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Do Dogs (*Canis familiaris*) Understand Invisible Displacement?

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Domestic dogs (*Canis familiaris*) perform above chance on invisible displacement tasks despite showing few other signs of possessing the necessary representational abilities. Four experiments investigated how dogs find an object that has been hidden in 1 of 3 opaque boxes. Dogs passed the task under a variety of control conditions, but only if the device used to displace the object ended up adjacent to the target box after the displacement. These results suggest that the search behavior of dogs was guided by simple associative rules rather than mental representation of the object's past trajectory. In contrast, Experiment 5 found that on the same task, 18- and 24-month-old children showed no disparity between trials in which the displacement device was adjacent or nonadjacent to the target box.

The invisible displacement task was originally conceived by Piaget (1937/1954) as a measure of toddlers' transition to Stage 6 in his theory of object permanence. In the classic task, the subject sees the experimenter hide a desired object under a displacement device, typically a small opaque container. The experimenter slides the displacement device under one of several hiding boxes, surreptitiously deposits the object beneath this box, and shows the subject that the displacement device is now empty. To find the object, the subject cannot rely on perceptual information alone but rather must infer the object's location by mentally representing its past trajectory (e.g., Call, 2001). The task is thus thought to provide evidence of representational thought: the ability to entertain representations of objects or events that cannot be directly perceived.

As such, Piaget's invisible displacement task continues to feature strongly in both developmental and comparative research and theory. In Perner's (1991) theory of representational development, for example, passing the invisible displacement task is one of several markers of the emergence of a capacity for secondary representation. Perner suggests that prior to the middle of their 2nd year, infants have access only to primary representations; that is, they maintain a direct model of reality that is continually updated with incoming perceptual information. Passing the invisible displacement task indicates that the child can go beyond a single updating model to entertain multiple models of the world. That is, the child is able to hold in mind a model of the current world (primary representation: displacement device empty) as well as a model of the past world (secondary representation: displacement device with object under large box). By collating these two models the child can infer the likely location of the surreptitiously displaced object. Children typically begin passing the invisible displacement task at approximately 18–24 months of age (e.g., Kramer, Hill, & Cohen, 1975; Piaget, 1937/1954). Perner (1991) argues that several other abilities emerging in the 2nd year, such as mirror self-recognition and pretend play, also involve secondary representations. At least some evidence for a cluster of developmental markers of secondary representation is available for chimpanzees, and a similar case can be made for orangutans and gorillas (Suddendorf & Whiten, 2001). However, there is scarce empirical support for secondary representation in monkeys and other mammals.

In line with this argument, chimpanzees (e.g., Call, 2001), gorillas (Natale, Antinucci, Spinozzi, & Potì, 1986), and orangutans (Call, 2001; de Blois, Novak, & Bond, 1998) have all passed the invisible displacement task. In contrast, testing across a wide range of species has failed to reveal consistent evidence of success on the task in most other animals, including dolphins (Doré, Goulet, & Herman, 1991), numerous species of monkeys (e.g., de Blois et al., 1998; Natale & Antinucci, 1989), cats (e.g., Doré, 1986; Dumas, 1992), hamsters (Thinus-Blanc & Scardigli, 1981), and domestic chickens (Étienne, 1973). However, striking exceptions to this pattern of findings have come from research with dogs (e.g., Gagnon & Doré, 1992, 1993, 1994; Triana & Pasnak, 1981) and psittacine birds (e.g., Pepperberg & Funk, 1990; Pepperberg & Kozak, 1986; Pepperberg, Willner, & Gravitz, 1997). In two longitudinal studies, puppies (Gagnon & Doré, 1994) and an African grey parrot (Pepperberg et al., 1997) were shown to progress through a sequence of stages on displacement tasks similar to those of human infants.

Piaget's (1937/1954) classic task has been modified to varying degrees in order to suit the sensory and motor characteristics of nonhuman species. For example, the modifications required to test quadruped species include the use of larger open-backed hiding boxes presented at a distance from the animal so that choice can be indicated by moving to a box. The boxes must be arranged in a semicircle so as to be equidistant from the subject, and both the displacement device and the object are usually attached to manipulandums (a pole and a length of thread, respectively), so that the experimenter can conduct the displacements in plain view of the subject. Adopting tasks that were designed for one species to test

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members of another may raise concerns about the validity of the measure. That is, does the task measure in the new species what it purports to measure in the old, or are there alternative ways the new species may pass or fail the task? Piagetian tasks may be solvable through the use of inadvertent experimenter cues or simple search strategies that bypass the cognitive structures they were designed to measure (for a review, see Pepperberg, 2002).

Gagnon and Doré (1992) suggested that methodological problems in the task used with psittacine birds (Pepperberg & Funk, 1990; Pepperberg & Kozak, 1986) might have encouraged local rule learning, rendering the evidence for invisible displacement understanding in psittacines inconclusive. *Local rule learning* refers to the chance discovery of an action that leads to success on a task and is then simply repeated (e.g., Étienne, 1973). On standard invisible displacements, there are various regularities in the task stimuli and procedure that could potentially be exploited in this way. For example, a subject may simply select the box visited by the displacement device and achieve success without necessarily having to mentally represent the object's hidden trajectory. Various precautions have been taken with dogs to guard against the use of such "lower level" strategies to solve the task. Olfactory cues were ruled out, both by providing misleading odor cues (Pasnak, Kurkjian, & Triana, 1988), and by masking them altogether (Gagnon & Doré, 1992). Breed differences were also discounted as an explanation for the success of dogs on the task (Gagnon & Doré, 1992). The number of tests and trials per test were limited to minimize opportunity for trial-and-error learning. Gagnon and Doré (1992) also noted that by moving the object via an attached length of transparent thread and the displacement device via an attached pole, their procedure with dogs avoids the cuing that may occur when the hiding locations are touched and lifted directly by an experimenter, as in the classic task used with children, as well as with nonhuman primates (e.g., Natale et al., 1986) and parrots (e.g., Pepperberg & Funk, 1990).

Nevertheless, Gagnon and Doré (1992, 1993) explored the possibility that local rule learning could still lead to success on the series of tasks they used with dogs. However, they rejected this possibility because post hoc analysis of their data revealed no evidence of learning over trials. In fact in one case, dogs' performance was more successful on an earlier task than a later task. This is in conflict with the reasoning that a gradual improvement in performance over trials (and over tests) should be evident if subjects have learned a successful local rule, such as "always chose the box visited by the displacement device." Moreover, Gagnon and Doré (1992) argued that if the association between the displacement device and hiding box had been powerful enough to produce one-trial learning, then there is no reason for dogs to perform better on an earlier task than a later task. However, for the dogs in question, the tests were presented in an order of increasing difficulty. Thus, performance may have been less successful on the later task simply because it was more difficult.

The possibility remains that dogs spontaneously use simple strategies to pass the task. A consistent finding has been that, although above chance, the performance of dogs on invisible displacements is significantly inferior to that on visible displacements (Gagnon & Doré, 1992, 1993, 1994). Gagnon and Doré (1993) carefully investigated which components of the invisible displacement procedure might reduce dogs' ability to accurately represent the hidden trajectory of an object. Delays of up to 20 s between the end of a displacement and their release for search did not affect dogs' performance. In contrast, the movement of the displacement device to its final position at the end of a displacement was found to create retroactive interference. However, these authors confirmed that it is the invisible transfer of the object from the displacement device to the target box that is the most difficult event to represent because when they kept the object visible as it was moved toward the target box, dogs still performed worse on invisible displacements than visible displacements. The authors thus concluded that dogs have an imperfect understanding of inferred movements.

Two studies using alternative paradigms have also suggested that dogs' understanding of displacement problems may be limited. Watson et al. (2001) found that in contrast to children, dogs failed to use deduction on a different search task. Deduction, along with representation, is deemed to be a prerequisite for invisible displacement understanding (Piaget, 1937/1954). A study investigating the spatial cognition of dogs and cats found that both species failed to infer invisible movements on a transposition task, in which hiding screens are moved instead of a displacement device (Doré, Fiset, Goulet, Dumas, & Gagnon, 1996). On the basis of this finding, Doré and Goulet (1998) proposed that dogs do not fully understand invisible displacement after all. However, the Piagetian paradigm has not yet been revisited to examine whether this is the case, and consequently researchers continue to attribute invisible displacement understanding to dogs (e.g., Agnetta, Hare, & Tomasello, 2000; Hauser, 2001; McKinley & Sambrook, 2000; Neiworth et al., 2003). Could dogs have persistently passed the task without being able to represent the past trajectory of the target? The present study was designed to investigate this question.

Dogs may have exploited various avenues for associative strategies to solve the task. The possibility of a "Clever Hans" effect was not explicitly addressed in most previous invisible displacement studies with animals. Even when sunglasses or baseball caps have been worn by experimenters to avoid giving eye-gaze cues (e.g., Call, 2001; de Blois et al., 1998; Pepperberg et al., 1997), subtle body movements may have affected subjects' performance. Dogs have shown considerable skill in the area of social cognition, outperforming apes in their ability to respond appropriately to a variety of human cues communicating the location of food (Hare, Brown, Williamson, & Tomasello, 2002). For example, dogs are able to use the placement of a marker, pointing, nodding or bowing, head and eye gaze, and, in some cases, even eye gaze alone to find food hidden at one of two locations (e.g., Agnetta et al., 2000; Hare, Call, & Tomasello, 1998; Miklósi, Polgárdi, Topál, & Csányi, 1998). Considering the sensitivity of dogs to human social signals, it would seem necessary to control for experimenter cues in the invisible displacement task.

A study on the representational capacities of a gorilla and a Japanese macaque (Natale et al., 1986) demonstrated the vulnerability of the invisible displacement paradigm to local rule learning. The use of stringent controls to prevent subjects from using operant rules to solve the task revealed differences in the strategies used by the great ape and the monkey. As discussed above, associating the object with the box manipulated by the experimenter is one such strategy that does not involve representation of the invisible displacement. When the experimenter placed the object under the displacement device and then simply lifted one of the two hiding boxes, the macaque searched at this incorrect hiding box on 50% of trials. In contrast, the gorilla always correctly chose the displacement device. In subsequent trials, once the macaque had learned to choose the displacement device, another potential cue was controlled for. Instead of the empty displacement device ending up adjacent to the target box (i.e., the correct hiding box) after the displacement, it was placed beside the irrelevant box so that it was nonadjacent to the target box. The macaque's performance again fell to chance. Even the gorilla's performance, although better than that of the monkey, was no longer better than chance. In sum, the results revealed that the macaque relied on two local rules: "Go to the box manipulated by the experimenter" and subsequently, "Go to the box adjacent to the displacement device." Natale et al. (1986) concluded that, in contrast to the gorilla, the macaque was unable to represent the past trajectory of the displacement device and infer the object's location.

The present set of experiments examined whether dogs are capable of representing invisible displacements. We introduced a condition to prevent inadvertent experimenter cues, and, following Natale et al.'s (1986) approach, we assessed the performance of dogs on the invisible displacement task under discrete control conditions designed to eliminate the use of specific local rules. By adapting Natale et al.'s false and nonlinear control trials for use with dogs, we investigated whether dogs pass the task through the use of local rules or through secondary representation. If dogs are capable of secondary representation, then performance should remain above chance on all control tasks.

As mentioned previously, there is always some concern about validity when tasks are adapted from one species to another. Here a task devised for human infants has been modified to test dogs. In Experiment 5, we gave children the version of the task administered to dogs. This was done to ascertain that the changes made to the classic invisible displacement task to render it suitable for dogs did not introduce new difficulties. If the task used with dogs is a valid human analogue, then children should perform on this version as they typically do on the classic task. First, however, we needed to replicate the procedures that have found dogs passing the invisible displacement task.

Experiment 1: Standard Visible and Invisible Displacement Tasks

Following Gagnon and Doré (1992), Experiment 1 investigated whether dogs perform above chance on visible and invisible displacement tasks. Gagnon and Doré (1992) found above-chance performance on both tasks, with significantly better performance on the visible than on the invisible displacement task. Replicating these findings would confirm that the testing methodology of the current experiment was equivalent. Although the present set-up followed that of Gagnon and Doré (1992) for the most part, there was one major modification. Instead of positioning the three hiding boxes 20 cm away from each other as in Gagnon and Doré (1992, 1993, 1994), this distance was doubled to 40 cm. In pilot trials, it was readily apparent that the 20-cm gap forced most dogs to go around one extremity of the array to get to a particular box, rather than taking the more direct route between two boxes. This seemed to pose a threat to the validity of the task: If the first box passed at one extreme of the array happened to contain the target object, a glance at its contents could easily arrest a dog that was otherwise heading to one of the other two boxes. Similarly, boxes could be eliminated successively before the dog opted to "choose" the correct one. No problem was observed with the 20-cm distance used between hiding boxes by Gagnon and Doré (1992, 1993, 1994; S. Gagnon, personal communication, December 4, 2003). Nevertheless, given our pilot trials, we opted to widen this gap between boxes in our attempt to replicate Gagnon and Doré's findings.

Method

Subjects

Nine domestic dogs (*Canis familiaris*), 5 males and 4 females, were recruited from private owners at the University of Queensland (ages ranging from 12 to 60 months, $M = 38.3$ months). Two selection criteria were specified: To participate dogs had to be (a) at least 1 year old and (b) motivated to attend to a ball. Ball motivation was defined as ball retrieval during the familiarization period. One dog was excluded for failing the latter criterion. Of the remaining 8 dogs in the experiment, 3 were mixed breeds (Australian cattle dog × Staffordshire bull terrier, Australian cattle dog × border collie, kelpie × bull terrier), 2 came from breeds classified by the American Kennel Club as herding dogs (border collie, German shepherd), 1 from the terrier group (West Highland white terrier), 1 sporting breed (golden retriever), and 1 nonsporting breed (toy poodle). None of the dogs in any of the experiments reported in the present study had received any prior instruction beyond basic obedience training, and all were naive to psychological experimentation.

Apparatus

Figure 1 is a photograph of the basic set-up of the apparatus used in the displacement tests. Standard green tennis balls served as target objects and were manipulated via attached lengths of transparent nylon thread measuring 1.25 m. A new ball was allocated to each dog to minimize odor cues, and balls were rubbed around the inside of each box before each session. The boxes used to hide the target object were three square plastic boxes (red, yellow, and blue) with five sides and open backs (36 cm wide × 36 cm high × 27 cm deep). Flat bricks (28.5 cm × 4.0 cm × 18.5 cm) wrapped in thick white calico cloth were placed in the bottom of each box

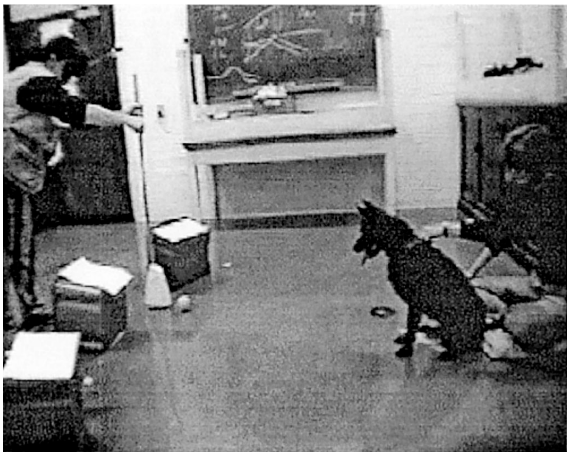

Figure 1. Photograph depicting the basic apparatus used in each task (the displacement device was not present in the standard visible displacement task) and the positions of the subject and the experimenter during displacements. Owners held their dogs during stimulus manipulations.

to prevent them from being knocked over as dogs searched for the target object. Extra calico cloth and pieces of polystyrene lined the insides of the boxes to absorb any sound made as the object was deposited. A data sheet informing the experimenter of the displacement sequences for each subject was placed on top of the central hiding box throughout test trials. Consequently, A4-sized paper was also placed on top of the other two hiding boxes.

The device used to displace the object was a white opaque V-shaped box with an open back (10 cm × 22 cm for each face of the V and 13 cm deep). The displacement device was fixed at the bottom of a 1-m vertical wooden pole. Small commercial beef liver treats served as reinforcers. Blindfolds were provided for dog owners to wear during stimulus presentations. White tape on the floor marked the positions of the boxes, displacement device, experimenter, and subject. All testing took place in a bare, well-lit room in the University of Queensland Veterinary Clinic measuring 5.95 m wide × 4 m high × 6.65 m long.

Procedure

Both tests were administered within a single session lasting approximately 20 min on average. Dogs were tested individually with their owners present. The experimenter spent the first 5–10 min of the session familiarizing the dog with the target object (tennis ball) and the testing apparatus. During this familiarization period, the experimenter placed the ball in each of the three boxes in a random order, as well as in the displacement device, and encouraged the subject to retrieve the ball. Dogs were reinforced with verbal praise and a food reward after each successful retrieval. The displacement device was placed at the left or right extremity of the box array during familiarization, and this position was alternated between subjects. The purpose of this familiarization period was to inform subjects of the hiding potential of the boxes and the displacement device, as well as to ensure that dogs were motivated to retrieve the ball from inside the boxes. This procedure had to be repeated once for 2 subjects who initially showed some hesitancy in putting their heads into the back of the boxes.

In all tests, subjects sat 1.5 m away from the semicircular array of boxes (i.e., equidistant from each box). Owners manually held their dogs in position by the collar or shoulders to prevent them from initiating any movement toward the stimuli before the displacement was complete. In order to eliminate any inadvertent cues, owners wore blindfolds during testing. A salient phrase such as “go fetch” or “where’s the ball?” was arranged with the owner to serve as a signal to release their dog. When giving this signal, the experimenter was careful to look only at the dog and remain motionless so as to avoid giving any cues as to the object’s location.

In all tests, the experimenter stood behind the central box, facing the subject, and held the end of the nylon thread attached to the ball. Each test included five trials. The experimenter started each trial by attracting the subject’s attention and then flicking her hand forward so that the ball was tossed out in front of one of the hiding boxes. The starting position of the ball varied randomly from trial to trial, as did the target box, with the ball never starting or finishing at the same location more than twice consecutively. Similarly, the starting and finishing positions of the displacement device were varied randomly from trial to trial, with the constraint that the displacement device never occupied the same position more than twice consecutively. The final position of the displacement device was always the same as its starting position, and its closed panel always faced the subject at this location. The displacement device could occupy four possible positions: between two adjacent boxes or at either end of the semicircle.

Following Gagnon and Doré (1992, 1994), retrieval—the dependent measure—was scored as successful on a trial if subjects went to the target box and made appropriate contact with the ball. Appropriate contact was operationalized as any one of the following behaviors: picking up the ball with the mouth, pawing the ball, or placing the muzzle on the ball. If a subject visited the displacement device before the target box, their search was still scored as correct. When successful, subjects were given a food reinforcer, verbal praise, and patting. Retrieval was scored as unsuccessful if subjects first looked in one of the irrelevant boxes, looked in the target box without making appropriate contact with the ball, or made no choice within 1 min of release.[1]

A research assistant monitored the subject’s attention to each step of the displacement. If a subject looked away during a displacement, the trial was restarted. Two tests were administered in the following order:

Standard visible displacement. After tossing the ball into its starting position, the experimenter pulled on the transparent thread attached to the ball so that the ball rolled along the floor from its starting position to the back of the target box, whereupon the experimenter gently swung it into the box and dropped the thread. The displacement device was not part of the stimulus array for this test.

Standard invisible displacement. Using the same procedure as in the standard visible displacement task, the experimenter first moved the ball from its starting position into the back of the displacement device. Holding the attached pole with her other hand (and keeping both hands close together), the experimenter moved the displacement device in midair, with its closed side facing the subject, behind the target box, and by pulling on the thread, invisibly transferred the ball from the displacement device into the back of the box. The thread was dropped and the displacement device was brought out from behind the box and rotated 180° on its vertical axis, low to the ground, so that the subject could see that it was now empty. It was then moved back to its starting position, set down, and rotated 180° so that its closed side was facing the subject once more.

Results and Discussion

Overall, dogs were highly motivated both to attend and to respond to the manipulations in both tests. No trials had to be repeated because of inattention in the standard visible displacement test, and subjects made an appropriate search attempt on every trial. In the standard invisible displacement test, 7.5% (3/40) of trials were repeated as a result of inattention, and in only 5.0% (2/40) of trials did subjects fail to search any of the boxes. A sign test comparing the first and fifth trials for each subject found no evidence of learning in the standard invisible displacement test. Two independent judges, blind to the research hypotheses, scored 50% of trials from videotape, and their scores agreed 100% with those of the researchers. (For all experiments presented herein, agreement was between 98% and 100%).

Group performance was assessed with one-sample t tests (all one-sample t tests in this study are one-tailed because there is no evidence of dogs performing below chance in previous research), comparing subjects’ mean scores on each test to that expected by chance (i.e., one-third correct responses). Performance in both tests was significantly above chance (an alpha level of .05 was used for all statistical tests): standard invisible, $t(7) = 2.66$, $p = .016$, and response was 100% correct in the standard visible test. Figure 2 illustrates the difference in performance on the visible and invisible displacement tests. As predicted, performance was significantly better on the visible than the invisible displacement test, $t(7) = 4.00$, $p = .005$.

The present results therefore successfully replicate Gagnon and Doré’s (1992, 1993, 1994) findings, in spite of the modifications in this study (e.g., the doubling of the distance between hiding boxes,

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[1] The potential here for false negatives was of concern to these authors; however, no dogs failed to make “appropriate contact” with the ball on any trials.

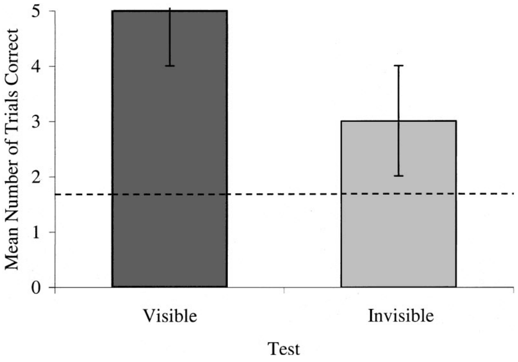

Figure 2. Mean (± *SE*) number of trials correct on standard visible and invisible displacement tests. Dotted line indicates performance expected by chance.

the blindfolding of dog owners, and the use of differently colored hiding boxes). Although visible displacements are easier for dogs, they do also perform significantly above chance on invisible displacements. This would suggest that dogs are capable of secondary representation. However, although no evidence of a systematic learning effect was found in these or previous results, there are potential alternative strategies that cannot yet be ruled out. Learning may be unlikely over only five trials, but this does not preclude the spontaneous formation of simple associative rules. A subject that is highly motivated to find a hidden ball but unequipped to mentally reconstruct its past trajectory must rely on cues in the environment, or else search boxes at random. The current results show that dogs do not search randomly. A second experiment thus examined the performance of dogs under stringent control conditions designed to preclude the use of three simple associative strategies.

Experiment 2: Invisible Displacement and Associative Strategies

Sensitivity to inadvertent experimenter cues is one way in which dogs could solve the invisible displacement task. Several investigators have lamented the unavoidable face-to-face procedure required for displacement tasks (e.g., Gagnon & Doré, 1993; Pepperberg & Kozak, 1986). However, the addition of a curtain to occlude the upper body and face of the experimenter during stimulus manipulations may be a simple means of controlling for inadvertent experimenter cues.

Natale et al. (1986) found that two local rules could lead to above-chance performance in the invisible displacement task without recourse to mental representation by the animal. The first rule, "Go to the box visited last by the experimenter," would equate to, "Go to the box visited last by the displacement device" for dogs, because the experimenter does not touch the boxes directly in the task used with dogs. This rule would consistently lead to success in all trials. The second rule, "Go to a box adjacent to the displacement device," also deserves attention because the position of the displacement device may be a powerful cue. Although Gagnon and Doré (1993) reported that the postdisplacement movement of the displacement device made the invisible displacement task more difficult for dogs than the visible displacement task, the effect of the displacement device's position relative to the target box was not analyzed.

Using a repeated measures design, we tested a new sample of dogs on a standard invisible displacement task (identical to that in Experiment 1) and three additional versions of the task designed to control for each of these alternative means by which dogs may succeed on the standard task. The question is whether dogs' performance is reduced to chance levels when these alternative routes to success are blocked. If subjects continue to perform above chance in all conditions, there is no reason to believe that dogs use these strategies.

Method

Subjects

By means of the same recruitment procedure and selection criteria as in Experiment 1, 10 dogs were volunteered by private owners to participate. Because the rationale behind this experiment was to compare the standard invisible displacement task with three control conditions, a third selection criterion was specified: Dogs had to show at least minimal success (1/5) on the standard invisible test. Two dogs (collie × sheltie and Italian greyhound) were excluded from the final sample because of inadequate attempts to retrieve the ball during the familiarization period. An additional dog (blue cattle dog) was excluded because of a zero success rate in the standard invisible displacement task. Of the 7 dogs remaining, 3 were females and 4 were males, with an age range of 16–120 months ($M = 41$ months). Three of these were from breeds classified as herding dogs (2 border collies and Australian shepherd), 1 was a sporting dog (golden Labrador), 1 came from the terrier breeds (Airedale terrier), and 2 were mixed breeds (Australian cattle dog × kelpie and bull terrier × kelpie).

Apparatus

The apparatus used in this experiment was the same as in Experiment 1. The only addition was an opaque white calico curtain (267 cm × 50 cm) used to occlude the experimenter's head and upper body in the first control condition. The curtain was suspended between the two walls on either side of the stimulus array by a 5.95-m string and two hooks.

Procedure

Dogs were tested individually except for 2 border collie siblings for whom separation was stressful. Each dog was tested separately, but the other remained in the room during testing, restrained by another owner. Each test consisted of five trials, and the success and error criteria were the same as in Experiment 1. The four tests were presented in random order and administered in a single session lasting approximately 25 min.

Standard invisible displacement. The procedure was identical to that described in Experiment 1.

Control 1: Experimenter cues. An opaque curtain suspended between the two walls on either side of the stimuli was used in this control condition. This curtain served to completely occlude the experimenter's face and upper body during the procedure. Because the curtain was only 50 cm high, it allowed the experimenter the same freedom of movement as in all tests, and it had no effect on the dogs' access to the back of the boxes. Dogs did not appear to be disturbed by the presence of the curtain and searched in the same way as they did in the other conditions.

Control 2: Last box rule. Because the experimenter does not touch the boxes directly in the task used with dogs, the procedure to control for this rule differed somewhat from that of Natale et al.'s (1986) false trials. Rather than lifting an irrelevant box, the experimenter moved the displacement device to an irrelevant box. As in the standard condition, after the object was transferred to the target box, the displacement device was brought out and rotated 180° on its vertical axis to show that it was empty. However, instead of returning it to its final location, the experimenter moved the displacement device behind one of the other two boxes and simulated the movement that would normally accompany the transfer of the ball from the displacement device to a box. The experimenter then moved the displacement device back to its final position, whereupon it was again rotated 180° on its vertical axis so that its closed side was facing the subject. Thus, the last box visited by the displacement device was never the target box. A strategy based on the rule, "Go to the last box visited by the displacement device," could not lead to successful retrieval here. The last box visited by the displacement device was varied randomly from trial to trial, with the constraint that it could not be the same box more than twice consecutively.

Control 3: Adjacency rule. Based on the nonlinear trials used by Natale et al. (1986), this control condition meant that, instead of being varied entirely randomly, the final position of the displacement device was randomly determined with the constraint that it never occupied a position adjacent to the target box. A strategy based on the rule, "Go to the box adjacent to the displacement device," could not lead to successful retrieval.

Results and Discussion

Motivation to search was very high: Over all four tests, only 6.4% (9/140) of trials had to be repeated as a result of inattention and 8.6% (12/140) of trials were recorded as no searches. A sign test found no evidence for any learning effects within or across tests by comparing the performance of dogs on the first and fifth trials of each test, as well as on the first and last trial of the four (randomly ordered) conditions overall (this was the case for all of the following experiments in the present study).

Figure 3 shows the mean performance of subjects in the standard invisible displacement task and in the three control conditions. As in Experiment 1, performance was significantly above chance in the standard invisible displacement task, $t(6) = 3.66$, $p = .006$, and also above chance in Control 2: Last box rule, $t(6) = 2.55$, $p = .022$, suggesting that dogs were not using a search strategy based on the last box visited by the displacement device. In contrast, dogs did not pass the task when potential experimenter cues were controlled for in Control 1: Experimenter cues, $t(6) = 1.30$, $p = .121$, or when the displacement device was nonadjacent to the target box after displacements in Control 3: Adjacency rule, $t(6) = -3.12$, $p = .022$. The latter was in fact significantly below chance.

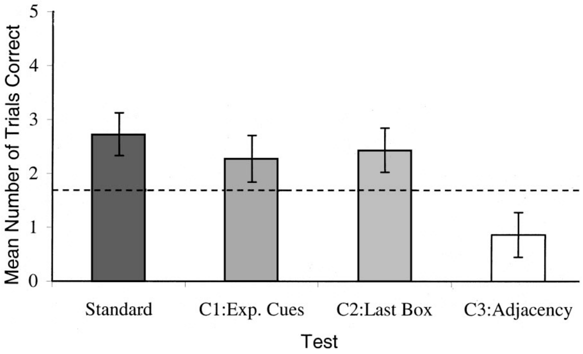

Figure 3. Mean (± *SE*) number of trials correct on standard invisible displacement test (Standard) and three control conditions: Control 1: Experimenter cues (C1:Exp. Cues); Control 2: Last box rule (C2:Last Box); and Control 3: Adjacency Rule (C3:Adjacency). Dotted line indicates performance expected by chance.

A repeated measures analysis of variance (ANOVA) revealed a significant main effect for condition, $F(3, 18) = 6.38$, $p = .004$, and was followed up with three planned comparisons (standard invisible vs. each of the three control conditions). Bonferroni-adjusted paired sample *t* tests (two-tailed) revealed that Control 3: Adjacency rule was the only test in which performance differed significantly, $t(7, 3 \text{ comparisons}) = 4.04$, $p = .007$.[2] When the test design prohibited the displacement device from ending up adjacent to the target box, dogs' performance was significantly degraded compared to that in the standard condition.

Closer inspection of the error responses in Control 3: Adjacency rule indicated that of the incorrect trials in which a search attempt was made ($n = 25$), 92% involved subjects searching first at a box adjacent to the displacement device. In other words, only 8% ($n = 2$) of the errors in this test could not be explained by a strategy based on the rule, "Go to a box adjacent to the displacement device." Although the final position of the displacement device in Control 3: Adjacency rule was randomized, with the constraint that it could never be adjacent to the target box, there had been no a priori reason to apply such a constraint to any of the other invisible displacement tests in Experiments 1 and 2. Apart from the restriction that it could not occupy the same position more than twice consecutively, the final position of the displacement device in all other tests was randomly determined. Consequently, there were some inequities between tasks in terms of adjacent and nonadjacent trials, which may have influenced their outcome.

Although the number of adjacent and nonadjacent trials was approximately equal across all tests in Experiments 1 and 2 (adjacent = 82, nonadjacent = 98), proportions within each test and condition varied quite considerably. In the absence of deliberate manipulations, further study is necessary before conclusions can be drawn about whether this strategy underlies performance in other conditions. However, post hoc analysis of the data from the present study is suggestive of a relationship between the position of the displacement device and search behavior. Across all tests in Experiments 1 and 2, 76.8% (63/82) of adjacent trials were passed, in contrast to only 20.4% (20/98) of nonadjacent trials. Figure 4 displays the proportion of adjacent and nonadjacent trials in each test, as well as the distribution of correct and incorrect searches within each trial type.

The random responding of dogs in Control 1: Experimenter cues may suggest that subtle cues inadvertently displayed by the experimenter guided the search of some subjects in other tests. Alternatively, the curtain may have served to distract dogs from the displacements, despite the fact that we noted no difference in search behavior from the standard condition. However, unequal weightings of adjacent and nonadjacent trials undermine any conclusions regarding performance on Controls 1 and 2. In fact, the percentages of success in Control 1: Experimenter cues for both adjacent (85%, 11/13) and nonadjacent (27%, 6/22) trials were

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[2] Because assumptions regarding the shape of the underlying distributions may be questionable, nonparametric tests (Friedman's test and Wilcoxon's signed-ranks test) were also performed in all experiments and the same pattern of results emerged.

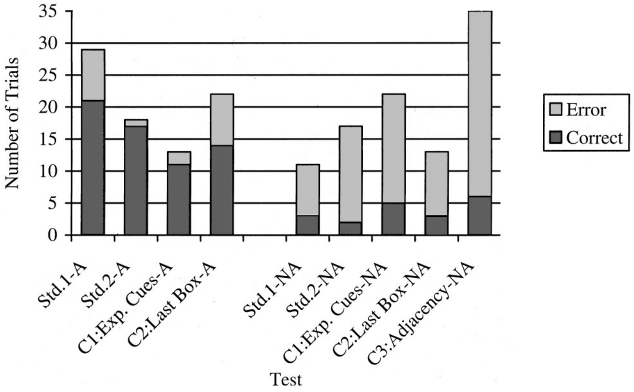

Figure 4. Proportions of adjacent (A) and nonadjacent (NA) trials within the standard (Std.1) test in Experiment 1 and the standard (Std.2) Control 1: Experimenter cues (C1:Exp. Cues); Control 2: Last box rule (C2:Last Box); and Control 3: Adjacency rule (C3:Adjacency) tests in Experiment 2. Stacks depict correct and error responses within each trial type per test.

actually higher than those in Control 2: Last box rule (64%, 14/22 on adjacent; 23%, 3/13 on nonadjacent), suggesting that adjacency proportions may have influenced the pattern of results.

Another experiment was thus designed to extricate the impact of these variables on the performance of dogs on the invisible displacement task. However, an important conclusion can be drawn from the results of Experiment 2: Dogs' performance was affected by changes to the task that ought not to interfere if they were using the representational reasoning the task is supposed to measure.

Experiment 3: Invisible Displacements and Adjacency

In order to ascertain which strategies dogs use to solve the invisible displacement task, we repeated the previous experiment with displacement device adjacency as a factor. Thus, an extra trial was added to each condition so that half the trials in each condition were adjacent and the other half nonadjacent. If the position of the displacement device guides dogs' search, we would expect performance to be significantly better on the adjacent trials than on the nonadjacent trials within and across conditions. If dogs do understand invisible displacements, their performance should not differ between adjacent and nonadjacent trials. To minimize the potentially distractive effect of the curtain in the experimenter cues condition, we suspended the curtain at the same height behind the experimenter in all other conditions. If the curtain itself is a distraction, then performance on the standard test should be negatively affected.

One further control condition was introduced. We were concerned that dogs might have used the simple rule, "Go to the first box visited by the displacement device." This is the reverse of the last box rule we controlled for in Experiment 2. The additional step used to control for the last box strategy would have been irrelevant if subjects were representing the movements of the object. However, if dogs were searching at the first box visited by the displacement device, the additional step would still have been irrelevant, and this strategy would have lead to success. Therefore, the above-chance performance on Control 2: Last box rule could have been an artifact of an alternative practical strategy, "Go to the first box visited by the displacement device." To eliminate this possibility, we designed an additional control condition to complement Control 2: Last box rule.

Method

Subjects

Twelve dogs were recruited from private owners. Two dogs (Pomeranian and Italian greyhound) had to be omitted because of a lack of ball motivation during familiarization. The final sample consisted of 7 females and 3 males with an age range of 22–96 months ($M = 57.3$ months). Two were mixed breeds (Australian cattle dog × collie and Australian cattle dog × kelpie), 3 were herding dogs (border collie, kelpie, and German shepherd), 2 were nonsporting breeds (cocker spaniel and Jack Russell), 1 was a terrier breed (Staffordshire bull terrier), and 2 were sporting dogs (Dalmatian and golden retriever).

Apparatus

The set-up was the same as in Experiment 2 except for two additional hooks to suspend the opaque curtain just behind the experimenter, and three blue boxes in place of the red, yellow, and blue boxes used in Experiment 2. Testing took place in a bare, well-lit room measuring 5.0 m wide × 3.0 m long × 5.5 m high.

Procedure

The opaque curtain was suspended in front of the experimenter in Control 1: Experimenter cues and behind the experimenter in the other three tests. The procedure for the standard invisible displacement task, Control 1: Experimenter cues and Control 2: Last box rule was identical to that in Experiment 2, except for the introduction of one extra trial per condition. Each condition comprised three adjacent and three nonadjacent trials presented in random order. In Controls 2 and 3, the adjacency of the first or last box to the displacement device was also randomly divided equally into adjacent and nonadjacent trials. Control 3: First box rule replaced the discrete adjacency rule control of Experiment 2. The procedure for this novel control was as follows:

Control 3: First Box Rule

In this test, an additional step was included in the displacement procedure. The experimenter simulated the transferal of the object to a box, then brought the displacement device out and rotated it 180° on its vertical axis to reveal that it still contained the object. The experimenter then moved the displacement device behind the target box and deposited the object there. The visibly empty displacement device was returned to its final position, whereupon it was rotated 180° on its vertical axis so that its closed side was facing the subject once more. Thus, the first box visited by the displacement device was never the target box. A strategy based on the rule, "Go to the first box visited by the displacement device," which would have been successful in every other test, could not lead to successful retrieval here. The first box visited by the displacement device was varied randomly from trial to trial, with the constraint that it could not be the same box more than twice consecutively.

The order of the four tests was again randomly determined across subjects. Sessions lasted approximately 25 min.

Results and Discussion

Motivation to search was very high: Over all four tests, 7.9% (19/240) of trials had to be repeated as a result of inattention and 10% (24/240) were recorded as no searches.

Figure 5 presents the mean performance of subjects in the standard invisible displacement task and in the three control tests. Performance was significantly above chance in all conditions, $t(9) > 2.25$, $p < .05$, except Control 2: Last box rule, $t(9) = .429$, $p = .339$. These results are contrary to those found in Experiment 2, in which Control 1: Experimenter cues was at chance and Control 2: Last box rule was above chance. This substantiates the suspicion that in Experiment 2 the pattern of results was dependent on adjacency proportions. A repeated measures 4 × 2 ANOVA with condition and adjacency as factors revealed a significant main effect of adjacency only, $F(1, 9) = 57.24$, $p = .001$. Bonferroni-adjusted paired sample *t* tests for four planned comparisons (adjacent vs. nonadjacent for each test) revealed that performance on adjacent trials was significantly better than on nonadjacent trials in standard invisible displacement, $t(9) = 5.24$, $p = .001$; Control 1, $t(9) = 3.35$, $p = .008$; and Control 2, $t(9) = 3.67$, $p = .005$, and approaching a significant difference in Control 3, $t(9) = 2.90$, $p = .018$. Figure 6 presents the stark difference in performance levels on adjacent and nonadjacent displacement trials across all four conditions.

Performance on the standard task in this experiment was comparable to that of Experiments 1 and 2, suggesting that the presence of the curtain throughout Experiment 3 and the use of differently colored hiding boxes in the first two experiments did not affect dogs' performance. In this experiment, performance was not reduced by controlling for experimenter cues, showing that subtle cues from the experimenter's face or upper body were not responsible for dogs passing the task. The above-chance performance in Control 3: First box rule demonstrates that dogs do not use a strategy based on the first box visited by the displacement device, and also indicates that the additional step involved in Controls 2 and 3 is not sufficient in itself to deteriorate the performance of subjects. Although the last box visited by the displacement device may have had some impact on dogs' performance, in Control 2 dogs only visited this box on one third of trials (20/60), and of these searches, 75% (15/20) could be attributed to an adjacency strategy. Moreover, in Control 2, as in all conditions, dogs passed the adjacent displacements, $t(9) > 2.09$, $p < .05$, but failed the nonadjacent displacements, $t(9) < -1.41$, $p > .05$. Indeed, dogs searched at a box adjacent to the displacement device in 74.5% (161/216) of searches made across all four conditions. The current experiment offers strong evidence to suggest that dogs base their search behavior on a simple adjacency rule rather than on mentally reconstructing the past trajectory of the object. In other words, their performance does not indicate that they understand invisible displacements.

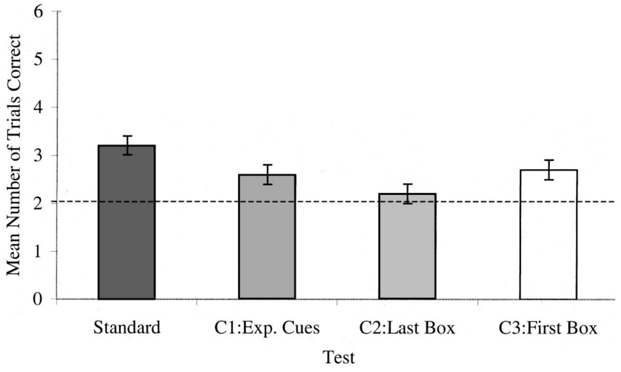

Figure 5. Mean (± *SE*) number of trials correct on standard invisible displacement test and three control conditions: Control 1: Experimenter cues (C1:Exp. Cues); Control 2: Last box rule (C2:Last Box); and Control 3: First Box Rule (C3:First Box). Dotted line indicates performance expected by chance.

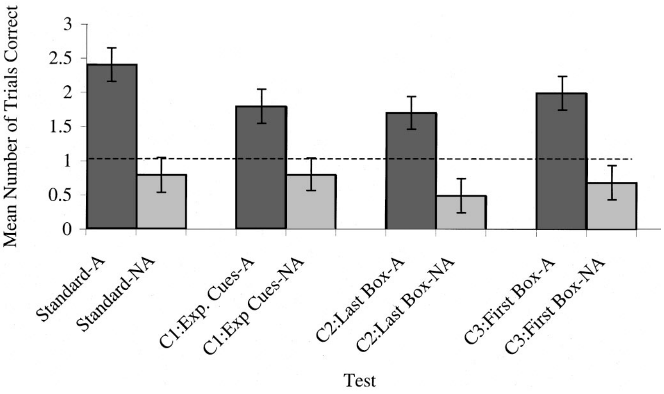

Figure 6. Mean (± *SE*) number of trials correct on adjacent (A) and nonadjacent (NA) components of standard invisible displacement test and three control conditions: Control 1: Experimenter cues (C1:Exp. Cues); Control 2: Last box rule (C2:Last Box); and Control 3: First box rule (C3:First Box). Dotted line indicates performance expected by chance.

However, how do we reconcile the present results with the fact that in some previous studies (Gagnon & Doré, 1992, Experiment 2; 1993, Experiments 1 and 2) the displacement device was only ever placed at either end of a semicircular array of four hiding boxes and yet dogs still passed? It may be that the 20-cm gap, as considered earlier, was too small for the test to be valid. It is also possible that dogs were utilizing other strategies that were not directly controlled for. Gagnon and Doré (1992, 1993, 1994) did not provide data on any performance differences between trials in which the displacement device was adjacent or nonadjacent to the target box. However, a small preference for boxes adjacent to the displacement device was noted (S. Gagnon, personal communication, December 4, 2003).

Nevertheless, there is a possibility that dogs only utilized an adjacent strategy in the current experiment because it offered some success; indeed, dogs would have been reinforced 50% of the time for using this strategy. However, dogs performed comparably in Experiments 1 and 2 when the position of the displacement device was determined entirely randomly. In fact, as a result of chance allocations, in Experiment 2 there were actually more nonadjacent trials than adjacent trials, and yet dogs visited a box adjacent to the displacement device on 74.3% (104/140) of trials, a proportion that is nearly identical to that of the current experiment (74.5%, 161/216). Thus it appears that, in our study at least, dogs approached the task with a bias for searching boxes next to the displacement device, regardless of adjacent and nonadjacent trial proportions.

Recently, Call (2001) reported that 19–26-month-old children, chimpanzees, and orangutans are biased toward a simple strategy of searching adjacent hiding boxes successively on standard double invisible displacement tasks. The data he presented suggest that this is due to a response bias or inhibition problem, rather than a memory deficit. Given that 26-month-old children can display such biases on more complex displacements, perhaps dogs do understand invisible displacements but fail trials in which the target box is not next to the displacement device because of a difficulty in inhibiting search in the immediate vicinity of the displacement device. Moreover, Natale et al. (1986) noted that the gorilla in their study had to be "pushed" into using a representational strategy because in the first task administered, it may have been easier for the gorilla to use a simple strategy based on association. Therefore, we devised Experiment 4 to see whether we might be able to "push" dogs into using a representational strategy.

Experiment 4: Removing the Displacement Device

It is possible that the presence of the displacement device in the searchable stimulus array creates a response inhibition problem for dogs. As the last place associated with the object's disappearance, the displacement device would seem to be a powerful search cue. Are dogs unable to refrain from moving toward the displacement device and searching in its vicinity, despite knowing where the object must be? Experiment 4 attempted to reduce this potential response bias and eliminate the opportunity to simply search a box next to the displacement device by removing it from the stimulus array before dogs were released to search for the object.

Method

Subjects

Ten dogs were recruited, consisting of 6 females and 4 males. Ages ranged from 22 to 132 months ($M = 56.6$ months). Six of the dogs were mixed breeds (Australian cattle dog × kelpie, collie × Australian cattle dog, Staffordshire bull terrier cross, beagle cross, Australian cattle dog cross, and miniature fox terrier × Jack Russell), 3 were nonsporting breeds (Jack Russell, schnauzer, miniature poodle), and 1 was a herding dog breed (German shepherd).

Apparatus

The apparatus was the same as in the standard invisible displacement task in Experiment 3, including the curtain suspended behind the experimenter. In addition, a hook to hold the displacement device was placed on the wall 1.5 m directly behind the experimenter. The hook was fixed sideways so as to suspend the displacement device vertically upside down by the pole (0.5 m above the ground), out of sight behind the curtain.

Procedure

In this experiment, a standard invisible displacement test always followed the no displacement device test. The standard test was implemented primarily to ensure that the sample was comparable to that of Experiment 3, and was placed second to avoid promoting search strategies involving the displacement device. In both conditions subjects were presented with three adjacent and three nonadjacent trials randomly combined. The same familiarization period as in all previous experiments preceded the tests, and the same criteria for successful retrieval was adhered to.

No Displacement Device

The procedure followed that of the standard test described in Experiment 3, until the point at which the displacement device is shown to be empty. The displacement device was moved to a final position mark and turned on its vertical axis so that its closed side faced the subject once more, but instead of placing the device down, the experimenter stepped back to the wall (ducking under the suspended curtain) and clasped the displacement device upside down against the wall in the hook. The experimenter stepped back to her position and gave the predetermined command (e.g., "where's the ball?"), signaling the owner to release the dog to search. The period between rotating the displacement device and the subject's release lasted no longer than 3 s. A 3-s delay after completion of the displacement was imposed on the standard test to balance out this factor. This experiment lasted 10 min on average for each subject.

Results and Discussion

In the standard test, only 10% (6/60) of trials involved dogs failing to search any of the boxes. In contrast, 43.3% (26/60) of no displacement device trials resulted in no searches. The majority of these trials involved dogs standing in front of the experimenter or going under the curtain to the wall and directing their attention to the displacement device hung up out of reach.

Figure 7 presents the results of the no displacement device and standard invisible displacement tests. The sample was found to be comparable to that of Experiment 3, with the group performing significantly above chance on the standard test, $t(9) = 2.54$, $p = .016$. However, performance in the no displacement device condition was at chance, $t(9) = -1.63$, $p = .069$.

Figure 8 presents the number of trials correct on each test as a function of adjacency. A repeated measures 2 × 2 ANOVA with condition and adjacency as factors revealed a significant main effect of condition, $F(1, 9) = 8.78$, $p = .016$, and of adjacency, $F(1, 9) = 11.39$, $p = .008$, but no significant Condition × Adjacency interaction. Bonferroni-adjusted paired sample t tests revealed that performance on the adjacent and nonadjacent components was significantly different for the standard test, $t(9) = 2.69$, $p = .025$, but failed to reach significance for the no displacement device test, $t(9) = 2.45$, $p = .037$. In the standard test, the adjacent component was significantly above chance, $t(9) = 3.34$, $p = .005$, whereas the nonadjacent component was at chance, $t(9) = -0.69$, $p = .255$. The complimentary pattern was found in the no displacement device condition: Performance on the adjacent trials was at chance, $t(9) = 0.001$, $p = .50$, and significantly below chance on the nonadjacent trials, $t(9) = -6.00$, $p = .001$.

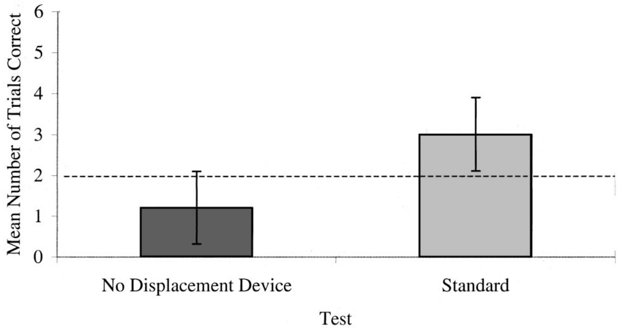

Figure 7. Mean (± *SE*) number of trials correct on no displacement device and standard invisible displacement tests. Dotted line indicates performance expected by chance.

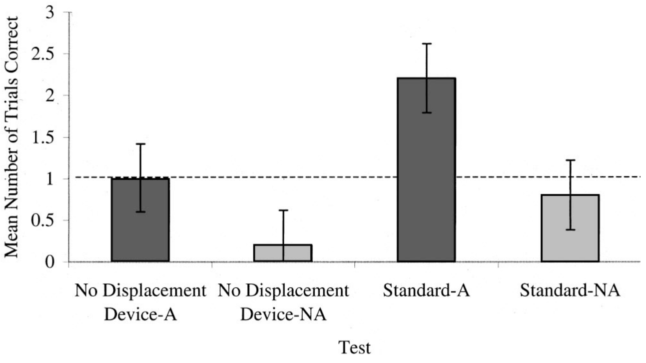

Figure 8. Mean (± *SE*) number of trials correct on adjacent (A) and nonadjacent (NA) components of no displacement device test and standard invisible displacement test. Dotted line indicates performance expected by chance.

Removing the displacement device did not "push" dogs into using a representational strategy; in fact, their performance was diminished. These results suggest that dogs rely heavily on the displacement device to guide their search for a hidden object. The relatively high number of inappropriate searches in this experiment would seem to indicate the difficulty subjects experienced when the displacement device was removed from the stimulus array.

Taken together, the results of these four experiments certainly provide strong evidence to suggest that dogs do not solve the invisible displacement task in the same way 2-year-old children do. Simple stimulus associations would seem to account for dogs' successful performance on the task. However, a possibility remains that the task used with dogs is not equivalent to the one Piaget (1937/1954) designed to measure representational capacities in children. For dogs, the task is presented in locomotor, as opposed to manipulative, space so that they must physically walk to the boxes and search rather than simply point at a box, and therefore a greater delay is imposed between the end of a displacement and search. The displacements are also presented via manipulandums rather than directly by the experimenter's hand as for children, which could arguably render the task used with dogs more distracting or complex. Consequently, to conclude that dogs approach the task differently than children, we needed to assess the performance of children on the paradigm used with dogs.

Experiment 5: Task Validity

The classic invisible displacement task designed for infants was substantially modified to suit the perceptual and motor characteristics of dogs. However, previous studies have not tested children on the task used with dogs to ensure that it is a valid human analogue task. The current experiment was conducted to answer two questions: Can human children pass the test used with dogs at the age typical for first competence on invisible displacement tasks, and do children use the adjacency rule to solve this task like dogs do?

Pilot trials quickly demonstrated the impracticality of administering 24 search trials to 18–24-month-old children. Unlike dogs, their attention span on such tasks is extremely short. Thus, only the standard invisible displacement task was administered, consisting of six trials, half of which were adjacent and half nonadjacent. If 18–24-month-old children perform above chance and show no difference in performance on adjacent and nonadjacent trials, we could conclude that the modifications to the classic task are not responsible for the failure of dogs on nonadjacent trials, and that dogs must approach the task differently than children. At 18 months of age, invisible displacement understanding may vary considerably, thus it was of interest to examine whether children rely on the position of the displacement device to guide their search before they are able to mentally represent the displacement device's past trajectory.

Method

Subjects

Twenty-six naive children aged 18 months and 24 months were volunteered by their parents to participate in this study. Five participants had to be excluded from the original sample as a result of timidity or noncompliance. Of the final sample of 21, 9 were 18 months and 12 were 24 months ($n = 12$), comprising 8 female and 13 male participants.

Apparatus

The apparatus used was the same as for the standard invisible displacement task in Experiment 3. The only exceptions were a "smiley face" on the ball, and bright colored stickers as rewards. Parents were not blindfolded during testing, and a curtain was not suspended behind the experimenter, because children were too easily distracted by these additions in pilot trials.

Procedure

The exact same procedure used in the standard task with dogs was administered to children. Each participant received six trials consisting of three adjacent trials and three nonadjacent trials randomly combined. Parents gently restrained children by the shoulder until they were allowed to search. Retrieval was scored as successful if participants pointed at the ball inside the correct box, touched the ball, or picked it up. Successful retrieval was reinforced with verbal praise, play with the ball, and a sticker. Sessions lasted approximately 10 min.

Results and Discussion

Overall, 17.5% (22/126) of trials had to be repeated as a result of inattention, and subjects made no search on 5.6% (7/126) of trials.

As a group, children performed significantly above chance on the standard invisible displacement task, $t(20) = 4.59$, $p = .001$, as shown in Figure 9. A 2 × 2 ANOVA with age and adjacency as factors indicated a significant effect of age only, $F(1, 19) = 11.20$, $p = .003$, with 24-month-olds performing better than 18-month-olds. Analyzed separately, 18-month-old children performed at chance on the standard task, $t(8) = 1.17$, $p = .138$, but showed no significant difference in performance on adjacent and nonadjacent displacements, $t(8) = 1.05$, $p = .325$. The absence of a disparity between adjacent and nonadjacent trials in children suggests that the test is a valid human analogue task for dogs. Unlike dogs, children did not fail the task when the target box was not adjacent to the displacement device. Twenty-four-month-old children are able to solve the invisible displacement task without recourse to an adjacency strategy. Furthermore, immediately prior to achieving

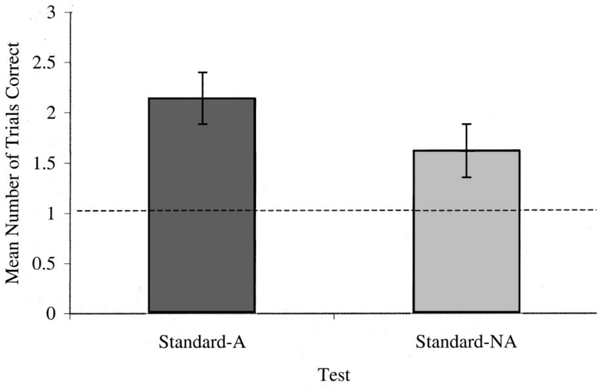

Figure 9. Mean (± *SE*) number of trials correct by 18- and 24-month-old children on standard invisible displacement test as a function of adjacent (A) and nonadjacent (NA) trials. Dotted line indicates performance expected by chance.

invisible displacement understanding, children do not seem to utilize a strategy based on the position of the displacement device to solve the task.

General Discussion

The present series of experiments offers strong evidence to suggest that dogs base their search behavior on a simple adjacency rule rather than on mentally reconstructing the past trajectory of an object in the invisible displacement task. Dogs performed above chance on the standard invisible displacement task (Experiments 1, 2, 3, and 4) and on tasks controlling for experimenter cues and for the local rule, "Go to the first box visited by the displacement device" (Experiment 3). However, despite displaying strong motivation for the ball throughout all tests, dogs failed the task if the displacement device was not adjacent to the target box after displacements (Experiments 2, 3, and 4). They also performed at chance when the object did not reside in the last box visited by the displacement device (Experiment 3). When the salience of the adjacency cue was dramatically reduced by the removal of the displacement device, dogs performed at chance (Experiment 4). There was hence no evidence to suggest that dogs represent the hidden movement of the object. Unlike children (Experiment 5), dogs' performance depended on the adjacency of the displacement device to the target box.

Searching at a box adjacent to the displacement device and at the last box visited are both strategies that a macaque, but not a gorilla, used to solve invisible displacements (Natale et al., 1986). Watson et al. (2001) found that on a task in which an object was hidden sequentially at three boxes, the majority of dogs began their search at the last box visited by the experimenter. However, the position of the displacement device undoubtedly exerted the greatest influence on dogs' search in the present study, as shown by the failure of dogs on nonadjacent trials in which the last box rule would have been successful. This concurs with the results of Doré et al. (1996), who found that in transposition tasks, dogs and cats searched at the screen nearest to the object's initial location. Similarly, on invisible displacement tasks, cats have demonstrated persistent search attempts at the screen nearest the displacement device (Doré, 1986, 1990). Doré and Goulet (1998) suggested that dogs rely on the external cue of the displacement device to guide their search because it is associated with the object at the time of its disappearance. However, the adjacency strategy may not be able to account for all of the previous findings with dogs because, as mentioned earlier, the displacement device was sometimes placed only at the ends of the hiding box array (Gagnon & Doré, 1992, 1993). In the current study at least, each sample of naive dogs tested approached the task with a bias for searching boxes adjacent to the displacement device. This tendency was equally strong whether the position of the displacement device was determined entirely randomly or with the constraint that on half of the trials it was adjacent, and on the other half nonadjacent to the target box. Dogs' failure when the target box was not the last box visited by the displacement device suggests that there may be a variety of more or less successful strategies that dogs spontaneously use, depending on regularities in the task stimuli.

The present results are in line with the reliance of children and apes on searching adjacent boxes (predominantly from left to right) when allowed two choices in double invisible displacement tasks (Call, 2001). Call (2001) rejected a memory-deficit hypothesis as an explanation for the difficulty of children and apes on double nonadjacent displacement problems (i.e., the displacement device visits two nonadjacent boxes) because their search patterns indicated that a response bias and inhibition problem could better account for the data. Call suggested that the subjects' representations of inferred movements may not be robust enough to override a sequential search bias. However, it should be noted that the displacements themselves were always conducted in a left-to-right sequential fashion in Call's study, therefore the response bias may have been a procedural artifact. Chimpanzees, orangutans, and children should therefore be tested on nonadjacent invisible displacements using a procedure like that of the current study to ascertain whether this response bias/inhibition problem is replicated, and indeed, whether they are able to pass under the additional control conditions of the current study. Results of such a study recently conducted in our laboratory suggest that, in contrast to dogs, chimpanzees do not seem to use simple search strategies to solve the invisible displacement task (Collier-Baker, Davis, Nielsen, & Suddendorf, 2003).

Call (2001) recommended that future studies modify the classic task used with children and apes to minimize the search bias he found. He suggested that the hiding screens be presented in a semicircle rather than in a line, and in locomotive, as opposed to manipulative, space to make search at irrelevant boxes more effortful. The task adapted for dogs uses precisely this procedure, and children, but not dogs, were capable of representing and inferring the location of hidden objects without recourse to a strategy based on the position of the displacement device on this version of the task. This would seem to confirm that the human analogue task used with dogs is a valid measure of invisible displacement understanding. However, there are two important points for consideration here. First, because of the limited attention span of 18- and 24-month-old children on the task, in Experiment 5 we only examined the use of an adjacency strategy in children. Surprisingly few studies have investigated whether children might use simple associative strategies to solve the invisible displacement task. However, Corrigan (1981) found that simple variations in testing procedures affected the ability of children to find an invisibly displaced object. Consequently, although children did not depend on the position of the displacement device to guide their search in the current study, the possibility remains that adjustments to the paradigm may yet reveal the use of such “lower level” strategies in children. A between-groups study to thoroughly test the performance of 18–24-month-old (and younger) children on all of the control conditions administered to dogs in the present series of experiments would be desirable.

Second, it could be argued that dogs suffer a response bias or inhibition problem on single invisible displacements, much like children and apes do on standard double invisible displacements. Perhaps dogs are unable to inhibit beginning their search around the last place they saw the object, despite the nonlinear arrangement of the boxes and the presentation of displacements in locomotive space. In fact, dogs have demonstrated an ability to use a physical marker (e.g., a sponge) placed in front of one of two hiding boxes by an experimenter as a cue to the location of hidden food (Agnetta et al., 2000; Hare et al., 2002). It is possible, therefore, that dogs interpret the displacement device used in the invisible displacement task in such a way, and persist in using this “cue” despite a lack of consistent reinforcement. However, it should be noted that the displacement device is a more ambiguous marker than the physical marker used in social cognition tasks; for example, the displacement device can be placed in between two boxes.

Dogs also failed nonadjacent trials in Experiment 4, in which the displacement device was not even part of the stimulus array when dogs were released to search. This would seem to suggest that they do indeed rely on the “cue” provided by the displacement device to guide their search and are unable to mentally represent the invisible displacement of the object. However, one could argue that the 3-s delay imposed after displacements in the standard condition of Experiment 4 was not sufficient to balance out the effects of removing the displacement device in the no displacement device condition. If dogs were completely distracted by the experimenter ducking under the curtain and clipping the displacement device onto the back wall, then the significant number of errors observed in this condition may be a result of them forgetting about the displacement entirely. However, it is striking that on almost half of the trials in the no displacement device condition, dogs did not search the hiding boxes at all. Considering the strong motivation dogs displayed for the ball and the fact that they can withstand delays of up to 20 s before they are allowed to search on standard invisible displacements (Gagnon & Doré, 1993), it is rather surprising that dogs would walk past the hiding boxes and simply stand in front of the experimenter or the displacement device hung upside down on the wall if they were capable of representing the object’s past trajectory. Nevertheless, further study may be necessary to interpret dogs’ performance on this task. A better standard task might involve the experimenter simulating the exact same movements displayed in the no displacement device task, but without actually moving the displacement device.

In the present series of experiments, we failed to find any evidence for dogs using secondary representation to solve the invisible displacement task. Strong sensitivity to human communicative cues, which has been selected for in the process of domestication (e.g., Hare et al., 2002), could potentially explain why dogs have persistently passed the standard task whereas other animals such as cats (e.g., Doré, 1986) and dolphins (Doré et al., 1991)—and of course children before around 2 years of age—have not. Being more motivated to interact with humans on such a retrieval task, dogs may be better able to exploit cues that lead to a moderate level of success. Although we cannot prove the absence of secondary representation, the data we have suggest that dogs rely on empirical strategy rather than on representation of an object’s past trajectory to solve the invisible displacement task. Secondary representation may be unique to the great apes, and of homologous origin in these species (Suddendorf & Whiten, 2001). Apart from great apes, the only remaining vertebrate species to have consistently passed the invisible displacement task are psittacine birds (e.g., Pepperberg & Funk, 1990). Given the present results, it would seem prudent to reexamine psittacine birds under the stringent control conditions administered in this study.

The current experiments have major implications for the use of the Piagetian framework in comparative research. Species attributed with equivalent cognitive capacities may use very different approaches to solving the same problem. Without the implementation of highly stringent controls, the supposedly complex invisible displacement task did not pose much of a problem for dogs. Furthermore, no learning effects were evident, which suggests that dogs formed associations spontaneously. The implementation of discrete control tasks is therefore recommended. At the same time, however, the ecological validity of the invisible displacement task as a comparative measure of representational capacities may require more attention. In what real-life contexts would particular species benefit from deducing invisible displacements? One simple means of ensuring that human analogue tasks used in comparative research have not acquired any special difficulties is to reverse the transfer. However, future studies may attempt to design new species-specific ways of presenting invisible displacements.

Nevertheless, the Piagetian framework remains one of the only theoretical systems to allow interspecific comparisons between levels and rates of development across cognitive domains (e.g., Doré & Dumas, 1987; Parker, 1990; Pepperberg, 2002). By making comparative tasks sensitive to strategies based on associative generalization, we increase our chances of identifying underlying cognitive mechanisms and broadening the comparative evolutionary picture. In conclusion, the present study has clarified some of the conflicting information in the literature about the capabilities of the domestic dog. Dogs were unable to solve the invisible displacement task when the device used to displace the object was not adjacent to the target box. This study highlights the potential for behavior based on empirical strategies to mimic that resulting from representational capacities.

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