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What Do Dogs know about Hidden Objects?

Holly C. Miller, Rebecca Rayburn-Reeves, and Thomas R. Zentall

University of Kentucky

Abstract

Previous research has found that dogs will search accurately for an invisibly displaced object when the task is simplified and contextual ambiguity is eliminated (Doré et. al., 1996; Miller et. al., 2008). For example, when an object is placed inside of one of two identical occluders attached to either end of a rotating beam and that beam is rotated 90°, dogs search inside of the appropriate occluder. The current research confirmed this finding and tested the possibility that the dogs were using a perceptual/conditioning mechanism (i.e., their gaze was drawn to the occluder as the object was placed inside and they continued looking at it as it rotated). The test was done by introducing a delay between the displacement of the object and the initiation of the dogs' search. In Experiment 1, during the delay, a barrier was placed between the dog and the apparatus. In Experiment 2, the lights were turned off during the delay. The search accuracy for some dogs was strongly affected by the delay, however, search accuracy for other dogs was not affected. These results suggest that although a perceptual/conditioning mechanism may be involved for some dogs, it cannot account for the performance of others. It is likely that these other dogs showed true object permanence.

Keywords

object permanence; visible displacement; invisible displacement; delay; dogs

According to Piaget (1954) infants do not see the external world as stable. The world they perceive is thought to be a disorganized jumble of successive pictures that appear and disappear. In this world, objects cease to exist as soon as they are no longer present. In this view, infants do not search actively for hidden objects because once the object is hidden it no longer exists. It is not until the cognitive concept that Piaget called *object permanence* develops that infants understand that objects exist even when they cannot be directly perceived. Piaget found that over the course of the first two years of life, infants develop the ability to find a toy that has been hidden in one of several identical hiding places (visible displacement). But initially this ability is fragile; after finding the object on successive trials at the same hiding place, an infant will continue to search for the object at that place despite the fact that it was observed being displaced at a different location. Piaget called this the A not B error. Later in development, Piaget found that infants can search accurately for an object that is successively hidden first in one place and then in another (successive visible displacement). Piaget found that at about 2 years of age, most children demonstrate a sophisticated knowledge of objects. At this age they are able to find an object that was last hidden in a hand or in a container (a displacement device)

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Send Correspondence to: Thomas R. Zentall, Department of Psychology, University of Kentucky, Lexington, KY 40506-0044, Phone: 859-257-4076, Fax: 859-323-1979, Email: E-mail: zentall@uky.edu.

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and then invisibly placed under a cover or behind one of several screens (standard invisible displacement). According to Piaget, children search accurately for the object behind the appropriate screen because they are able to mentally reconstruct the invisible displacement by representing the movements of the object that is absent from the perceptual field.

Because of the straightforward and adaptable nature of object permanence tests, Piagetian object permanence tests have been used not only to study human development but also to study the abilities of other species. Non-human animals can be tested with visible and invisible displacements and comparisons can be drawn between humans and other animals. If animals show search behaviors similar to young children, it implies either that simple mechanisms control successful searching for displaced objects, or that animals have a similar ability to conceive of objects as independent entities that exist in spite of their invisible movement.

Research with dogs has found that they are able to search accurately for visibly displaced objects (Fiset, Beaulieu, and Landry, 2003; Gagnon and Doré, 1992, 1993, 1994; Triana and Pasnak 1981), they do not commit the A-not-B error, and they search successfully on successive visible displacements (Gagnon and Dore, 1992). Furthermore, they are able to retain the memory of a visibly displaced object for some time. Gagnon and Dore (1993) found that when dogs observed an object being hidden behind one of four screens and they were required to wait up to 23 s, they were able to retrieve the target object 87% of the time. Fiset et al. (2003) found that dogs searched at levels above chance for an object hidden in one of four boxes even when their view of the locations was obscured by an opaque barrier and the delay duration was as long as 4 min.

There is also some evidence suggesting that dogs can search accurately on standard invisible displacements (Gagnon and Dore, 1992). However, these findings have been challenged by researchers who found that the search behavior of domestic dogs in invisible displacements is guided by other visual cues that are present (Collier-Baker, Davis, and Suddendorf, 2004; Fiset and LeBlanc, 2007). In both studies researchers found that when the dogs searched for a target object hidden behind one of several screens, they were likely biased both by the final position of the experimenter and by the final location of the displacement device because when those cues were eliminated, the dogs did not search accurately for the invisibly displaced objects.

Some have argued that dogs fail to search accurately for invisibly displaced objects because they do not have the necessary capacity for deductive reasoning (Watson, Gergely, Csanyi, Topal, Gacsi, and Sarkozi, 2001). A dog will watch an experimenter place an object into a displacement device, and it will watch the displacement device as it moves successively (clockwise or counterclockwise) behind three separate screens. When the displacement device is then revealed to be empty, not knowing that the experimenter has placed the toy in his pocket, the dog will then look behind each screen. However, Watson et al. (2001) reported that the dogs did not increase the speed of their search when they failed to find the object behind the first two screens. The authors reasoned that if the dogs were able to use the information acquired from their failure to find the object behind the first two screens, they should have searched faster as they moved from the second to the third screen. However, the dog's apparent failure to use the information provided by investigating the first two screens may result from the complexity of the task. When there are only two containers and one is lifted by a string and shown to be empty and then set back down, dogs have been found to search in the other container (Erdohegyi, Topál, Virányi, and Miklósi, 2007).

Under other conditions, dogs do appear to search accurately for invisibly displaced objects. Doré, Fiset, Goulet, Dumas, and Gagnon (1996) found that dogs can search accurately for an object if it is visibly moved behind one of several visually unique screens and then the screen is visibly displaced (invisible transposition). As in the Piagetian standard invisible

displacement test, the object is invisibly moved from one location to another. Dogs search successfully on invisible transpositions but this ability appears to depend on whether another screen replaces the screen behind which the object was placed. That is, if the original position of the target screen is empty, the dogs search behind the appropriate screen. But if a different screen replaces the appropriate screen, the dogs often search in the original location.

Similar results were found when dogs were tested with a rotation problem (Fiset, 2007; Miller, Gipson, Vaughan, Rayburn-Reeves, and Zentall, 2008). In this test an object is hidden in one of two containers at either end of a beam and then the beam itself is rotated. The container remains within the dogs view, but the object hidden inside of the container is invisibly displaced to a new location. Fiset (2007) found that when the beam was rotated 180°, the dogs tended to search in the original location. Children (30 months) and great apes perform similarly when a platform is rotated 180° and the target object is initially placed in the left or right container (Barth & Call, 2006). However, their poor performance is likely due to the presence of conflicting contextual cues. When the beam is rotated 180°, an empty container appears where the target container originally was. When these conflicting cues are eliminated (by rotating the apparatus only 90°), the dogs search accurately for the invisibly displaced object (Miller et al., 2009). They also search accurately when they are led around the apparatus either 90° or 180°. That is, dogs search accurately when the interfering contextual cues are reduced by rotating the apparatus only 90° or by changing the dogs' perspective. Thus, when invisible displacement tests are simplified (as in the 90° rotation) and there is direct perceptual evidence that the target object could not be hidden at its initial position, dogs search accurately for an invisibly displaced object. It is possible, however, that under these conditions the mechanism responsible for search accuracy is perceptual or conditioned rather than cognitive. If the dog actively attends to the target object (because it is highly motivated to obtain it) it may continue looking at the container into which the object disappeared (possibly because it has become a conditioned stimulus). When that container is then moved, the dog may follow its movement because it is looking at that container. When released, the dog will then search the container at which it is looking and reinforcement would be obtained for doing so.

Anecdotal evidence suggests that this perceptual/conditioning explanation is not sufficient to explain the results (Miller et. al., 2008). For example, in a rotation test, dogs do not generally appear to track the target container by orienting towards it. Furthermore, they almost always direct their gaze towards the experimenter after the rotation and before they are released. If search accuracy was controlled by such a perceptual/conditioning mechanism, one would expect that looking at the experimenter would disrupt choice accuracy. However, a stronger argument against a perceptual account would be obtained if accurate searching could be found when the dog was prevented from searching for the object immediately after the rotation of the containers.

Experiment 1 was designed to reduce the likelihood that the mechanism responsible for accurate search by dogs in the 90° rotation test is perceptual/conditioning by interpolating a delay of 0, 5, 10, and 15 s between the rotation of the apparatus and the release of the dog. An opaque barrier was placed in between the dog and the apparatus during the delay. After the delay, the barrier was removed and the dog was allowed to search for the object in either of the containers. If dogs can remember where the object is, they should search accurately even after a short delay.

Experiment 1

Method

Subjects—Six dogs were recruited (*Canis familiaris*) from private owners, 1 male and 5 females, ranging from 1 to 11 yrs in age, ($M = 5$ yr). All dog owners were given a short

questionnaire. Owners confirmed that their dogs matched several selection criteria: they were motivated by the opportunity to interact with the experimenters, they were motivated by food reinforcers, and they were comfortable being handled when food reinforcers were nearby (dogs were excluded if they had a history of aggressively guarding food resources). Finally, the owners had to be willing to prevent access to food for 4 hr prior to participating. Of the dogs that participated in the experiment, all 6 came from breeds classified by the American Kennel Club as herding dogs (3 Australian shepherds, 2 border collies and a Belgian sheepdog). All of the dogs had been trained to sit and to walk next to their owners on command. All dogs had participated in previous experiments where they searched for hidden objects.

Apparatus—A wooden beam (1.83 m long $\times$ 14.0 cm wide $\times$ 3.8 cm thick) was attached to a wooden base by a small post (7.6 cm long) at its center. The post rested inside a hole that was slightly larger in diameter and 2 cm deeper than the post itself so the beam could easily rotate around this post. A 1.83 m length of transparent fishing line (5.5 kg test, 0.30 mm diameter) was attached to each end of the beam to allow the beam to be rotated from a distance. Two identical opaque occluders (containers 25.4 cm wide $\times$ 30 cm high $\times$ 20 cm deep) were attached to the beam, one on each end. Within each occluder was a plastic container (20 cm wide $\times$ 10 cm high $\times$ 14 cm deep) that contained approximately 100 g of dog treats. This container served as a false bottom and was covered tightly with a perforated plastic lid that allowed the odor of the treats to escape but prevented access to the treats. The treats were the same as those that were used to bait the occluders and were replenished before each dog was tested. The treats (Pet Botanics semi-moist Chicken & Brown Rice dinner dog food) were cut into 2 g portions. Each occluder also contained a plastic bowl (15 cm diameter $\times$ 7.5 cm high). A third bowl served as the target object for all dogs. The opaque barrier (1.40 m wide and 1.22 m tall) placed in between the dog and the apparatus during the delay was constructed from a metal frame, on which an opaque cloth was draped. This particular barrier was used because it effectively blocked the dog's view of the apparatus in a previously run control condition (Miller et. al, 2009).

All testing took place in locations that were familiar to the dog. Three dogs were tested inside their home and three were tested outside in their yard. All locations were large enough to accommodate the full rotation of the apparatus. A digital video camera (Sony model no. DCR-HC26) was used to record the dogs' choices.

Procedure—The visible and invisible displacement tests were administered in two separate sessions (7 days apart) lasting approximately 20 min each. Dogs were tested individually with their owners present. The owners restrained the dogs when necessary. The experimenter spent the first 5 min of the session familiarizing the dog with the apparatus and the owner with the procedure. Following this familiarization period, the experimenter trained the dog to associate each of the three bowls with food. This was done by placing a treat inside a bowl and offering the bowl to the dog. Once the dog had eaten out of each of the three bowls, one of the bowls was placed inside each of the occluders. The third was baited and offered to the dog once more. After the training trials, the experimenter allowed the unrestrained dog to follow her as she held the remaining bowl. The bowl was not obscured from the dog's view (the dog was physically close enough to follow the bowl) as it was placed inside an occluder. The dog was allowed to consume the food immediately. The procedure was repeated with the other occluder. The order of baiting the two occluders was counterbalanced over dogs. The purpose of this pre-training was to allow the dogs to experience the hiding potential of the occluders, as well as to ensure that the dogs would put their heads inside the occluders to reach the target object, as dogs are sometimes reluctant to do so.

In all tests, the dogs sat approximately 2 m away from the center of the apparatus (a distance determined by the size of the dog; each dog was far enough away from the apparatus to prevent

it from seeing inside the occluder when it was directly in front of the dog). To prevent the dog from initiating any preemptory movement towards the occluders, the owner sat behind the dog on a chair and manually restrained the dog by a short leash (1 m) attached to the dog's collar in a position that was equidistant from each occluder. To reduce the possibility of inadvertent cues, the owner was instructed to look at the center of the wooden beam and to avoid interacting with the dog during the trial. A phrase such as "Okay!" or "Find-it" was arranged with the owner to serve as a signal to release the dog. When giving this signal, the experimenter was careful to avoid providing any cues relevant to the object's location.

Visible displacement tests—On the first session, all dogs were tested with visible displacements. These began with the experimenter standing 1.0 m behind the center of the apparatus and approximately 3.0 m in front of the dog. The beam was placed perpendicular to the axis of the dog so that one occluder was to the right of the dog and the other occluder was to the left (see Figure 1a). The experimenter placed a treat inside the target bowl and attracted the dog's attention by saying "Cookie!" or "Treats!" Once the dog was visually attending, the experimenter proceeded to walk to the left or right occluder (the location was to the left or right equally often and randomly assigned with the provision that the same occluder could not be baited more than twice in a row). Once the experimenter reached the assigned occluder, she placed the bowl inside of it and on top of the false bottom. On a trial without a delay, the experimenter then quietly backed away from the occluder, assumed a neutral position that was equidistant from each occluder, and cued the release of the dog. On delay trials, the experimenter placed the bowl inside the occluder, backed away to a neutral position, and a second experimenter placed the opaque barrier in front of the dog. The second experimenter stood to the side of the barrier to ensure that the dog's view of the apparatus was blocked entirely for the randomly determined duration. There were an equal number of trials at each delay (0, 5, 10, 15 s). At the end of delay the second experimenter moved the barrier away from the dog and first experimenter cued the release of the dog. The dog was then allowed to approach either occluder. Any physical contact with an occluder, or visual inspection of its contents, was considered a choice. Following a correct choice, the dog retrieved the food reward by physically inserting its head inside the occluder. All dogs were rewarded with additional verbal praise for a correct choice. If the dog did not choose correctly, the experimenter used the phrase "Too bad" before removing the bowl from the correct occluder. The owner then retrieved the dog.

Invisible Displacement tests—Dogs were tested with invisible displacements during the second session. The beam was placed in line with the dog so that one occluder was directly in front of the dog (see Figure 1b). The experimenter placed a treat in the bowl before attracting the dog's attention. Once the dog was visually attending, the experimenter walked towards the dog on the right side of the beam and placed the bowl inside the occluder. The experimenter then collected the nylon line attached to that end of the beam and backed away to collect the nylon line attached to the other end. While standing behind the far occluder, the experimenter used the lines to rotate the beam 90° by extending both her left and right arms away from her body symmetrically (see Figure 1a; the occluder and direction of rotation were randomly assigned). Once the beam was rotated, the experimenter assumed a neutral position behind the center of the apparatus and cued the release of the dog. The first two invisible displacement trials were conducted without a delay between baiting and the time at which the dog was released. This was done to reduce the novelty of the rotation before delay testing. Once these trials were completed, the invisible displacement delay testing began. On these trials, the first experimenter baited the occluder, rotated the beam 90°, and then the second experimenter moved the barrier in front of the dog. After the delay, the second experimenter removed the barrier and the first experimenter cued the release of the dog. There were an equal number of trials (4) at each delay (0, 5, 10, 15 s) and delays were randomly assigned with the provision

that the first two trials were without delays, that the correct location (left or right) was not the same for more than two consecutive trials, and that each dog was assigned a different order of delay.

Results

Visible and Invisible Displacement Delay testing—Search accuracy at each delay interval for both visible and invisible displacement tests are presented in Figure 2. Dogs searched more accurately on the visible displacement test than they did on the invisible displacement test. A two-way repeated measures analysis of variance was performed on the data with type of test (visible and invisible) and delay (0, 5, 10, or 15 s) as factors. The analysis indicated that there was a significant effect of test type, $F(1, 15) = 8.43$, $p = .03$, and a significant effect of delay, $F(3, 15) = 9.39$, $p < .01$, but there was no significant Test Type $\times$ Delay interaction, $F(3, 15) = .08$, $p = .97$. The delay data for each dog on the visible and invisible delay test trials appear in Figure 3.

The visible displacement data were further analyzed by comparing no-delay and 5-s delay accuracy to chance levels (50%) using a repeated measures t-test. When there was no delay between the displacement and the search attempt, dogs searched accurately 95.83% of the time, at a level that was significantly above chance $t(5) = 11$, $p < .01$. When there was a 5-sec delay, dogs also searched accurately 83.3% of the time which was significantly above chance $t(5) = 6.32$, $p < .01$. There was no difference in accuracy between the 0-s and 5-s delays $t(5) = 1.46$, $p = .2$.

The invisible displacement data were further analyzed by comparing no-delay and 5 s delay accuracy to chance levels (50%) using a repeated measures t-test. When there was no delay between the rotation and the search attempt, dogs searched accurately 79.2% of the time, at a level that was significantly above chance $t(5) = 3.8$, $p = .01$. However, on average, search accuracy dropped to 58.2% following the 5-s delay $t(5) = .79$, $p = .46$. The difference in accuracy between the 0-s and 5-s delays was marginally significant $t(5) = 2.08$, $p = .09$.

Discussion

Miller et al. (2008) found that when a hidden object is placed inside of one of two identical occluders placed on either end of a rotating beam, and that beam is rotated 90°, dogs will search accurately for the invisibly displaced object. The results of the current study confirm this finding. The dogs searched accurately when they were allowed to search for the object immediately following the invisible displacement.

We suggested here that the mechanism responsible for accurate searching by dogs under these conditions may be perceptual/conditioning. We suggested that if this were true, then search accuracy should be poorer if, after the displacement, the dog is prevented from immediately searching for the object. We found that all of the dogs searched accurately on the visible displacement test following a 5-s delay. This result supports Fiset et al. (2003) who found that dogs search accurately on a visible displacement even when they are delayed by durations of up to 4 min. However, we found that (on average) dogs did not search accurately once delays were introduced following the invisible displacement. The only exception was a border collie named Cricket who searched accurately at all but the longest delay.

It is clear that the delay created by moving a barrier in front of the dog resulted in an increase in errors. What is not clear is why one dog of six continued to search accurately. It could be that this dog was the only one to remember the location of the hidden object and the others were relying on perceptual/conditioning cues. However, it is possible that the movement of the barrier was disruptive and that only one dog was capable of remembering the location of

the hidden object despite the disruption. This hypothesis is supported by previous research that found that the nature of the delay affects the matching accuracy for pigeons on a matching to sample task (Roberts and Grant, 1978). Pigeons perform less accurately when the delay between the offset of the sample and the onset of the comparisons is illuminated rather than dark.

Experiment 2 was designed to determine whether dogs would search more accurately if the delay was dark. The dark delay was accomplished by turning off the lights in the experimental room. Following the delay, the lights were turned on and the dog was allowed to search for the object in either of the two containers.

Experiment 2

Method

Subjects—Six dogs (*Canis familiaris*) were recruited, 3 males and 3 females, ranging in age from 3 to 8 yr, ($M = 5.5$ yr) and belonging to private owners. Selection criteria were the same as for Experiment 1. Of the dogs that participated in the experiment, five came from breeds classified by the American Kennel Club as herding dogs (four Belgian Tervuren and a German shepherd), and one was a sporting dog (a Springer spaniel). All dogs had similar training and experience as those tested in Experiment 1.

Apparatus—The apparatus and materials were the same as those used in Experiment 1 except that one dog was motivated to work for food, but was even more motivated to interact with his favorite toy. All conditions remained the same for this dog, except that a toy was used as his target object.

All testing took place at night (20:00 hrs) inside a white painted room (11.6 m long $\times$ 4.6 m wide) with a window (.9 m long $\times$.9 m wide) that was covered with an opaque dark colored cloth and a door that was shut during the experiment. There was a single ceiling light that was used to illuminate the room. When the light was on ($lx=227$) the apparatus was clearly visible. When the light was turned off, the room was dark such that the human experimenters were unable to see objects in the room ($lx=.07$). Although dogs are quite sensitive to low levels of illumination (Miller and Murphy, 1995) like humans, they need considerably more light to be able to detect shapes in a dark environment (Hood and Finkle, 1986). Furthermore, research using electroretinography has found that dogs' eyes require substantially longer time to adapt to the dark compared to humans (Kemp and Jacobson, 1992). Given that the apparatus did not emit light and did not move during the delay, that dog's eyes adapt slowly, and that the delays did not exceed 30 s, it is unlikely that the dogs could perceive the apparatus at any time during the delay. The duration of the delay was timed with a Timex™ digital watch. This watch features a timer mode in which the face of the watch illuminated at the end of the timed duration. A digital video camera (Sony model no. DCR-HC26) was used to record the dogs' choices.

Procedure

Phase I: Visible displacement tests: The procedure used in Experiment 2 was similar to the one used in Experiment 1 except that the first four visible displacement trials were conducted without a delay between baiting and the time at which the dog was released. Once these trials were completed, the visible displacement delay testing began. On visible displacement trials the experimenter placed the bowl inside of the occluder, backed away to a neutral position, and a second experimenter (who stood at the far side of the room near the light-switch) turned off the lights for the randomly assigned delay duration (0, 5, 10, 15 s). When the second experimenter turned on the lights, the first experimenter cued the release of the dog.

Invisible Displacement tests: The invisible displacement test was similar to that described in Experiment 1 except that the first four invisible displacement trials were conducted without a delay between baiting and the dog's released. Once these trials were completed, invisible displacement delay testing began. On these trials the first experimenter baited the occluder, rotated the beam 90°, and then the second experimenter turned off the lights. After the delay, the second experimenter turned the lights on and the first experimenter cued the release of the dog.

Phase II: The dogs that searched accurately with delays in the first phase were re-tested with visible and invisible displacements that were similar to the first phase except that the duration of the dark intervals was extended (0, 10, 20, 30 s).

If a dog's search performance was unaffected by these extended delays, than it were tested with 12 control trials at the end of the experiment. On these trials, the dog was tested with the invisible displacement (90° rotation) but the visual cues provided by the rotation were eliminated by placing a barrier in front of the dog, prior to the rotation. The barrier was removed immediately following the rotation and the dog was allowed to search for the displaced object.

Results

Visible and Invisible Displacement testing—The mean correct choice on the first four trials of visible and invisible displacement testing (0-s delay) appear in Figure 4. The dogs searched accurately on the visible displacement test 100% of the time. The dogs also searched accurately 83.3% of the time on the invisible displacement test (trials correct ranged from 3 to 4, $M = 3.3$) which was significantly above chance (50%), $t(5) = 6.32, p < .01$. However, the dogs searched more accurately on the visible displacement test than they did on the invisible displacement test $t(5) = 3.16, p = .02$.

Delay testing

Phase 1: Search accuracy at each delay interval for both visible and invisible displacement tests are presented in Figure 5. As can be seen in Figure 5, dogs searched more accurately on the visible displacement test than on the invisible displacement test. A two-way repeated measures analysis of variance was performed on the data with type of test (visible or invisible) and delay (0, 5, 10, or 15 s) as factors. The analysis indicated that there was a significant effect of test type, $F(1, 15) = 8.85, p = .03$, but no significant effect of delay, $F(3, 15) = 1.21, p = .34$. Nor was there a significant Test Type $\times$ Delay interaction, $F(3, 15) = 2.12, p = .14$. The failure to find an effect of delay was likely due to the large individual differences in delay accuracy. The delay data for each dog on the visible and invisible delay test trials appear in Figure 6.

When search accuracy on the visible displacement test without a delay was compared to that following a 5-s delay, no differences were found. Dogs searched accurately on every trial. A repeated measures t -test was used to determine that dogs also searched accurately on the invisible displacement test without a delay $t(5) = 3.16, p = .03$. However, their search accuracy following a 5-s delay (62.5%) was not significantly different from chance, $t(5) = 1, p = .3$. The performance on invisible displacement trials without delays was significantly better than when there was a 5-s delay, $t(5) = 5, p < .01$.

Phase 2: Only two of the dogs, Maria and Gator, were tested in Phase 2. Search accuracy for these two dogs at each delay for visible and invisible tests is presented in Figure 7. On average, the dogs searched more accurately on the visible displacement test. However, a two-way repeated measures analysis of variance performed on the data with type of test (visible or invisible) and delay (0, 10, 20, or 30 s) as factors, indicated that none of the effects was

statistically reliable; test type $F(1, 3) = 1, p = .5$, delay $F(3, 3) = 1, p = .5$, or Test Type $\times$ Delay interaction $F(3, 3) = 1, p = .5$. One dog, Gator, was not affected by the delay, whereas the other dog performed worse, on average, on the invisible displacement test than on the visible displacement test during delay testing (see Figure 8). Consequently, Gator was tested with the control procedure. On control trials Gator searched accurately only 50% of the time (i.e., at chance level).

Discussion

The results of Experiment 2 suggest that dogs can search accurately for a visibly displaced object following a dark delay. But, again, we found that following a short delay (5-s) dogs did not search accurately on average for the invisibly displaced object. However, when the delays were dark, large individual differences were found. For example, some of the dogs stopped searching accurately at all delays, whereas others only searched accurately when the delay was short (5 s), and still others searched accurately at all of the delays. The two most successful dogs, Maria and Gator, were retested with longer delay intervals and similar results were found. One of those dogs, Gator, was unaffected by the longest delay, whereas Maria performed well but searched less accurately than at the shorter delays.

Maria and Gator's owners reported that their dog did not remain oriented towards the occluder throughout the delay. Despite the fact that owner's could not see their dogs, they reported that the leashes they held were often pulled in different directions, that the dogs often turned in circles, or jumped onto their owners. Thus, it is unlikely that Maria and Gator were bridging the delays by orienting towards the correct occluder during the rotation and by maintaining that position during the delay.

Overall, it appears that the use of a dark delay was less disruptive than the barrier. The difference in performance could be attributed to the movement of the barrier which may have served as a distraction, interfering with memory for the location of the displaced object. Research with pigeons (Roberts and Grant, 1978) supports this account.

General Discussion

The results of both Experiment 1 and Experiment 2 suggest that dogs can search accurately following a delayed visible displacement. However, in general, dogs do not search accurately for an invisibly displaced object (90° rotation) following a short delay. This suggests that dogs' search strategy for an invisibly displaced object is easily disrupted, though this disruption is decreased when the delay is dark. Yet, in both Experiments, there were a few dogs that searched accurately following a delay. This suggests that the search strategy for some dogs must involve a cognitive component that relies on more than perceptual/conditional cues.

The fact that the current experiment was conducted in the presence of a human experimenter leaves open the possibility that inadvertent social cues were detected by the dogs. Although the experimenter went to great lengths to avoid providing such cues, the best evidence that social cues did not play a significant role in this experiment comes from previously reported control conditions that failed to find successful performance (Miller et al., 2009). When dogs were tested with the invisible displacement (90° rotation) but the visual cues provided by the rotation were eliminated by placing a barrier in front of the dogs prior to the rotation, the dogs did not search accurately for the object. Had inadvertent social or odor cues been a factor, the dogs should have been able to search more accurately.

Gagnon & Doré, 1992 found that performance on the traditional invisible displacement test was better when it was preceded by the visible test. For this reason we used that order of testing in the present study. Although it may be that prior visible displacement testing affected the

dogs' incentive motivation or increased attention to the occluders, it does not account for the fact that the dogs were able to track the 90° rotation and search the correct occluder following a delay. The results of the present experiments suggest that dogs have the capacity for a level of object permanence demonstrated by accurate performance with invisible displacement of the target object. Furthermore, the results suggest that at least some dogs were not relying on a perceptual/conditional mechanism to guide their search behavior.

References

- Erdőhegyi Á, Topál J, Virányi Z, Miklósi Á. Dog-logic: inferential reasoning in a two-way choice task and its restricted use. *Animal Behaviour* 2007;74:725–737.
- Barth J, Call J. Tracking the displacement of objects: A series of tasks with great apes (*Pan troglodytes*, *Pan pauciscus*, *Gorilla gorilla*, and *Pongo pygmaeus*) and young children (*Homo sapiens*). *Journal of Experimental Psychology: Animal Behavior Processes* 2006;32:239–252. [PubMed: 16834492]
- Collier-Baker E, Davis J, Suddendorf T. Do dogs (*Canis familiaris*) understand invisible displacement? *Journal of Comparative Psychology* 2004;118:421–433. [PubMed: 15584779]
- Doré FY, Fiset S, Goulet S, Dumas M-C, Gagnon S. Search behavior in cats and dogs : Interspecific differences in working memory and spatial cognition. *Animal Learning & Behavior* 1996;24:142–149.
- Fiset S, Beaulieu C, Landry F. Duration of dogs' (*Canis Familiaris*) working memory in search for disappearing objects. *Animal Cognition* 2003;6:1–10. [PubMed: 12658530]
- Fiset, S. Spatial rotation of hidden objects in domestic dogs. Paper presented at the meeting of the International Conference on Comparative Cognition; Melbourne, FL. 2007 Mar.
- Fiset S, LeBlanc V. Invisible displacement understanding in domestic dogs (*Canis familiaris*): the role of visual cues in search behavior. *Animal Cognition* 2007;10:211–224. [PubMed: 17165041]
- Gagnon S, Doré FY. Search behavior in various breeds of adult dogs (*Canis familiaris*): object permanence and olfactory cues. *Journal of Comparative Psychology* 1992;106:58–68. [PubMed: 1365009]
- Gagnon S, Doré FY. Search behavior of dogs (*Canis familiaris*) in invisible displacement tasks. *Animal Learning & Behavior* 1993;21:246–254.
- Gagnon S, Doré FY. A cross-sectional analysis of object permanence development in dogs (*Canis familiaris*). *Journal of Comparative Psychology* 1994;108:220–232. [PubMed: 7924252]
- Hood, DC.; Finkelstein, MA. Sensitivity to light. In: Boff, K.; Kaufman, L.; Thomas, J., editors. *Handbook of Perception and Human Performance*. Vol. Vol. 1. New York: Wiley-Interscience; 1986.
- Kemp CM, Jacobson SG. Rhodopsin levels in the central retinas of normal miniature poodles and those with progressive rod-cone degeneration. *Experimental Eye Research* 1992;54:947–956. [PubMed: 1521585]
- Miller H, Gipson C, Vaughan A, Rayburn-Reeves R, Zentall TR. Object permanence in dogs : invisible displacement in a rotation task. *Psychonomic Bulletin & Review* 2009;16(1):150–155. [PubMed: 19145026]
- Miller PE, Murphy CJ. Vision in dogs. *Journal of American Veterinary Medical Association* 1995;Vol 207(12):1623–1634.
- Piaget, J. *The construction of reality in the child*. New York: Basic Books; 1954.
- Robert WA, Grant DS. An analysis of light-induced retroactive inhibition in pigeon short-term memory. *Learning and Motivation* 1978;Vol 4(3):219–236.
- Triana E, Pasnak R. Object permanence in cats and dogs. *Animal Learning & Behavior* 1981;9:135–139.
- Watson JS, Gyorgy G, Csanyi V, Topál J, Gacsi M, Sarkozi Z. Distinguishing logic from association in the solution of an invisible displacement task by children (*Homo sapiens*) and dogs (*Canis familiaris*): using negation of disjunction. *Journal of Comparative Psychology* 2001;115:219–226. [PubMed: 11594490]
- West RE, Young RJ. Do domestic dogs show any evidence of being able to count? *Animal Cognition* 2002;Vol 5(3):183–186. [PubMed: 12357291]

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a.

b.

Figure 1.
(A). Apparatus and dog in the starting position for the visible displacement test. (B). Apparatus and dog in the starting position for the 90° invisible displacement test.

Figure 2.
Search accuracy in the barrier condition at each delay interval for both visible and invisible displacement tests.

Figure 3.

Search accuracy in the barrier condition for each dog at each delay interval for both visible and invisible displacement tests.

Figure 4.
Search accuracy on the visible and invisible tests for the first 4 no-delay trials.

Figure 5.

Phase I mean search accuracy at each delay interval for both visible and invisible displacement tests.

Figure 6.

Phase I search accuracy for each dog at each delay interval for both visible and invisible displacement tests.

Figure 7.
Phase II mean search accuracy at each delay interval for both visible and invisible displacement tests

Figure 8.
Phase II search accuracy for each dog at each delay interval for both visible and invisible displacement tests