dogs using a discrimination paradigm before subjecting them to the string-pulling task and found no effect even of this higher-level training, suggesting that dogs cannot even profit from prior discrimination training (e.g. discriminating between a baited and non-baited string) in a means-end paradigm. During the test trials, learning only occurred in condition 3 ("Strong proximity + support"), where the performance of the dogs increased from the first 6 trials to the last 6 trials, but even here the dogs were successful already in the first 6 trials. This suggests that learning was not necessary to solve the task but only improved the performance.

Dogs have been reported to strongly rely on proximity when tested in a string-pulling task (Osthaus et al. 2005), which might be accounted to insufficient inhibitory control in regard to the closer reward. In condition 2, where the reward/object was just moved a little bit closer to the dogs compared to the distance of both rewards/objects in condition 1, the performance of the dogs was not significantly improved. Interestingly, analyzing the first three conditions, we found that the dogs in this support problem were not very prone to a

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proximity bias and that proximity only helped if it was exaggerated (condition 3). However, very interesting was condition 4, where we found a significant difference in performance of dogs tested with toys vs. dogs tested with a food reward. In contrast to previous findings, that animals perform better if non-food items are used in problem solving tasks, dogs in our study performed significantly better if food was used instead of an object that could be exchanged for a food reward. A possible explanation for this somewhat surprising result is, that we only tested those dogs with toys that showed high motivation to retrieve toys prior to the testing. Moreover, between trials, owners would shortly play with their dogs with the retrieved toy to sustain motivation. The higher motivation of dogs rewarded with toys was also apparent in the fact that needed fewer sessions to complete the task than dogs tested with a food reward (of 14 dogs tested with toys, only 2 needed 4 or more sessions whereas 5 of 12 dogs tested with food needed 4 or more sessions; data for 3 dogs are missing). Thus, the motivation and the general excitement might have been higher in the dogs rewarded with the toy than dogs rewarded with food, overriding their ability to inhibit the preference for the closer reward in condition 3. The fact that we only found an effect of type of reward in condition 4 might stem from the difficulty of the task: in all other three test conditions, proximity was not so clearly offset against the correct choice, leading to overall better performance of the dogs, which might have hidden the effect of the type of reward.

Another factor that has been reported to influence dogs' problem solving abilities is the type and degree of training they received (Marshall-Pescini et al. 2008; Osthaus et al. 2003; Range et al. 2009). Especially in regard to means-end understanding, it has been found that clicker-trained dogs outperform non-clicker trained dogs (Osthaus et al. 2003). However, in our study we found no significant difference in the performance of the dogs in regard to their training history. This is understandable since – in contrast to the Osthaus' study where it was measured whether the direct pawing for the food was replaced by the action of pulling on the string – in our study the same action had to be applied on one of the two boards and success depended on whether the right board was chosen based on seeing the reward/object 'on' or 'off' the board.

Subjects may solve means-end problems either by understanding the underlying physical concept of connectivity or by choosing based on perceptual features such as the contact between the 'means' and the 'end' (Tomasello & Call 1997). Recent studies suggest that chimpanzees as well as tamarins (*Saguinus Oedipus*) base their choice on the perceptual features of the staged problem rather than on a concept of physical connection (Povinelli 2000; Santos et al. 2005; Vonk & Subiaul 2009), while keas might actually understand the concept of connectivity when tested in the support problem (Auersperg et al. 2009). Further support for a difference in understanding of support problems in primates and birds comes from studies investigating support relations where chimpanzees (Bird & Emery 2010; Cacchione & Krist 2004) but not rooks (*Corvus frugilegus*) (Bird & Emery 2010) failed to consider the *type* of contact e.g. whether an object was actually supported by the given contact or with the same amount of contact but just hanging in the air. In the present study, we cannot distinguish whether dogs understood the means-end connection based on perception or whether they actually understood the underlying physical concept.

Moreover, compared to a previous study on means-end understanding in dogs using the string-pulling task, dogs – that were rewarded with food - could even solve the support problem if proximity of the inaccessible reward was a confounding factor. Why the performance of the dogs in the 'on-off' problem differs from the one in the string-pulling task is an open question. One possibility is that dogs have a lot more opportunities to learn something about objects placed on other objects during their daily experiences than learning about objects connected to strings. Another possibility is that the on-off problem is less complex in that 'contact' is easier to perceive in the on-off problem than in the string-pulling problem e.g. in the support problem the object is resting with its whole surface on the support. However, to our knowledge all species that have been tested in both – the string-pulling and the support – tasks, have also performed well in both, suggesting that the difference in performance between the two tasks might be dog specific. Finally, an important fact is that we only tested very simple conditions in the current study and it might well be possible that the dogs would fail in more difficult versions (e.g. crossed boards), which would support the latter hypothesis that perception and not understanding explains the performance of the dogs in the two tasks.

In summary, this study demonstrates that dogs can solve simple means-end tasks and do so without learning. Whether they would also be able to solve more complicated versions and whether the performance in the present study is driven by causal inference needs to be elucidated in future investigations.

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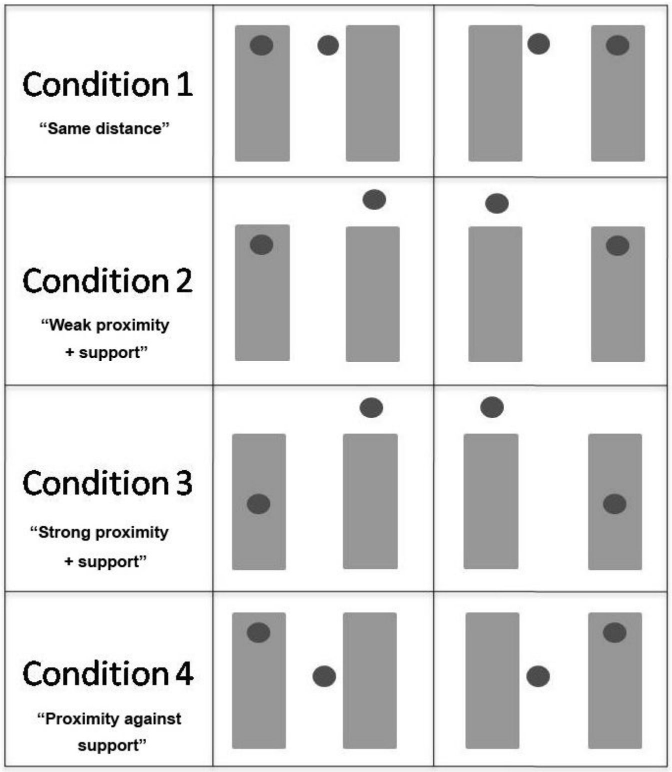

Figure 1. The four different conditions presented to the dogs. Trials of the different conditions were randomly intermixed.

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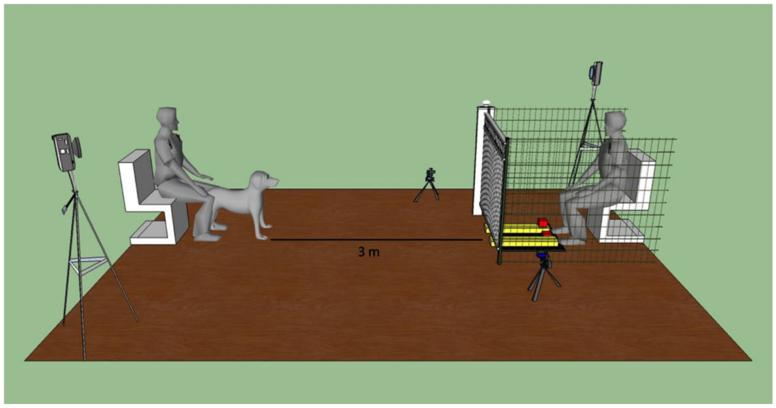

Figure 2. Sketch of the experimental set-up.

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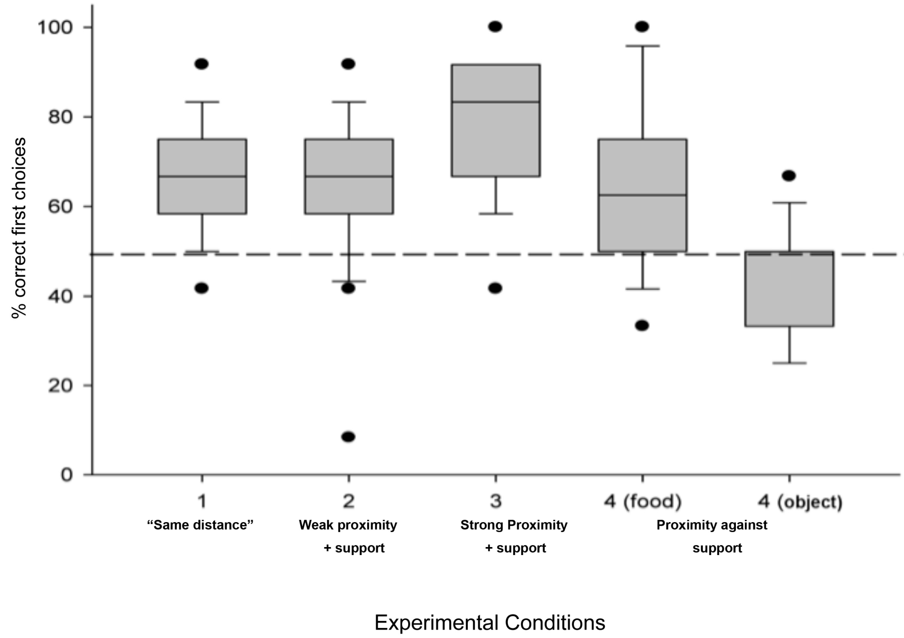

Figure 3. Box plots showing the percentage of correct choices of the dogs in the four different conditions.

In condition 4, the dogs were separated into dogs tested with a food reward and dogs tested with a toy reward according to the results of the general linear mixed model. Shaded boxes represent the interquartile range, bars within shaded boxes are median values and whiskers indicate the 5th and 95th percentile. The dashed line indicates chance level of performance. Both groups performed significantly above chance (see text for details).

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Table 1

Summary of the results of the general linear mixed model determining whether sex, type of reward and type of training influenced the performance of the dogs in each of the four different test conditions.

All 2-way interactions were found to be non-significant and were omitted from the table. Shaded boxes represent significant results.

Condition	Factor	DF	t-value	P
Condition 1	Sex	1, 29	1.008	0.323
	Type of reward	1, 26	0.654	0.519
	Type of training	1, 26	1.893	0.07
	Learning	1, 29	1.369	0.181
Condition 2	Sex	1, 28	0.254	0.802
	Type of reward	1, 26	0.578	0.568
	Type of training	1, 26	−0.361	0.721
	Learning	1, 29	1.920	0.065
Condition 3	Sex	1, 29	1.609	0.118
	Type of reward	1, 27	−0.277	0.784
	Type of training	1, 26	−1.239	0.226
	Learning	1, 29	2.441	0.021
Condition 4	Sex	1, 29	−1.533	0.136
	Type of reward	1, 26	3.320	0.003
	Type of training	1, 26	−0.941	0.355
	Learning	1, 29	0.992	0.329