DISSERTATION

A REEXAMINATION OF OBJECT PERMANENCE IN DOMESTIC DOGS

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WE HEREBY RECOMMEND THAT THE DISSERTATION PREPARED UNDER OUR SUPERVISION BY JENNIE WILLIS JAMTGAARD ENTITLED "A REEXAMINATION OF OBJECT PERMANENCE IN DOMESTIC DOGS" BE ACCEPTED AS FULFILLING IN PART REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY.

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ABSTRACT OF DISSERTATION

A REEXAMINATION OF OBJECT PERMANENCE IN DOMESTIC DOGS

Object permanence is the primary cognitive milestone achieved by non-verbal human infants and has been an obvious focus for comparative studies. There are inherent challenges to adapting the Piagetian framework to other species. Previous studies on domestic dogs have failed to control for the effects of olfaction and learning which could confound the interpretation of results. My experimental design controls for both of these effects and reexamines object permanence in domestic dogs. I found that domestic dogs as a species are capable of achieving a fully developed object concept (36 %), although I observed great diversity in performance. I found that the effects of breed, sex, and age differences could not account for this diversity. In contrast to previous studies, I found that dogs as young as four months showed complete object permanence, in contrast to previously published findings. Through random order task presentation in single trials, I rigorously examined ordinality, and found that it was highly conserved in 98.8% of trials. Additionally, this method shows that object permanence cannot be attributed to learning or previous experience. I found further evidence supporting ordinality of stage acquisition by examining the mistakes dogs made a higher order tasks. I observed the A not B error in two dogs at the appropriate stage, in contrast with previous studies. I also found that dogs at stage 5b showed stage 5 search behavior, and dogs at stage 6a showed stage 6 search behavior ($p < 0.001$) which demonstrates the theorized operational schema of particular cognitive stages. This has not been reported previously in dogs. I found that there was no difference in search times between visible and invisible displacements, but unsuccessful trials were significantly longer than successful trials. Since I only included active search times in this analysis, this difference alludes to metacognition, i.e., dogs' knew that they did not know how to solve the tasks. Search behaviors were also different between trials with different outcomes, which further supports the metacognition hypothesis. Overall, my experiment was the first to effectively address biological concerns with the application of cognitive tasks to domestic dogs.

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“We need another and a wiser, and perhaps more mystical concept of animals. Remote from universal nature, and living by complicated artifice, man in civilization surveys the creature through the glass of his knowledge and sees thereby, a feather magnified and the whole image in distortion. We patronize them for their incompleteness, for their tragic fate in having taken a form so far below ourselves. And therein we err, and greatly err. For the animal shall not be measured by man. In a world older and more complete than ours, they move finished and complete, gifted with extensions of the senses we have lost or never attained, living by voices we will never hear. They are not bretheren, they are not underlings; they are other nations, caught with ourselves in the net of life and time, fellow prisoners of the splendor and travail of the earth.”

From *The Outermost House*, by Henry Beston

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CHAPTER 1: A CRITICAL LOOK AT COMPARATIVE OBJECT PERMANENCE

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ABSTRACT

Object permanence is the primary milestone in pre-verbal human infants and has been of obvious interest to the field of comparative cognition. This ability to mentally represent objects when they are out of sensory perception is of great biological importance, and logically could be attributed to animals that share homologous brain structure with humans. A wide variety of mammals and birds have been tested for their acquisition of Piagetian object permanence, but great apes and arguably parrots and domestic dogs are the only species that have demonstrated a fully developed object concept. Some challenges in adapting human cognitive tests to other species include adequate control for all sensory modalities, control for the learning effect inherent in multiple trial presentation, and appropriate interpretation of search behavior in problem solving as evidence for the underlying assumptions the animal makes about the world. Most studies fail to account for one or more of these concerns, which motivates a careful examination of their results and interpretations.

INTRODUCTION

Object permanence is the ability to mentally represent objects when they are removed from immediate sensory perception and is the primary milestone in the development of human infants. The acquisition of object permanence begins prior to the onset of language and has been a focus for comparative cognitive studies. The biological importance of object permanence in non-human species lies primarily in predator avoidance and prey acquisition behavior, but also has implications for problem solving, communication, learning and memory. The area of the brain that is associated with higher learning and cognition in humans is also found in other mammals and birds, a shared homology that implies shared cognitive abilities. Piagetian object permanence has been examined in a variety of species, but only great apes and probably psittacine birds and domestic dogs demonstrate a fully developed object concept.

Many challenges arise when Piagetian methods are adapted to non-human species. Control for olfactory cues is critical when asking if the object was "hidden" or displaced. In addition, most experiments present the same task multiple times, allowing success to be misinterpreted as cognition, when in fact learning has occurred. Finally, interpretation of search behavior and mistakes is the most salient feature in analysis of cognition, and also the most difficult to assess. If these behaviors are correctly interpreted, the animal's underlying assumptions and problem solving strategies become apparent and shed light on internal mental processes. In this paper, I will examine the comparative object permanence literature, focusing on methods that fall short in one or more of these three areas. I will offer alternate interpretations for many observed results that are more consistent with the biological application of cognition.

BACKGROUND

The work of Jean Piaget has had a profound and lasting impact on the field of psychology. A prominent child psychologist in the 1930's, Piaget observed the development of his own three children; this prompted his brilliant assertions about the order and make-up of cognitive stages (Piaget, 1952/1936, 1954/1937). These theories have withstood rigorous scrutiny in numerous subsequent studies on human infants (Bjork & Cummings, 1984; Bremner, 1978; Butterworth, 1977; Uzgiris & Hunt, 1975). The detailed behavioral observations of each stage of development put forth by Piaget and further elaborated on by Uzgiris and Hunt (1975) have motivated comparative researchers to apply Piagetian principles to other species.

Piagetian development is divided into four main periods: the sensorimotor period (0-24 months), the pre-operational period (2-7 years), the concrete operational period (8-12 years) and the formal operational period (12 to adulthood). Each period is dominated by a specific cognitive element, which is a necessary precursor to the next period (Piaget, 1954/1937). Piaget speculated on the biological basis of these cognitive stages, and asserted that every human child would acquire all of these periods in the same order, with no stage skipped or reversed. This theory is called ordinality (Uzgiris & Hunt, 1975) and has important implications for the evolution of cognition. Comparative researchers gravitate toward the sensorimotor period because many of its milestones can be observed in the absence of language.

Development of object permanence is the hallmark of the sensorimotor period in human infants. Concepts of time, space and causality are also developed in this period (Appendix I). Object permanence is the ability to mentally represent a hidden object. In humans, a species that relies heavily on vision, this is tested by removing the object from the visual field. In other species, the object must be removed from all sensory modalities. Object permanence is such a pervasive idea to the adult mind that imagining an object truly vanishes when hidden is a difficult thought exercise.

Object permanence is divided into six sequentially acquired stages (Appendix II). Stages 1 and 2 are described as attention to an object and the ability to track it visually and are limited by the slow development of vision and motor function in humans. These stages are brief in other mammals where motor development is more rapid (Dumas & Dore, 1989, 1991; Funk, 1996; Gagnon & Dore, 1994; Pepperberg, Willner & Gravitz, 1997; Pollak, Prior & Gunturkun, 2000). Stage 3 is the ability to search for a partially occluded object, and the mental reconstruction of the whole from only a partial picture. The subject can only be successful if it is allowed to initiate search behavior prior to occlusion. Stage 4 is the first stage of permanence in which mental representation of a completely displaced object occurs. In stage 4a, the subject can search effectively only if the search is initiated prior to the disappearance of the object. However, in stage 4b, the subject can be successful in finding the object even after its complete disappearance. The tasks for stage 4 are both called *single visible displacements*. The *sequential visible displacement* presents a single visible displacement where the hiding location (A) remains constant for several trials. Then in a subsequent trial, the object is hidden in a new location (B). Subjects at Stage 4 will make a classic error here, known as the A-not-B error. The presence of this error in stage 4 is shaped by the subject's belief that their own actions determine their success in searching ("I will find it here because I search here"). The stage 4 subject ignores perceptual cues in favor of this egocentric view, and chooses to search at location A. Previous success at this location only reinforces their underlying schema for making this choice. The transformation of a subject from stage 4 to stage 5 happens with a shift to reliance on immediate perceptual cues, with the subject recognizing that the object is independent of their own actions ("I will find it here because it disappeared here"). The classic error is resolved in Stage 5a and subjects are successful at sequential visible displacements. Stage 5b subjects can solve a *successive visible displacement*, in which an object is repeatedly displaced and then reappears prior to a final hiding location. As a part of stage 5b, *single invisible displacements* can be solved. A single invisible displacement involves the immediate removal of the object from sensory perception by placing it in a container or covering it in some way. The already hidden object is then further displaced at another location. The subject is then shown the empty cover or container, and must infer the invisible displacement. Since the object cannot be immediately perceived, subjects at stage 5 are fail at this task. Interestingly, the A-not-B error manifests again with stage 5 subjects in tests of *sequential invisible displacements.* These tests are similar to sequential visible displacements in that the same successful hiding location (A) is repeated for several trials and then is changed to a new location (B). However, the object itself is already "hidden" (invisibly displaced-see stage 5b). Subjects in stage 6a can accomplish sequential visible displacements successfully, but remain unable to solve *successive invisible displacements.* In the latter test, the object is repeatedly invisibly displaced and reappears prior to its final hiding location. Complete object permanence is achieved by accomplishing this task, and corresponds to stage 6b (Piaget, 1952/1936, Uzgiris & Hunt, 1975).

Object permanence has far reaching implications for further cognitive development in humans. As object permanence develops, an infant can proceed to symbolic representation of objects, which is the beginning of language. Language develops in humans first through naming of immediately observable objects, and then proceeds to the requesting of absent objects (Flavell, 2004). By the two-word stage, the infant is able to verbally recall events that happened in the past. This phenomenon occurs simultaneously with full object permanence acquisition (Hockett, 1960). Ultimately, abstract thought builds on the basic principle of object permanence.

The relationship of language and cognition has been of special interest to researchers on primates and birds, since these species can be trained to use human language to communicate (Lieberman, 1984; Steklis & Raleigh, 1979). Rice (1980) claims that language training cannot influence a non-linguistic concept for which the subject is unready. In contrast, Premack (1983, 1984) asserts that animals trained in language tasks are predisposed to do better on object permanence tasks. This argument is consistent with the preservation of ordinality in cognitive stages, since language development is a part of cognition. Pepperberg (Pepperberg & Funk, 1990; Pepperberg & Kozak, 1986) states that language comprehension does not appear to be a necessary prerequisite for object permanence. However, these studies only address species in which language ability is present, and compare trained to untrained individuals.

Mammals' brains are largely homologous, and it is a logical extension of physical similarity to expect comparable cognitive abilities. The cerebral cortex (frontal lobe) is primarily associated with intelligence and cognition. [Birds lack this specific area, but have an analogous region called the striatal area which is thought to function in the same way (Thompson, 1993).] Mammals are unique in possessing the cingulate area, which regulates motor activity and is associated with higher learning in addition to many aspects of social and maternal behavior (Maclean, 1985, 1986). The cerebral cortex, amygdala and hippocampus all play roles in working memory (Goldman-Rakic, 1992). Working memory is the neural organization of mental and sensory information into short-term memory. The hippocampus organizes contextual cues, which are especially important in invisible displacement tasks. The relationship between memory and object permanence becomes apparent when search behaviors and mistakes are analyzed.

The biological importance of object permanence has been discussed as primarily relating to prey location and predator avoidance (Etienne, 1984). Since true object permanence must be assessed only in the absence of other sensory cues, it is difficult to distinguish between cognition and sensory perception in nature. Therefore, laboratory studies have been conducted on a number of species including non-human primates, cats, dogs, hamsters, doves, chickens, magpies and parrots (Appendix III). The presence of object permanence in diverse species of birds and mammals provides evidence that cognition may be phylogenetically conserved.

There are many challenges associated with developing an experimental design that accurately translates the Piagetian task into the conceptual framework of another species. In this paper, I will address the three primary issues faced by comparative work in object permanence: inadequate control for olfactory cues, the confounding effect of learning through multiple trial presentation, and the interpretation of search behavior and mistakes. I will offer a biological interpretation of results, which contrasts with current thinking in the field.

ALTERNATE SENSORY MODALITIES

Jakob von Uexküll introduced the fundamental idea of *umwelt* to biology decades ago, which has guided experimental designs in biology since that time (Von Uexküll, 1926). The external environment of each animal, *umwelt*, is shaped by the specific sensory stimuli that animal receives. For instance, a human cannot experience the world in the same way as a bat with ultrasonic hearing or a bee that can see in ultraviolet. The *umwelt* of each animal is different. This pervasive and paradigm changing concept remains influential in the design and interpretation of biological studies on non-human species. *Umwelt* directly affects the examination of the object concept, since primates, cats, dogs and birds all perceive different qualities of an object. Researchers must carefully control sensory input and filter interpretations in light of *umwelt*, or risk misunderstanding the results of their study.

Object permanence tasks traditionally remove or hide desired objects from a subject's visual perception. In humans and other primates this method is appropriate and represents a complete displacement from all sensory perception. However, different sensory modalities are highly specialized in some non-primate mammals such as domestic dogs and house cats. In these species, olfaction, or the sense of smell, is well developed and functional at birth (Fox, 1971), reflecting its innate relevance to development. This shift in primary sensory input makes adapting a visual test to an olfactory species challenging. Scent cues need to be eliminated in order to accurately represent a Piagetian displacement and assess cognition. However, motivation to search must be preserved, which requires the choice of an intrinsically valuable object. Food is the most obvious choice for animals, but also the most likely to emit olfactory cues. Unfortunately, attempted control of scent cues in comparative studies falls into three main categories: confusion or deception, use of a neutral "non-scented" item, or some variant of an odor masking technique. All of these methods fail as true control for olfactory cues, and some of them compromise other aspects of cognitive assessment.

Motivation

In object permanence trial presentation, a subject must be motivated to search for a hidden object. Failure to search may be due to the difficulty of task or the lack of motivation (Uzgiris & Hunt, 1975) and it is important to distinguish the difference in comparative studies. Trials in human infants use a toy or other object that possesses intrinsic value to the child. The child searches because it is intrinsically rewarding to find the object, not because the experimenter extrinsically rewards the child with praise or other reinforcement. Intrinsic rewards are powerful because they driven by a desire to seek an inherently valuable item and the reward is immediately and always available. In contrast, extrinsic rewards are those given by the trainer, experimenter or parent in an attempt to give meaning to a neutral item. The subject's motivation to perform for these rewards is more variable, and less reliable. Much of the quality of performance depends on the type and timing of reward and the reinforcement schedule. The neutral item acquires meaning only through instrumental conditioning and this value may attenuate over time. The performance of intrinsically motivated subjects and that of extrinsically rewarded subjects is therefore not comparable, and may not even assess cognition in the same way. The challenge for researchers is to find a search object that holds intrinsic value to the subject, and control for all sensory attributes. This is a key point that deserves consideration in comparative literature.

Confusion or Deception- No Real Control

When intrinsically motivating objects are used in object permanence trials and olfactory cues are not controlled, both domestic dogs and house cats are unilaterally successful at the most difficult invisible displacements (Triana & Pasnak, 1981). For most animals, food is the most intrinsically rewarding search object that could be used in object permanence trials. Toys may have variable interest, and neutral items have no innate appeal. Triana & Pasnak (1981) used food items as the search object in one of their experiments on cats and dogs and attempted to control for olfactory cues by hiding the item in an "illogical" location. All animals of both species were successful in every task and in every trial. In a second experiment, Triana & Pasnak (1981) used cloth pillows as the search object and found that dogs and cats were unsuccessful at tasks above stage 4b. For both species, these second results are in sharp contrast to their performance with food. Thinus-Blanc, Poucet & Chapuis (1982) also used food on tests performed on cats and attempted to control for olfactory cues by hiding the search item in an illogical location. This did not affect the animal's choices, since they were still very successful. Funk (1996) used a similar kind of deception to address the possible olfactory cues of seeds with New Zealand Parakeets.

These studies (Triana & Pasnak, 1981; Thinus-Blanc et al., 1982) illustrate several important points. First, the choice of item appeared to influence the success of the animals. Food is an intrinsically motivating search item and yielded more participation and success. Dogs were more likely to search for a pillow than cats, but even their performance was more varied than with food. Non-food items are not as intrinsically motivating for either species and this is reflected in their success. Second, animals were so successful in tasks involving food it may be that the scent cues emitted did not allow a displacement to be performed at all, that is, the object while visually absent, never disappeared from perception. Pasnak, Kirkijian, & Triana later concluded this (1988). This possibility seriously confounds the results, and this is echoed throughout later studies in both species.

Use of a Neutral Item

Comparative object permanence tests have used neutral items, or items with no intrinsic value, as search items for two primary reasons: 1) a direct mimic of specific items used in human cognitive studies, or 2) an attempt to control for overt scent cues. An early study on cats, Gruber (1971) used pieces of cloth, and found that cats did not perform above a stage 4 level of object permanence. Though his experiments did not accurately test all stages, it is possible that cats were not motivated to perform at higher levels. The unilateral success of cats and dogs with the use of food as a search item (Triana & Pasnak, 1981; Thinus-Blanc et al., 1982) prompted researchers on cats to shift to the use of a neutral object in an effort to control for olfactory cues. The neutral object, usually a wooden dowel, was paired with food through operant conditioning (Dore et al., 1996; Dumas, 1992, 2000; Goulet, et al., 1994). The wooden dowel does not have intrinsic value, but only acquires meaning after pairing with food, an extrinsic reward. Cats were often tested in a food-deprived state (Dore et al. 1996; Goulet et al. 1994) to increase the value of the reward. However, cats in these studies universally failed at invisible displacements (Stage 6), the most complicated and advanced set of tasks in object permanence. The number of training sessions and the type of reward varied with the experiment, but the crux of the problem remained the same. The subject was not intrinsically motivated to search for the item and the additional layer of complexity introduced by instrumental learning may have eroded the reliability of the results. This is especially true in view of Uzgiris & Hunt's (1975) observation that children fail to search correctly both when the administration of a task is too difficult or when the subject lacks motivation. The neutral object procedure certainly changes the representation of the task, because so much of performance relies on the strength of the training and the value extrinsically attributed to the object. Involvement of instrumental learning clouds interpretations of results because both frustration and lack of motivation may play a part in failed performance.

Odor Masking

Object permanence experiments performed in dogs addressed canine olfaction by applying an “odor masking” procedure instead of a clear control of scent cues (Gagnon & Dore, 1992, 1993, 1994; Dore et al., 1996; Fiset, Beaulieu & Landry, 2003). Gagnon and Dore (1992) designed this technique, which was used in some form by the later experimenters. In their method, heavily scented rubber toys were used as search objects in displacements, the room was sprayed with scent after every third trial and in addition “dummy” toys were placed behind non-target screens. Fans were also employed to distribute scent. Scent was not eliminated by those methods. Instead they were an attempt to flood the room with scent. Under such circumstances, the possibility exists that olfaction will be used to “track” these items through their displacements. Given the acuity of canine olfaction, dogs are able to discern the age of a scent and distinguish easily between minute quantity differences (McCartney, 1968; Passe & Walker, 1985). Therefore, the odor masking method would not have been satisfactory to control olfactory cues. Unfortunately, most other object permanence studies on dogs (Gagnon & Dore, 1993, 1994; Dore et al., 1996; Fiset et al., 2003) used the general method outlined by Gagnon and Dore (1992). This means that there has been no scientific control of scent cues in object permanence studies performed on dogs or cats to date.

Gagnon and Dore (1992) also assert that dogs do not use scent cues to locate hidden objects. This is a powerful statement, cited by subsequent studies as a reason that scent cues do not need to be controlled at all (Gagnon & Dore, 1993; Fiset et al., 2003). Outside of the field of comparative cognition, however, there is much biological evidence to the contrary (Miller et al., 1996; Pearsall & Verbruggen, 1982; Sommerville, et al., 1993; Steen & Wilsson, 1990, Wright, 1964). While Gagnon and Dore (1992) analyzed overt sniffing behavior in different tasks and found that the presence of this behavior did not impact success, scent discrimination occurs with every inhalation (Von Bekesy, 1964), and overt sniffing behavior may not be present when the scent is easily discernable. In other words, sniffing behavior alone does not represent an accurate measure of the presence and relevance of olfactory cues. Interestingly, in an effort to control for olfactory cues, Fiset et al. (2003) excluded dogs that "relied" on their sense of smell too much. Additionally, although Gagnon and Dore (1992, 1993) and Dore et al. (1996) attributed a low incidence of non-responsive trials to highly motivated subjects, that also could result from the persistent presence of olfactory cues that never allowed a true "displacement" from sensory perception to occur.

THE LEARNING EFFECT

Piaget (1952/1936, 1954/1937) asserts that cognitive constructs are acquired sequentially and build on each other, which is supported by later work on human infants (Uzgiris & Hunt, 1975; Bjork & Cummings, 1983). According to Piaget (1954/1937), cognition cannot be learned, but develops through the integration of experiences with innate cognitive constructs over time. In this framework, a subject cannot be taught to give the right answer if they have not achieved that cognitive stage. Traditionally, object permanence tasks are presented many times to the same infant, and are also usually assessed in the order of acquisition (Uzgiris & Hunt, 1975). Studies in other species have adopted this method. However, recent work suggests that previous experience in a task demonstrates a learning effect in humans (Johnson, et al., 2003; Scholl, 2004), house cats (Dore, 1986, 1990; Dumas & Dore, 1989) and in domestic dogs (Gagnon & Dore, 1992). Additionally, the first choice of an animal in a search task is often not recorded in favor of a later successful choice (Etienne, 1973; Thinus-Blanc & Scardigli, 1981) or a test may be performed multiple times until a successful criterion is reached (Pepperberg & Kozak, 1986; Gagnon & Dore, 1994). All three of these procedures confound the results of cognitive tests because trial and error learning, not object permanence, may account for observed success.

Sequential Order of Presentation

The order of acquisition of object permanence tasks, called ordinality (Uzgiris & Hunt, 1975), coupled with traditional longitudinal developmental studies, has often led comparative researchers to present object permanence tasks in a particular order. In assessment of cognition in adult animals, this order is unnecessary and may even provide the subject with the experience that affects the later success. By experiencing simpler visible displacements first, the animal may learn a pattern that predicts successful hiding locations instead of inferring that information from perceptual cues. While many studies present animals with tasks in the order of acquisition (Funk, 1996; Gruber, Girgus & Banuazizi., 1971; Pepperberg & Kozak, 1986), other studies varied the presentation somewhat . The latter studies showed that previous experience with visible displacements improved performance at invisible displacement tasks (Dumas & Dore, 1989; Dore, 1990; Gagnon & Dore, 1992). Dore (1990) found that even experience with covers used to hide desired objects improved the persistence of search behavior in cats. Gagnon and Dore (1994) reported that improvement in stage 6 tasks was only significant if all tasks were presented in order: they did not see a difference if only one or two visible displacements were presented first. Two studies (Pepperberg & Funk, 1990; Thinus-Blanc, et al., 1982) presented at least some tasks out of order and concluded that there did not appear to be a learning effect. The majority of evidence from these studies points to an increase in success at higher level tasks when exposed to lower level tasks first. Comparative studies could control for this by presenting tasks in a random order.

Multiple Trial Presentations

The inherent problem with presenting the same task multiple times to an animal when testing cognition is that learning may occur and confound results. There is a historical precedent for presenting the same task multiple times in human studies (Bjork & Cummings, 1984; Piaget, 1954/1937, Uzgiris & Hunt, 1975), but also recent evidence that suggests that learning may occur when this is done (Johnson, et al., 2003; Scholl, 2004). Many comparative studies have employed multiple trials in cats (Dumas, 1992; Dumas & Dore, 1989; Goulet et al., 1994; Gruber et al., 1971; Thinus-Blanc et al., 1982; Triana & Pasnak, 1981), dogs (Dore et al., 1996; Gagnon & Dore, 1992, 1993, 1994; Triana & Pasnak, 1981), hamsters (Thinus-Blanc & Scardigli, 1981), psittacine birds (Pepperberg & Funk, 1990; Pepperberg & Kozak, 1986), chickens, (Etienne, 1973) and ring doves (Dumas and Wilkie, 1995). Although

Pepperberg and Funk (1990) claimed they saw no evidence of learning as a result of multiple trial presentation, most other studies neglected to analyze their data in this way.

Some researchers have presented the same task an unlimited number of times until a successful criterion was reached (Gagnon & Dore, 1994; Pepperberg & Kozak, 1986;). True longitudinal studies by their nature must present tasks many times to capture the exact age at which the cognitive stage occurs (Pepperberg, et al., 1997; Pollak et al., 2000). However, it is important to distinguish between procedures used in longitudinal developmental studies and tests performed on adult animals or in cross sectional studies. When assessing adult animals, it is not consistent to compare a species that "achieved" a cognitive stage after 20 trials and with one that was successful in the first presentation.

Other researchers have used operant conditioning to reinforce successful choices, which is a true example of training (Dore, 1986, 1990; Gagnon & Dore, 1992, 1993; Goulet et al., 1994; Pepperberg & Funk; 1990; Pepperberg & Kozak, 1986). In recent studies, cats are shaped and trained to touch the object as a part of the search procedure, in addition to being rewarded when they make a correct choice. This procedure of rewarding successful choices in object permanence tasks is another way to bypass the use of an intrinsically motivating item (as discussed above). Again, such training may not result in a level of success comparable to that inspired by intrinsically motivating objects.

Recording the last choice instead of the first

In object permanence tasks, only the first choice of an animal should be recorded. If the subject is allowed to investigate other hiding locations then successful trials must be interpreted as learning instead of cognition. Thinus-Blanc and Scardigli (1981) allowed subjects to correct their choices during a trial. This procedure clearly allows trial and error learning to take place. Dumas and Dore (1989) scored a trial as successful if the subject went to the container first, then the correct screen. Search at the container is clearly behavior associated with a Stage 5 search behavior (see below) and should be scored as a mistake in invisible displacement tasks. Few authors explicitly indicate how their trials are scored, and it is possible that this error is widespread.

INTERPRETING SEARCH BEHAVIOR

Though many comparative experiments test object permanence, relatively few specifically address search behavior and mistakes. Search behavior is important to analyze because it allows a glimpse into the underlying mental processes used in solving problems. Piaget asserted that each cognitive stage was driven by a particular set of schema, or assumptions about the world, that governed that subject's actions toward the environment. Generally speaking, this means that an animal makes predictable mistakes that correspond with its cognitive level. This idea has been explored thoroughly in human infants, and evidence has been observed in some primate studies. However, the majority of comparative experimentation on search behavior mechanisms has been in house cats and domestic dogs. Performance in other species is more uniform, while there are discrepancies in the literature on these two carnivores. While some limited evidence shows house cats can solve invisible displacements (Dumas, 1992; Triana & Pasnak, 1981), the majority of studies conclude they cannot (Dore, 1986,1990; Dumas & Dore, 1989; Goulet et al., 1994; Pasnak et al., 1988) (but see above for possible limitations). Experiments on dogs indicate that they can solve invisible displacements (Gagnon and Dore, 1992, 1993, 1994; Triana & Pasnak, 1981). Further exploration of search behavior indicates that while they are successful at traditional object permanence tasks, they may not fully understand invisible displacements if the concepts are presented in a different way (Dore et al., 1996)(see above for a discussion of impaired methods). Both cats and dogs are pet species and carnivores, so on the surface this disparity seems perplexing and unexpected.

There are two areas in which search behavior and mistakes in cats and dogs differ from other mammals. First, the A-not-B, or stage 4 error has not been observed in either cats or dogs but is present in humans, primates and birds. Second, cats and sometimes dogs appear to display stage 5 search behavior when tested in stage 6 tasks. I will review the literature in both of these areas and provide some alternate interpretations for findings.

Stage 4 Search Behavior: The A-not-B error

Stage 4 marks the beginning of active search in object permanence. The transformation of an animal from stage 4 to stage 5 is striking and easily discernable by the initial presence of a classic error (A-not-B) and its later disappearance as the animal reaches stage 5 . The sequential visible displacement task that isolates this error presents a single visible displacement where the hiding location (A) remains constant for several trials. Then in a subsequent trial, the object is hidden in a new location (B). The stage 4 organism is governed by the belief that their own actions on an object determine their success in searching (I will find it here because I search here). The stage 4 subject will choose to search at location A, even when immediate perception indicates the object is not there. It believes its own actions are linked with its success, and since their previous experience with location A is positive, it will ignore perceptual cues in favor of this underlying belief. This egocentrism fades as it moves to stage 5, when its search strategies are guided by immediate perceptual cues (I will find it here because it disappeared here). The classic A-not-B error disappears and the subject is able to solve sequential displacements in stage 5.

The A-not-B error has received a great deal of attention in human literature (Bjork & Cummings, 1984; Bremner, 1978; Butterworth, 1977; Harris, 1983; Wellman, Cross & Bartsch, 1986) and has also been observed in primates (Mathieu & Bergeron, 1981; Poti, 1989, Redshaw, 1978; Spinozzi, 1989) and birds (Funk, 1996; Pepperberg, Willner & Gravitz, 1997). However, developmental studies on dogs, cats and magpies (Dumas & Dore, 1989, 1991; Gagnon & Dore, 1994; Pollak et al., 2000) did not demonstrate the A-not-B error. Adult mammals and birds also failed to exhibit this classic error (Dore, 1986; Dumas, 1992; Gagnon & Dore, 1992, 1993; Pepperberg & Funk, 1990; Pepperberg & Kozak, 1986), although all of these species demonstrated competence at higher cognitive stages, indicating that they had bypassed the crucial window for observation of this error.

Rapid motor development that expedites the time frame of early stage acquisition is thought to account for the absence of the A-not-B error in cats and dogs. In this vein, studies in humans suggest understanding of object permanence develops well before the infants' ability to physically act on it (Baillargeon, et al., 1990. In rapidly developing species, the A-not-B error would have only a brief observable period. However, due to the methods used in object permanence studies in cats, dogs and magpies, it is not possible to conclusively state that the A-not-B error does not exist in these species. In both longitudinal and cross sectional studies, sampling errors were made that could account for the lack of detection of this classical phenomenon. Dumas and Dore (1991) conducted a longitudinal study of object permanence in house cats. No human analog tests were performed, but rather the day-to-day behaviors were analyzed in a Piagetian framework. Video recordings were taken continuously in the nest box, but only two 15-minute periods were analyzed each day. The failure to observe the error might be the result of sampling error or analytical constraints. In other studies, cross sectional, not longitudinal, studies were conducted on cats and dogs (Dumas & Dore, 1989; Gagnon & Dore, 1994). This is an important distinction since different groups of animals were tested at specific ages, instead of following one group of animals throughout its development. Dumas and Dore (1989) tested kittens at 5 weeks and 7 weeks for stages of object permanence. The 5 week kittens were not performing active search behavior (stage 3), but the 7-weeks kittens performed stage 4 tests without the presence of the A-not-B error. However, they were operating at a higher cognitive level by that age (stage 5); a finding that is expected according to Piaget, since the opportunity to observe the A-not-B error would only occur when testing a subject at stage 4. Kittens obviously achieve stage 4 around 6 weeks of age; kittens of that age were not tested in this study. Gagnon and Dore (1994) tested puppies and found rapid development appears to take place between weeks 6 (stage 4a) and week 7 (stage 5b), again indicating that the window for observation of the A-not-B error may have been missed. Similarly, the longitudinal study conducted on magpies may not have observed the A-not-B error due to their testing schedule, as acknowledged by the authors (Pollak et al., 2000). Overall, more rigorous longitudinal tests need to be performed on these species before explicit statements can be made about the presence or absence of this classic error.

Stage 5 Search Behavior: Recognition or Recall

Piaget has clearly distinguished between the two types of representation that allow an organism to acquire and structure knowledge about its environment and regulate its interaction with the world. Primitive representation (stage 5) requires the presence of external substitutes to represent absent objects. In contrast, symbolic representation (stage 6) uses internal substitutes in the form of words or mental images for the same purpose. According to Piaget, the stage 6 animal is capable of recall whereas the stage 5 animal would be capable of recognition only. This difference has important implications for understanding the biological frame of reference in a species.

Great apes clearly function at stage 6 competence, while the results on psittacine birds and dogs are more ambiguous. In contrast, monkeys, cats, hamsters and non-psittacine birds appear to demonstrate stage 5 competence (Appendix 3). There are numerous concerns about methods (addressed above) that overshadow the results in many of these studies. However, even without such concerns, there are still logical fallacies in interpretation that emerge.

House cats and domestic dogs, both pet animals, may differ in cognitive ability. The approach of cats and dogs to stage 6 problems has been the focus of much research. Dogs can solve traditional invisible displacements (stage 6b), while cats cannot. However, dogs have a higher rate of success at solving visible displacements (stages 4 and 5) than invisible displacements. Some dogs do not succeed at invisible displacements, while others do, demonstrating individual differences in a species that has stage 6 capacity (Gagnon & Dore, 1992, 1993).

In an attempt to isolate underlying mental processes, some experiments modified displacement tasks. Dogs, but not cats, could use the empty container as information for inferring an invisible displacement. In contrast, cats nearly universally searched at the container, whether or not it was shown to them as empty (Dore et al. 1996). This is typical stage 5 search behavior, since the container is the last known location of the object according to perceptual cues. The pairing of the object to the container is strong in associative memory and subsequent perceptual cues are ignored by a stage 5 animal in favor of the initial association. When Goulet et al. (1994) performed an invisible displacement using a transparent container; search behavior was equally distributed between the target screen and the container. In another experiment, an object was visibly displaced and then invisibly moved to another screen (the subject did not view the second movement. Although an auditory cue was provided, and cats were briefly shown what was behind both screens, searches were equally distributed between the first and second screens (Goulet et al., 1994). These findings may demonstrate that cats can associate the elements of the task, but may not mentally represent the object transfer.

The experimental data on dogs are consistent with stage 6 performance (Dumas, 1998; Gagnon & Dore, 1992, 1993, 1994; Fiset, 2003) except for Dore et al. (1996), who analyzed response to a variant of the traditional displacement task called invisible transposition. Invisible transposition tasks visibly displace an object behind a screen, and then move the entire screen (with the object behind it) to a new location. This is considered to be a simpler variant of invisible displacement because the inferred movement of the object has a perceptual cue (screens are moved) and is achieved by infants at around 20 months of age (Sophian, 1985). Dore et al. (1996) tested both cats and dogs in invisible transposition tasks and found that cats failed at invisible transpositions in generally the same way as they fail at invisible displacements. Dogs were able to solve most types of transpositions, but showed a decrease in success at two particular types of transpositions that did not have a clear perceptual cue. From these data, Dore et al. (1996) conclude that both cats and dogs operate at stage 5. Invisible transpositions do not correlate clearly with the stages of object permanence, and it is possible that as predators, dogs and cats make certain assumptions about the world that were not reflected in these tests.

Two important findings have come out of the dissection of specific elements of search behavior. First, the delay inherent in invisible displacement tasks prompted experiments in cats and dogs that investigated working memory. These studies universally concluded that delays in search were not responsible for success or failure at invisible displacements (Dore, et al., 1996; Fiset, 2003; Goulet et al., 1994). Second, the type of cue that both species used to orient on the target screen was spatial (geographic) in nature, not figurative (color, size etc.) (Dore, et al., 1996). These findings make intuitive ecological sense, since in nature spatial cues are less likely to change over time. Problems with method still plague these studies, since an underlying motivational issue may impair responses in cats.

Differential success in traditional invisible displacement tasks by cats and dogs indicates that they operate at different cognitive levels. Nonetheless, Dore and Goulet (1998) echoed the assertion of Dore et al. (1996) by proposing that both species operate at the same cognitive level House cats and domestic dogs are frequently grouped together in thought exercises as somehow closely related, since they are both pet species. While both species are members of the order Carnivora, the species from which they were domesticated were vastly different in social structure and ecological niches. It is tempting to persist in seeking cognitive similarity between these two species and this may have motivated a large number of the cat and dog comparative studies. In reality, the biology of Felidae and Canidae argues against the expectation of cognitive similarity.

Dore and Goulet (1998) suggest that cats, dogs (and by extension monkeys and birds) are not capable of recall, but only of recognition. Attempting to reconcile the learning and memory abilities these species are known for with their theory, Dore and Goulet use the paradigm of amnesiac humans, who can improve their performance at tasks that are never remembered. Dore and Goulet (1998) also intimate that human memory recall is completely spontaneous, and does not require an environmental cue to trigger. Biologically speaking, it is hard to reconcile particular ecological attributes if cats, dogs, monkeys and birds do not have memory recall. For instance, food caching is a trait shared by wild felines, canines and birds. This behavior is not triggered by recognition of the sites but by the need to recover stored food (Sherry, 1984). When analyzed in this way, almost all memory recall has a sensory stimulus; even so-called spontaneous memory drifts in humans.

CONCLUSION

The field of comparative cognition has exciting and far reaching implications for understanding animal minds. Piagetian development provides a framework for evaluating animals according to concrete observable behaviors. Understandably, this principle draws researchers to Piaget's theory to investigate the sensorimotor period, or the time before language. In this paper I have addressed some errors in interpretation and method and suggested possible solutions. First, we must remember the concept of *umwelt*, which takes into account sensory acuity different from our own. This must be forefront in our minds as we attempt to ask "human" questions of other animals. Ignoring this may mean that the phenomenon we hoped to examine was never tested at all. Second, Morgan's Canon reminds us to not attribute a more complicated explanation where a simpler one fits. It is for this reason that potential learning effects must be controlled before success can be seen as evidence for cognition. Third, examination of search behavior is important to understanding underlying mental processes, and should be completely explored and interpreted within the conceptual framework of each species. Overall, a more robust and controlled approach to examining animal cognition needs to be employed by future studies. Comparative psychologists must also be biologists or they will find that the animals they hope to understand have eluded them.

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Appendix I: An Overview of Milestones in the Sensorimotor Period in Humans (modified from Piaget, 1952/ 1936)

Stage	Age	Milestones
Stage I: Reflexes	Birth to 6 weeks	Simple reflexes (e.g. Sucking)
Stage II: Primary Circular Reactions	6 weeks to 4 months	First acquired habits (e.g. Thumb sucking)
Stage III: Secondary Circular Reactions	4 to 8 months	Coordination of vision and prehension: goal directed behavior (e.g. Reaching for objects)
Stage IV: Co-coordinated Secondary Circular Reactions	9 to 12 months	Coordination between means and goals (e.g. Searching for hidden objects)
Stage V: Tertiary circular reactions	12 to 18 months	Discovery of new means (e.g. Analyzes water falling under different conditions: from a sponge, from a cup etc.)
Stage VI: Symbolic Representation	Beyond 18 months	Insight Concepts of object, space, time, and causality are acquired

Appendix II: An Overview of the Stages of Object Permanence in Humans (modified from Piaget, 1954/ 1937)

Stage/Substage	Milestone	Description of Response
1	None	Eyes fail to track a moving object
2	Visual Tracking	Eyes can follow object to point of disappearance; no search behavior
3	Partially Occluded Object	Subject can retrieve objects if they are touched prior to disappearance; mental reconstruction of object from a partial visual cue
4a	Single Visible Displacement	Subject can retrieve a completely occluded object if search behavior is initiated before disappearance
4b	Single Visible Displacement	Subject can retrieve a completely occluded object even if search behavior is initiated after the disappearance
4b	Sequential Visible Displacement	Subject fails to retrieve displaced object hidden at one location during previous trials; now hidden at a novel location; searches at previously successful location, classical mistake called A-not-B error
5a	Sequential Visible Displacement	Subject can retrieve an object hidden at one location during previous trials now hidden at a new location; relies on perceptual information over previous success: no presence of A-not-B error
5b	Successive Visible Displacements	Subject can follow successive disappearances and reappearances of object in the same trial; searching only in the place of the last disappearance
5b	Single Invisible Displacement	Subject can follow the disappearance of an object first visually occluded, then displaced at another location; relies on logical inference of perceptual cues
5b	Sequential Invisible Displacement	Subject fails to follow serial invisible displacements at one location, then at a novel location; A-not-B error resurfaces in this task at this stage
6a	Sequential Invisible Displacement	Subject can retrieve the invisibly displaced item hidden at a novel location; no presence of the A-not-B error
6b	Successive Invisible Displacement	Subject can follow the multiple disappearances of an invisibly displaced object,; relies on logical inference of perceptual cues

Appendix III: Level of Object Permanence Achieved by Various Species

Species	Highest Stage	Authors
Great Apes		
Chimpanzee	6b	Beran & Minahan, 2000; Mathieu & Bergeron, 1981; Mathieu et al., 1976; Spinozzi & Poti, 1993; Tomasello et al., 1993, Wood et al., 1980
Gorilla	6b	Natale et al., 1986; Spinozzi & Natale et al., 1989; Redshaw, 1978
Orangutan	6b	de Blois, et al., 1998
Monkeys		
Capuchin monkey	5	Dumas & Brunet, 1994; Spinozzi, 1989
Crab eating macaque	5	Poti, 1989
Japanese macaque	5	Antinucci et al., 1982; Natale et al., 1986; Parker, 1977; Poti, 1989
Marmoset	6b	Mendes et al., 2004
Rhesus monkey	5	de Blois & Novak, 1994; Wise & Wise, 1974
Squirrel monkey	5	de Blois, et al., 1998; Vaughter et al., 1972
Carnivores		
Domestic dogs	6b	Gagnon and Dore, 1992, 1993; Triana & Pasnak, 1981
Domestic dogs	5*	Dore et.al
House cats	6b	Dumas, 1992; Triana & Pasnak, 1981
House cats	5b	Dore, 1986, 1990; Dore et al., 1996; Dumas & Dore, 1989; Goulet et al., 1994; Pasnak Kurkijan & Triana, 1988
Other Mammals		
Golden Hamster	4a**	Thinus-Blanc & Scardigli, 1981
Psittacine Birds		
African Grey Parrot	6b	Pepperberg& Funk, 1990; Pepperberg & Kozak, 1986; Pepperberg & Willner, 1997
Cockatiel	6b	Pepperberg& Funk, 1990
Illiger Macaw	6b	Pepperberg & Funk, 1990
New Zealand Parakeets	6b	Funk, 1996
Parakeet	6***	Pepperberg & Funk, 1990
Other Birds		
Chicken	4a**	Etienne, 1973
Magpie	5b	Pollak et al., 2000
Ring Dove	4a	Dumas & Wilkie, 1995

* Indicates findings from invisible transposition tests only

** Methods were found to be associative learning

***Subject died prior to completing the test

CHAPTER 2: METHOD FOR CONTROLLING OLFACTORY CUES IN OBJECT PERMANENCE DISPLACEMENT TESTS

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Abstract

Investigation of object permanence, a cognitive construct described in humans and primates, tests the organism's ability to follow the manipulations of search items outside of its immediate sensory perception. For canines, their most acute sense is olfaction, and object permanence studies performed to date fail to control for olfactory cues. I conducted two sets of experiments to find an effective method of controlling olfactory cues, and to determine if differences in search behavior existed in controlled and uncontrolled situations. In experiment 1, I tested 130 dogs in two groups of 65 dogs each. Dogs in Group A searched for a small, obscure visual cue (< 2.5 cm and brown) and dogs in Group B searched for a large, salient visual cue (> 9 cm and yellow). I used food in both groups because it is intrinsically motivating and highly odiferous. I used a large, yellow visual cue in Group B because yellow is a color dogs can see and it was in sharp contrast to the brown background. There was a significant difference in performance between Group A and B when olfactory cues were controlled ($p < 0.001$), but no difference in performance between the two groups when cues were not controlled. Experiment 2 built on the method used in Experiment 1 to investigate what effect olfactory cue control had on overt sniffing search behaviors in dogs when items were hidden, or visibly displaced. I tested 65 dogs in two visible displacement trials, using the same controlled and uncontrolled methods outlined in Experiment 1 for group A dogs. Dogs were universally successful in the uncontrolled hiding task ($\overline{X}$ = 100% success), but were less successful in the controlled trial ($\overline{X}$ = 23.1%, SE = 5.2%; $p < 0.001$). Additionally, I analyzed overt sniffing behavior in both trials since it had been previously reported as an unimportant indicator of olfactory search behavior. Sniffing behavior was observed significantly more frequently in controlled trials ($\overline{X}$ = 78.4%, SE = 5.1%) than in uncontrolled trials ($\overline{X}$= 12.3 %, SE = 4.1%; $p < 0.001$). Overall, behavioral responses indicate that the Ziploc™ method is an effective control for olfactory cues when testing domestic dogs. This simple, effective method could have important applicability in comparative psychological studies.

Introduction

Object permanence is the ability of individuals to mentally represent an object that is out of their immediate sensory perception. Human infants fully develop the object concept by the age of 18-24 months. Comparative studies that have addressed object permanence in dogs share a common failing. In adapting a displacement task from the human, primarily visual, paradigm, these studies have failed to adequately control for olfactory cues. Since the problem solving tasks assessing various stages of human cognitive development involve visible displacements (i.e. the object is removed from the sight of the subject), it is essential in the case of canine studies that the item be removed from other fields of perception. Failure to do this results in a failure to test the actual cognitive construct. If the dog can smell the object the during the entire test, it has not been displaced. Success in such trials can be more reasonably and parsimoniously attributed to sensory perception, not cognition.

Finding a search item that motivates the subject species is paramount in comparative studies in object permanence. If a suitable search item is not used, the lack of participation and success of the subject can be misinterpreted. For instance, Triana and Pasnak (1981) discovered this when testing object permanence in dogs. [Their study was flawed on a number of levels, as they themselves concluded later (Pasnak, Kirkijian & Triana., 1988).] They performed two different experiments, each using a different target item. When a soft pillow was used, dogs were not as motivated to perform, and did not perform successfully in all tasks. When food was used, possibly without adequate control of scent cues, all dogs were successful at all tasks. This finding illustrates both the importance of a motivating item and controlled olfactory cues in the interpretation of success in the right context.

By using items that are intrinsically rewarding, the possibility exists that olfaction will be used to "track" these items through their displacements. No study to date has actually controlled for olfactory cues. Gagnon and Dore (1992) attempted the first robust analysis of object permanence in dogs. They masked scent cues by liberally sprinkling rose water over the target object (a small rubber toy) and throughout the test area. Fans were also employed to distribute scent. Since dogs are able to discern aging of scents and distinguish easily between minute quantity differences (Ashton, Earyrs, & Moulton, 1957; Marshall & Moulton, 1981; Miller, Houghton & Carr, 1996; Passe & Walker, 1985; Pearsall & Verbruggen, 1982;

Sommerville, Darling & Broom, 1993; Steen & Wilsson, 1990), this method would not have been satisfactory to control olfactory cues. Unfortunately, most other studies testing aspects of object permanence used the general method outlined by Gagnon and Dore (1992), casting doubt on results obtained and interpreted by other researchers (Gagnon & Dore, 1993, 1994; Dore et al., 1996; Fiset, Beaulieu & Landry, 2003).

Gagnon and Dore (1992) also documented the use of olfaction by the presence of overt sniffing behavior. They found that sniffing was significantly more prevalent in invisible displacements than in visible displacements, but that there was no performance difference associated with sniffing. They interpreted this result to mean that dogs did not use olfactory cues in search behavior for lost objects. However, scent discrimination occurs with every inhalation (Von Bekesy, 1964), and overt sniffing behavior may not be present when the scent is easily discernable. Sniffing behavior alone does not represent an accurate measure of the presence and relevance of olfactory cues. Additionally, Gagnon and Dore (1992, 1993) and Dore et al. (1996) all reported a low incidence of non-responsive trials. They attributed that to highly motivated subjects, but it could be due to the persistent presence of olfactory cues that never allowed a true "displacement" from sensory perception to occur.

Olfaction is a fundamental and acute sense in both domestic dogs and wild dogs. There is ample physical evidence pointing to the evolutionary significance of olfaction to canines. Compared with primates and other primarily visual mammals, the olfactory bulb in the canine brain is much larger. Approximately 250 million neurons in more than 1000 different classes (Buck & Axel, 1991) are on nasal epithelial tissue which itself exhibits extremely high surface area (Cain, 1988). The canine nose can discriminate particles at the concentration of one part per trillion and is unparalleled by machinery (McCartney, 1968; Passe & Walker, 1985). Information gained from olfactory neurons has a separate route and a different method of processing when it gets to the brain (Axel, 1995). Moreover, olfactory neurons are the only neurons that are myelinated and fully functional at birth in puppies, indicating that olfaction plays an early and important role in development (Fox, 1971).

Olfaction plays a role in both survival and communication in canines. Prey location and tracking, as well as predator avoidance, are important aspects of survival. Dogs are highly sensitive to classes of compounds associated with body fluids and injury (Pearsall & Verbruggen, 1982; Wright, 1964), and can determine the direction of a set of tracks by discriminating the chemical decay rate of each individual track (Wright, 1964). Chemical communication is well developed between conspecifics. Dogs are able to identify specific individuals (Dunbar & Carmichael, 1981; Sommerville & Green, 1989) and determine sexual status of mates (Beach, Beuhler & Dunbar, 1983) from urinary scent cues. Domestic search dogs are able to distinguish between identical twins (Hepper, 1986; Kalmus, 1955;) and people in different emotional states (LeGuerer, 1994; Strong, Brown & Walker, 1999). Relative to the experience of dogs, the world of olfactory discrimination is alien to humans; until acknowledge the biological abilities of the species we test, we cannot hope to design effective experiments in cognition.

In this study, I provide a new method for control of olfactory cues in comparative cognition studies. Inspired by advertising claims that Ziploc™ bags were airtight, I designed a procedure to eliminate any odor cue from escaping from the bag or contaminating the outer surface of the bag, while preserving the view of the search item inside the bag. This allowed me to control for olfactory cues while preserving the integrity of the task and without modifying any other element, in contrast to other studies (Dore et al., 1996; Dumas, 1992, 2000; Dumas & Dore, 1989, 1991; Goulet, Dore & Rousseau, 1994; Gruber, Girgus & Banuazizi, 1971; Pasnak et al, 1988; Thinus-Blanc, Poucet & Chapuis, 1982; Triana & Pasnak, 1981).

In this paper, I outline the method for implementing proper olfactory cue control, show behavioral differences in performance based on olfactory cue control, and postulate the reasons for the increase in overt sniffing behavior. Through behavioral evidence, I show that success and search performance in domestic dogs differs significantly between controlled and uncontrolled olfactory situations. This is the first concrete evidence for this effect in domestic dogs in object permanence tests. In addition, I found that sniffing behavior significantly increased when olfactory cues were controlled, alluding to the possibility of inhalation of scent cues with each breath in uncontrolled situation. Gagnon and Dore (1992) observed a much lower incidence of sniffing, which may be further evidence of incomplete or inadequate olfactory cue control using the masking method.

EXPERIMENT 1

The aim of this experiment was to determine the effectiveness of an olfactory cue control method for application to object permanence tests in dogs.

Method

Subjects

One hundred and thirty home reared naïve domestic dogs (75 females, and 55 males) participated in this study. Dogs ranged from 3 months and 12 years of age ($\overline{X}$ = 2.4 years). The dogs represented 42 breeds, in all seven AKC breed groups. The dogs were tested in two groups (A & B, see below) of 65 individuals each, in both olfactory controlled and non-controlled situations. The test facility, a daycare service, was familiar to all of the dogs, and the dogs were habituated to attending daycare for a period of two weeks prior to testing. The dogs were not food deprived and were fed at least two hours prior to testing. All trials were conducted between 9 am and 2 pm. Pilot studies revealed that dogs were too excited to participate before or after that time interval; they associated early/late removal from the main groups with imminent return and reunion with their owners. The variables in their home environment were not controlled, but were assumed to be randomly distributed across test groups.

Apparatus

The target object was a Milkbone™ puppy biscuit, chosen for its salience and desirability as a food item, as well as for its small, consistent size (2.4 X 1.2 cm) and brown color. The biscuit was presented in two formats. Dogs in Group A (small item) were tested with the biscuit alone. The biscuit did not present a strong visual cue; it was small in size, and its color blended into the background. Dogs in Group B (large item) , were tested with a biscuit inserted into a yellow rubber disk 9.5 cm in diameter. Dogs can clearly distinguish the color yellow (Jacobs et al., 1993; Neitz, Geist & Jacobs, 1989) and the size allowed a distinguishable visible cue (Humphrey & Warner, 1934; Karn & Munn, 1932).

Double Freezer Ziploc™ bags were used to control olfactory cues. I chose them because they were transparent and are advertised as airtight. Dogs could observe but not smell the contents of the bag.. A wide variety of other studies have used Ziploc™ bags to maintain airtight conditions in experiments (Bogaert, Goeman & de Ridder, 2004; Brixie, Neilson & Kim, 1997; Kim, Hearnsberger & Eun, 1995; Rozum & Maurer, 1997).

Procedure

Dogs were acclimated to experimenters and surroundings for 10 minutes, during which they were free to interact with the environment and the experimenters. Dogs who showed aggressive or fearful responses that did not abate within ten minutes were not tested.

Two people participated in the trial. The experimenter handled the bag and displaced the target object. The handler restrained the dog and placed the target object in the bag. Two other individuals observed, timed and recorded data from each trial but did not interact with the dog.

After the initial acclimation period, the dog was removed from the room while the trial was set up. The handler brought the dog back into the room, holding it by its collar. The dog and handler were stationary when the experimenter approached. All experimenters washed their hands prior to each trial with the same brand of dish soap to ensure no relevant scent cues were on the outside of the bag. Other methods of sterile handling, such as latex gloves, had been shown to have an aversive effect (Willis-Jamtgaard, unpublished data).

The experimenter carried a Ziploc™ bag to the dog, and opened it approximately 30 cm from the dog's face at eye level, where the discrimination ability of canine vision is most acute (Parry, 1953). The dog was restrained by the collar by the handler who held the target item, either the biscuit alone (Group A) or the biscuit + disk (Group B). The handler, with the dog's attention focused on the transfer, dropped the target object into the bag held open by the experimenter, being careful not to touch the outside of the bag with the object or hands. If the target item or hand touched the exterior of the bag, as determined by the experimenter or the handler, the dog was removed from the room, and the trial was set up again.

Each dog was subjected to two trials, one with an unsealed bag (uncontrolled condition) and one with a completely sealed bag (olfactory cue controlled condition). The two trials were presented in random order and the dog was removed from the room between trials. Group A dogs were tested in the above conditions with the biscuit only (small visual cue) while Group B dogs were tested with the biscuit + disk (large visual cue). The experimenter placed the bag containing the item on the ground 2.5 meters away from the dog, within its visual field. When the experimenter returned to the dog, the dog was released to search for the item.

A trial was successful if the dog performed directed action on the target object within 60 seconds of initiating search behavior. Directed actions were defined as pawing, mouthing, nosing, biting or retrieving. Sniffing alone without physical contact or other directed action did not constitute a successful trial.

Results

I used a logistic regression model to determine if breed, age or sex influenced performance and found no significant influence. I pooled the data and used a chi-square analysis to compare differences in performance of dogs in controlled and uncontrolled trials. There was a significant performance difference between Group A (small object) and Group B (large object) in the olfactory controlled trials ($X^2 = 86.8$, $df = 3$, $p < 0.001$). Small objects were visually obscured on the brown carpet and difficult to locate (mean success = 21.5% , SE = 5%) while large objects appeared to be easier to locate (100% success). There was no difference between the groups in the uncontrolled trials ($X^2 = 1.25$, $df = 3$, $p > 0.1$). Small objects ($\overline{X}$ = 93.8%, SE = 2.9 %.) were located as easily as large objects ($\overline{X}$ = 97.5%, SE = 1.7%) (Figure 1).

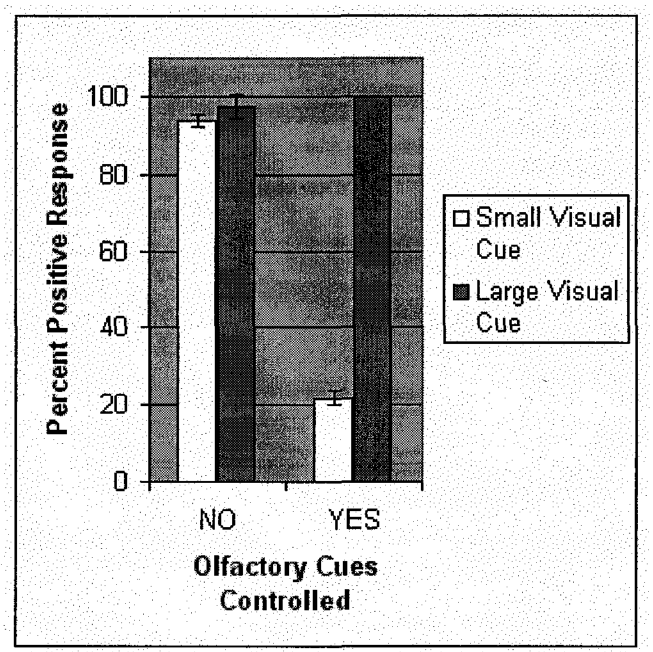

Figure 2.1: Responses to large and small visual stimuli in the presence and absence of olfactory cue control

Discussion

The degree to which an item is visually conspicuous has an effect on search success only when that item is in a sealed bag. Therefore, the Ziploc™ bag method of olfactory cue control appears to be extremely effective based on the difference in successful search behavior between controlled and uncontrolled groups when the search item was visually inconspicuous. The situation presented to dogs in Group A (small object) required them to rely on senses other than vision to locate the object. This provided a more accurate test of their reliance on olfactory cues in searching and the effectiveness of control. When the object was small and obscured and when bags were sealed, dogs were unable to locate the item the majority of the time, meaning that olfactory cues were unavailable to them. This finding is consistent with other published work using Ziploc bags as airtight containers (Bogaert et al., 2004; Brixie et al., 1997; Kim et al, 1995; Rozum & Maurer, 1997).

The size and contrast of the object appears to influence success, i.e. dogs are able to use other senses when their primary mode of perception is eliminated. When the target object was large (Group B), the sealed/unsealed bag treatment made no difference. For such a test, it is important to choose a search item that is able to be clearly seen, given dogs' visual limitations in color and discrimination (Jacobs et al., 1993; Neitz et al., 1989; Piechl, 1991).

This experiment used objects that were within the dogs' visual field, not hidden objects. The behavioral evidence from this experiment indicates that dogs rely heavily on olfaction even when the task does not involve disappearance. An object permanence experiment is supposed to test the ability of an animal to mentally represent an object outside their sensory perception (Piaget, 1952/1936, 1954/1937). It is clear from the results of Experiment 1 that both olfactory cue control in testing and a shift in the dogs' primary search mode are possible with careful experimental design.

EXPERIMENT 2

The aim of this second experiment was to determine the effect of the Ziploc™ olfactory cue control method (see above) on a simple displacement or hiding task where the object was removed from the visual field of the dog. Gagnon and Dore (1992) found that dogs displayed overt sniffing behavior when items were displaced in the more difficult object permanence tasks. They concluded that dogs did not use olfaction in searching for lost objects because sniffing behavior did not seem to correlate with success. I hypothesized that olfactory cues were being processed in easier tasks with every inhalation, but the overt sniffing behavior did not manifest until the dogs were confused. To test this hypothesis, I designed a simple displacement task using the small item situation (described for Group A above) that looked at the presence of sniffing behaviors and success in the controlled and uncontrolled situations.

Method

Subjects

Sixty five home reared domestic dogs (39 females, and 26 males) that were used in Experiment 1 (Group A) participated in this experiment. Dogs ranged between 3 months and 12 years, with the mean age being 2.5 years of age. The dogs represented 28 different breeds and six of the seven AKC breed groups (Herding, Working, Sporting, Non-sporting, Hound and Terrier).

Apparatus

All conditions were the same as for the small object situation (Group A) in Experiment 1, except that a single opaque screen (100 cm X 90 cm) was used to obscure the object.

Procedure

The experimenter carried a Ziploc™ bag to the dog, and opened it approximately 30 cm from the dog's face at eye level. The handler restrained the dog by the collar and also held the target item (biscuit). The handler, with the dog's attention focused on the transfer, dropped the target object into the bag held open by the experimenter, being careful not to touch the outside of the bag with the object or hands. If the target item or hand touched the exterior of the bag, as determined by the experimenter or the handler, the dog was removed from the room, and the trial was set up again.

The experimenter placed the bag containing the item on the behind an opaque screen 2 meters from the dog. The disappearance trajectory was within its visual field. When the experimenter returned to the dog, the dog was released to search for the item.

A trial was successful if the dog performed directed action on the target object within 60 seconds of initiating search behavior. Directed actions were defined as pawing, mouthing, nosing, biting or retrieving. Sniffing alone without physical contact or other directed action did not constitute a successful trial. Overt sniffing behavior was documented when the dog took a deliberate forceful inhalation through the nose during the search process. One or more episodes of overt sniffing during a trial qualified as the presence of sniffing behavior.

Results

First, I used a logistic regression model to determine if breed, age or sex influenced performance and found those variables had no significant effect. I pooled the data and used a paired t-test to analyze performance differences between the controlled and uncontrolled situations in the simple displacement task. I found that there was a significant performance difference between controlled and uncontrolled displacements ($p < 0.001$). When olfactory cues were not controlled, dogs were universally successful ($\bar{X}$ = 100%). In controlled trials, success was significantly lower ($\bar{X}$ = 23.1%; $p < 0.001$), similar to the results of Experiment 1.

In analyzing the presence of sniffing behaviors, I also used a logistic regression model to determine if breed, age or sex influenced the display of sniffing behavior and found those variables had no significant effect. I pooled the data and used a paired t-test to analyze the presence of sniffing behaviors in the controlled and uncontrolled trials of the displacement task. Dogs displayed significantly more overt sniffing behavior in the controlled trials ($\bar{X}$ = 78.4%, SE = 5.1%) than in the uncontrolled trials ($\bar{X}$ = 12.3%, SE = 4%; $p < 0.001$) (Figure 2).

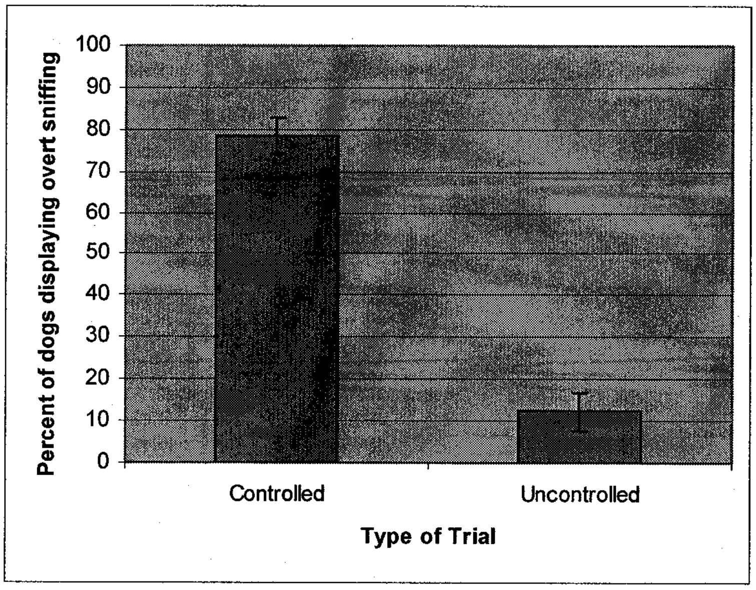

Figure 2. 2: Percent dogs displaying overt sniffing behavior in the presence and absence of olfactory cue control

Discussion

The difference in performance success between the uncontrolled and controlled olfactory cue situations is consistent with results of Experiment 1. The increased frequency of sniffing behavior when olfactory cues were controlled may demonstrate the reliance of dogs on olfactory cues and alludes to a more passive method of scent cue processing when cues are readily available. This result supports the importance of olfactory cue control techniques in displacement experiments.

Gagnon and Dore (1992) found that overt sniffing behavior occurred during the more difficult displacement tasks, not the easier tasks. The simple displacement presented in my experiment would be categorized as an easy task. Because the presence of overt sniffing behavior was observed in the controlled trial but not in the uncontrolled trial, this frames Gagnon and Dore's interpretation differently. The minimal overt sniffing in their easier tasks may indicate that their rose water method of masking scent cues was ineffective.

General Discussion

Behavioral evidence presented in my experiments illustrates the importance of eliminating olfactory cues in object permanence (displacement) tests. I found a drastic difference that depended on the control of olfactory cues. This finding casts doubt on previously published studies in dogs (Dore et al., 1996; Dumas, 1998; Fiset et al, 2003; Gagnon & Dore, 1992,1993, 1994; Pasnak et al., 1988; Triana & Pasnak, 1981) and in other species with olfactory acuity (Dumas, 1992, 2000; Dumas & Dore, 1989, 1991; Dore et al., 1996; Goulet, et al. 1994; Gruber et al., 1971; Pasnak et al, 1988; Thinus-Blanc & Scardigli, 1981; Thinus-Blanc et al., 1982; Triana & Pasnak, 1981).

Previous studies on object permanence in dogs have attempted to address the domestic dog's ability to locate items by scent in different ways (Dore et al., 1996; Dumas, 1998; Fiset et al, 2003; Gagnon & Dore, 1992, 1993, 1994; Pasnak et al., 1988; Triana & Pasnak, 1981), but none of the methods mentioned above have been shown to eliminate potential olfactory cues in searching. My method of eliminating olfactory cues provides a true scientific control of this important confounding variable in comparative cognition studies in dogs. This method is almost universally applicable to other species; ease and low cost are also appealing aspects.

In summary, a closer look at all comparative studies is needed so that experimental design takes the biological abilities of the species into account. Such convoluted methods have been used to mask olfactory cues that in many instances the nature of the displacement problem is obscured. Decades after von Uexkull emphasized the importance of umwelt, we still struggle with this fundamental concept. There are many challenges in applying human cognitive tests to other species, and it is imperative that we carefully blend biology and psychology to effectively answer these important questions.

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CHAPTER 3: A REEXAMINATION OF OBJECT PERMANENCE IN THE DOMESTIC DOG

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Abstract

Object permanence is the primary cognitive milestone achieved by non-verbal human infants and has been an obvious focus for comparative studies. There are inherent challenges to adapting the Piagetian framework to other species. Previous studies on domestic dogs, and indeed other animals, have failed to control for the effects of olfaction and learning which could confound the interpretation of results. My experimental design controls for both of these effects and reexamines object permanence in domestic dogs. In agreement with previous studies, I found that domestic dogs as a species are capable of achieving a fully developed object concept (36 %), although I observed great diversity in performance. I found that the effects of breed, sex, and age differences could not account for this diversity. In contrast to previous studies, I found that dogs as young as four months showed complete object permanence, in contrast to previously published findings. Through random order task presentation in single trials, I rigorously examined ordinality, and found that it was highly conserved in 98.8% of trials. Additionally, this method shows that object permanence cannot be attributed to learning or previous experience. I found further evidence supporting ordinality of stage acquisition by examining the mistakes dogs

made a higher order tasks. I observed the A not B error in two dogs at the appropriate stage, in contrast with previous studies. I also found that dogs at stage 5b showed stage 5 search behavior, and dogs at stage 6a showed stage 6 search behavior ($p < 0.001$) which demonstrates the theorized operational schema of particular cognitive stages. This has not been reported previously in dogs. I found that there was no difference in search times between visible and invisible displacements, but unsuccessful trials were significantly longer than successful trials. Since I only included active search times in this analysis, this difference alludes to metacognition, i.e., dogs' knew that they did not know how to solve the tasks. Search behaviors were also different between trials with different outcomes, which further supports the metacognition hypothesis. Overall, my experiment was the first to effectively address biological concerns with the application of cognitive tasks to domestic dogs. My experimental design is simple and effective, and could easily be applied to other species.

Introduction

Animals and humans inhabit a world in which objects move in space. The appearance, disappearance and reappearance of objects play a fundamental role in daily survival. The ability to recognize an object as being the same despite manipulation and to find that object if it has disappeared is of great adaptive value. Etienne (1984) discussed hunting and predator avoidance strategies in this context. Admittedly, animals can solve these problems using sensory perception, if such cues are available. However, some natural problems may present no perceptual cue on which to rely. These require a more abstract solution in which the animal must be able to represent the absent object and understand relationships of objects in space. Piaget provides an ideal conceptual framework for the investigation of how organisms solve these problems.

Object permanence is a cognitive construct defined by Jean Piaget as the ability to mentally represent an object that is hidden from sensory perception (Piaget, 1954/1937). The object concept is fully developed by the end of the sensorimotor period, approximately 18-24 months of age in humans. Since this cognitive structure is the primary non-verbal milestone achieved in humans, it has been an obvious focus for comparative studies in cognition. Piaget's concept of cognition is attractive to comparative researchers for two main reasons: 1) It provides behaviorally observable stages and 2) it is viewed as biological in nature with stages acquired sequentially.

Object permanence is divided into six stages. In stages 1 and 2 infants show little interest in objects and do not display search behavior. In Stage 3, the object concept begins to emerge with visual accommodation and the reconstruction of an invisible whole from a visible part. In Stage 4, the subject can find a hidden object only if search for the object begins prior to disappearance (Stage 4a). Later (Stage 4b), this condition is no longer a prerequisite to success (*single visible displacement*). However, stage 4b subject cannot solve *sequential invisible displacements* and displays the classic A-not-B error (in which subject cannot separate their own actions from the movements of the object). In stage 5, the A not B error resolves and attempts at sequential (Stage 5a) and *successive visible displacements* (Stage 5b) become successful. As a part of stage 5b, *single invisible displacements* can be solved, but the A-not-B error manifests again if *sequential invisible displacements* are attempted. Success at sequential invisible displacements (Stage 6a) and *successive invisible displacements* (Stage 6b) results in a fully developed object concept (Piaget, 1952/1936, 1954/1936) (Appendix I)

Underlying mechanisms driving search behavior change throughout development, which can explain the choices that animals make when operating at various levels of cognition. Search behavior at stage 4 relies on egocentrism, or the subject's belief that their own actions determine the location of the object. Stage 5 subjects are guided by perceptual cues. In stage 6, animals are able to form an internal symbolic representation of the object and infer invisible transfers of the object based on logical evidence. Ordinality, or the sequential nature of the stages, builds on the development of operational schema. Piagetian stages of development are acquired in order, with no stage skipped or reversed (Uzgiris & Hunt, 1975). Animal studies have supported this idea, providing further evidence of the biological nature of cognition, with a single exception (Funk, 1996).

Three main challenges exist in adapting Piagetian object permanence tasks to other species: 1) Controlling for sensory cues, 2) ensuring that cognition and not learning is what is being measured and 3) interpreting search behavior and mistakes in the appropriate context for understanding the underlying behavioral mechanisms involved with their cognitive level. I will briefly explore weaknesses in other studies in these three areas (for a complete review see Willis-Jamtgaard, 2005a), and explain how my study controls for each of these effects.

The idea of *umwelt* has been a formative concept in biology for decades (Von Uexküll, 1926), however in comparative psychology it has been frequently overlooked. In translating and adapting "human questions" to other species, often non-visual perception is often ignored in experimental design. This has been especially true in dogs with olfaction, where odor masking (Dore et al., 1996, Fiset, Beaulieu & Landry, 2003; Gagnon & Dore, 1992, 1993, 1994) or deception (Triana & Pasnak, 1981) techniques were used. In all of these cases, olfactory cues remained present, which changed the nature of the cognitive task. Since olfactory cues were not eliminated, a "displacement" never occurred. In this study, I used the Ziploc™ method of olfactory cue control (Willis-Jamtgaard, 2005b) to eliminate possible scent cues. This allowed me to use food, an intrinsically valuable search item, despite its enticing scent. By doing this, my study most closely approximates the innate interest that infants demonstrate in searching for desired objects in traditional object permanence tests (Uzgiris & Hunt, 1975).

Cognition is a combination of innate drives and developmental experience with the world that takes place over time (Piaget, 1952/1936, 1954/1937). According to this hypothesis, a subject at a particular cognitive stage cannot be taught to make a choice contrary to its operational schema (Bjork & Cummings, 1984; Bremner, 1978; Butterworth, 1977; Uzgiris & Hunt, 1975). This means that even pointing at the correct hiding location cannot induce a correct response that the subject is not cognitively able to give (Triana & Pasnak, 1981). However, recent evidence suggests that previous experience with object permanence tasks does show an improvement in performance (Johnson, Amso & Slemmer, 2003; Scholl, 2004). This "learning effect" has been demonstrated in comparative studies as well as through the order of task presentation (Dore, 1990; Dumas & Dore, 1989; Gagnon & Dore, 1992) and has been shown to increase success at solving displacements. Presentation of multiple trials of the same task is likely to influence success in the same way, although most studies neglected to analyze their data in this way (Dore et al., 1996; Dumas, 1992; Dumas & Dore, 1989; Dumas & Wilkie, 1995; Etienne, 1973; Gagnon & Dore, 1992, 1993, 1994; Goulet, et al., 1994; Pepperberg & Kozak, 1986). My study presents tasks in a random order and only once to control for potential learning effects. Moreover, this method provides a robust assessment of ordinality, even though it is not a longitudinal study. Ordinality has not yet been tested comparatively through random presentation of tasks.

Search behavior and mistakes made by animals in comparative cognitive experiments can sometimes shed light on the thought process or schema used by that animal. Search time, specific confusion behaviors and the type of mistake made are all ways in which behavioral observations can provide evidence of such schema. Gagnon and Dore (1993) discussed search time differences between visible and invisible displacements, finding that dogs take longer to search in invisible displacement tasks. Previously, they found that dogs made more mistakes in invisible displacements than in visible displacements (Gagnon & Dore, 1992). They proposed that both of these observations might be due to the time delay inherent in invisible displacements, which could adversely affect working memory. Further research concluded that working memory was unaffected by delays as long as four minutes (Dumas, 1998; Fiset et al., 2003). Decrease in success rate may be attributable to the increased complexity of invisible displacements. I investigated this phenomenon, and analyzed search time differences between visible and invisible displacements regardless of outcome, and also successful and unsuccessful outcome regardless of stage. In contrast with Gagnon and Dore (1993), I found no difference between mean search times of visible and invisible displacements. However, I found search times in unsuccessful trials were significantly longer than in successful trials. This has some potentially interesting implications, including metacognition or "knowing what you know", which is difficult to address in non-verbal species.

Despite abundant evidence showing dogs are able to solve invisible displacements (Dore et al., 1996, Gagnon & Dore, 1992, 1993, 1994; Dumas, 1998; Fiset et al., 2003), Dore and Goulet (1998) assert that they do not fully understand the elements of invisible displacement on the basis of analyzing search behavior. They assert that dogs, like cats, show stage 5 search behavior. I analyzed mistakes made at the invisible displacement tasks to determine if the type of mistake corresponded to the highest cognitive stage achieved by the dog. I did find a significant relationship between the two factors, which means that mistakes do correlate to the operational schema associated with the subject's cognitive stage. This casts doubt on the idea that performance and search behavior do not correspond to the same stage, as asserted by Dore & Goulet (1998).

Method

Subjects

Sixty-five home reared domestic dogs (36 females and 29 males) participated in this experiment. Dogs ranged between the ages of 4 months and 6 years, with the mean age being 2.36 years. My experiment included dogs up to age six, but not older because of possible sensory and cognitive deterioration. No dog with an observed or owner described sensory deficit was used. Birth dates were provided by the owners, and in some cases of rescue dogs, were approximate. The dogs represented 31 different breeds, with members in all seven AKC breed groups. All dogs were owned dogs. The variables in their home environment were not controlled.

The test facility, a daycare service, was familiar to all of the dogs, and the dogs were habituated to attending daycare for a period of two weeks prior to testing. Participants were selected based on a lack of anxiety or aggression during the acclimation period and their desire to consume Milkbone™ dog biscuits. Fifty-one dogs were excluded from this study because they did not meet the evaluation criteria (see Appendix).

Dogs were not food deprived during this experiment. They had been separated from their owners for at least two hours, and no food had been given during that separation period. However, all the dogs had a morning meal 2 or more hours prior to testing. All trials were conducted between 9 am and 2 pm. Pilot studies revealed that dogs were too excited to participate before 9 am or after 2 pm, since they associated early/late removal from the main groups with imminent return and reunion with their owners.

Apparatus

The target object was a Milkbone™ puppy biscuit inserted into a yellow rubber disk (Goodie Ship™) 9 cm in diameter. The disk was chosen for easy identification and discrimination at a distance. Double Ziploc™ freezer bags were used to control olfactory cues. The experimenters washed their hands with soap prior to each trial, and opened a Ziploc™ bag. The handler, with the dog's attention focused on the transfer, dropped the target object into the bag held open by the experimenter, being careful not to touch the outside of the bag with the object or his/her hands. The experimenter sealed the bag, and performed the appropriate displacement (Willis-Jamtgaard, 2005b).

Screens were white foam board panels (100 cm X 90 cm tall) with sides angled at 45 degrees to prevent viewing from the front. Four screens were arranged in a semi-circle be equidistant from the subject's starting position. For invisible displacements, an opaque container made of brown paper was used. The container was discarded at the end of each trial, and the screens were wiped down with a dilute solution of dish soap to further control any odor cues.

Procedure

A ten-minute acclimation period was used to familiarize the dog with the experimenters and the surroundings during which the dog was free to interact with the environment and the experimenters. Dogs who showed aggressive or fearful responses that did not abate within ten minutes were not tested.

A trial was considered successful if the dog actively searched and performed directed action on the target object within 60 seconds of the displacement of the object. Directed actions were considered pawing, mouthing, nosing, biting or retrieving. Sniffing alone without physical contact or other directed action did not constitute a successful trial. Active searching was defined as the investigation of screens or containers, either correctly or incorrectly. Only the first choice location investigated by the dog was recorded. After their first choice, dogs were removed from the room and the next test trial was set up. Passive response was defined as the investigation of unrelated portions of the room (gates, windows, walls) or the lack of any search behavior (sitting or laying down). Dogs that displayed passive responses for 60 seconds were recorded as a negative response for that cognitive stage. I chose 60 seconds as the duration based on previous studies (Gagnon and Dore, 1992, 1993). In a pilot study, I investigated performance up to four minutes, and found that no dog ever initiated active search behavior after 60 seconds, effectively giving up prior to this time.

The potential effect of cuing in face-to-face administration of Piagetian object permanence task certainly exists. Every effort was made to minimize this possibility. The handler and experimenter did not interact with the dog after the dog was released to search. They faced in random directions and stood with arms folded. No verbal or physical interaction occurred during the trial after the dog was released to search. Olfactory cues were controlled in the same way for all tasks (Willis-Jamtgaard, 2005b).

Task 1 was always administered first. This simple displacement, described below, was used to assess motivation to search for a lost object. This task did not directly correspond to a particular cognitive stage, but tested comfort with the screen and the basic displacement procedure. If a dog did not perform an active search in this task, it was not tested further and excluded from the study.

A trial consisted of the presentation of one of the tasks (listed below) and the opportunity for the dog to display search behavior. After the subject's first search choice was recorded, the dog was removed from the room prior to the next trial. Tasks 2-8 were presented in random order to minimize any effect learning or experience might have. Each task was administered only once.

Task 1: Simple visible displacement

The dog was positioned two meters from a single screen and the handler held the collar to restrain the dog during the displacement procedure. The item was placed in a Ziploc bag using the method described above, and the experimenter displaced the item behind the screen. The dog was released to initiate search behavior once the experimenter had returned to the dog (within 5 seconds).

Task 2: Single visible displacement (4a)

The dog was positioned at the center of four equidistant screens, approximately two meters away and was held by the handler. The item was displaced behind one of the four screens, and the animal was released to search prior to the disappearance of the object.

Task 3: Single visible displacement (4b)

The procedure is the same as in Task 2, except that search behavior was not initiated until the experimenter returned to the dog after displacing the object. The object was completely out of sight at this time.

Task 4: Sequential visible displacement (4b/5a)

Because this task asks about the relative importance of perception and prior experience, multiple trials were performed. A single visible displacement was performed four times (Task 3) using the same screen for successful location. On the fifth trial, the item was displaced behind a different screen. The subject's performance here distinguished between stage 4b and stage 5a.

Task 5: Successive visible displacement (5b)

The dog was positioned and restrained as described above. The search item was displaced behind one screen, reappeared in the subject's visual field, and was displaced behind a second screen. The dog was allowed to initiate search behavior once the experimenter returned to the dog.

Task 6: Single invisible displacement (5b)

The item was placed into the container as the dog observed. The container was closed prior to further manipulation of the item. The experimenter moved behind a screen, removed the search item from the container while out of the dog's view, and returned to the dog. The dog was shown the empty container, which was then moved to a separate location on the floor in an opposite direction from the screens. The experimenter returned to the dog, and the dog was allowed to initiate search behavior.

Task 7: Sequential invisible displacement (6a)

This task also required the performance of multiple trials. The single invisible displacement (Task 6) was repeated four times, with the same screen being used as a successful choice. On the fifth trial, the item was displaced behind a different screen. The subject's performance here differentiated between stage 5b and stage 6a.

Task 8: Successive invisible displacement (6b)

This task was analogous to Task 5, except it involved the invisible displacement procedure. The item was displaced behind one screen, then reappeared within the subject's visual field and was displaced behind a second screen.

Results

Assessment of Object Permanence

My results confirm that domestic dogs achieve the highest stage of object permanence, even under olfactory cue controlled conditions. However, their success was not uniform (Table 1). Most of the dogs achieved stage 5b or higher (92%), while only 36% achieved complete stage 6b object permanence.

Highest Stage of Object Permanence Achieved	Corresponding Tasks	Number of Dogs
Stage 4a	Task 2	0
Stage 4b	Tasks 3 and 4	2
Stage 5a	Task 4	3
Stage 5b	Task 5 and 6	24
Stage 6a	Task 7	12
Stage 6b	Task 8	24

Table 3. 1: Highest stage of object permanence achieved in domestic dogs

I used a logistic regression model to determine if age, breed and sex influenced the achievement of object permanence in the domestic dog, and found no significant differences for any of those variables. I pooled the data and used a one-way ANOVA on the highest stage and found significant differences among all the performance categories except 4b and 5a ($p < 0.001$, $N = 65$) (Figure 1).

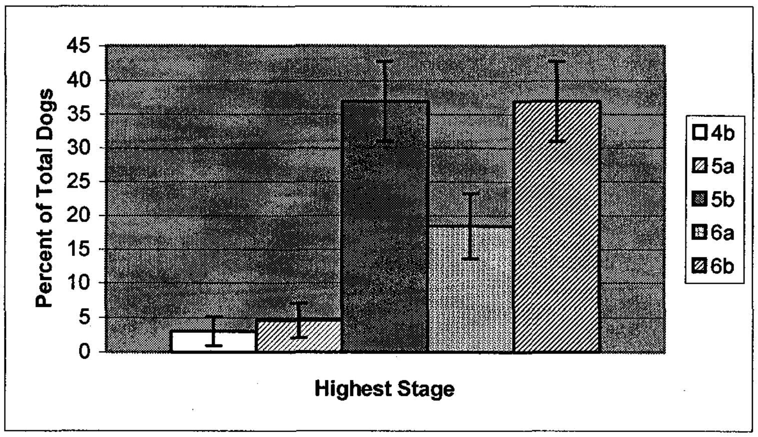

Figure 3. 2: Highest stage of object permanence achieved in domestic dogs

Ordinality

Ordinality was highly conserved in my object permanence study, meaning that success at higher stages was rarely seen without success at lower stages. Each dog was administered a total of seven tasks, in a random order, after first assessing motivation to search with a single trial of a simple displacement problem. In all, there were a total of 520 tasks assessing stages of object permanence. Ordinality was conserved in 98.8% of these tasks. In six tasks, one in each of six different dogs, a lower stage was failed, and the dog was successful at higher stages. This occurred in one 6a task, three 5b tasks, and two 4b tasks.

Search Strategies and Mistakes

In general, I observed two primary strategies for dealing with a displacement problem: active search and passive response. Active search was considered a directed movement toward a relevant part of the room or apparatus. Passive response was deemed a lack of directed investigation, when the dog did not move from the initial location, or investigated other parts of the room unrelated to the test. In stage 6b invisible displacement tasks, search behavior directed at the container would correspond to stage 5 search behavior, or reliance on immediate perceptual cues. Search behavior directed at the first screen would show stage 6a search behavior, or the ability to partially infer the invisible transfer of the object from the container.

For two dogs, 4b was the highest stage achieved. Both dogs showed the A not B error in sequential visible displacement, and in all invisible displacement tasks searched at the container instead of the screens. Both dogs showed active search behavior during all trials.

Three dogs achieved stage 5a as their highest successful stage. At higher stages tested, all of these dogs exhibited passive response instead of active search, with a single task exception for one of the dogs. At 6a, that dog searched at the container.

Twenty-five dogs achieved stage 5b as their highest stage and showed great uniformity in their responses. There were two tasks associated with stage 5b, the successive visible displacement and the single invisible displacement. All 25 dogs were successful at the successive visible displacement task. However, only two were successful at the single invisible displacement task. Twenty-two of the dogs displayed search behavior at the container in this task, while one dog searched at a random screen. In the sequential invisible displacement task, corresponding to stage 6a, 23 of the dogs searched at the container, one dog searched at a random screen, and one dog was successful (see above for ordinality results). During the successive invisible displacement task, 19 of the dogs searched at the container, 3 dogs searched at the first screen, and 3 dogs lost interest and exhibited passive responses.

Twelve dogs achieved stage 6a as their highest stage, and made mistakes at the stage 6b task. Eight of them searched at the first screen, while only three searched at the container. One dog lost interest and exhibited a passive response.

I analyzed the active searches at the stage 6b task of dogs whose highest stages were 5b and 6a. More dogs whose highest stage was 5b chose to search at the container (which corresponds to stage 5 search behavior), while more dogs at stage 6a searched at the first screen (which corresponds to stage 6 search behavior) (Figure 2). I used a chi-squared analysis to compare stage 5 and stage 6 mistakes and found the correlated to the highest stage achieved by the dog ($X^2 = 13.8$, df = 1; $p < 0.001$, N = 33).

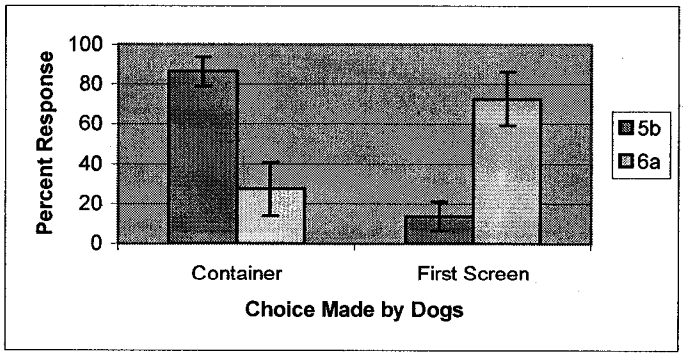

Figure 3.3: Active search choices during the 6b task made dog whose highest successful stage was 5b or 6a

Search Times

I analyzed search times in three different ways. Only active searches were included in this analysis. Trials in which dogs lost interest or timed out were not analyzed.

First, I found the mean successful search time among all tasks ($\bar{X} = 5.7$ s, SE = 0.41 s) was significantly shorter than the mean unsuccessful search time for all tasks ($\bar{X} = 11.7$ s, SE = 1.36 s; $p < 0.001$, unpaired t-test, N = 506) (Figure 3).

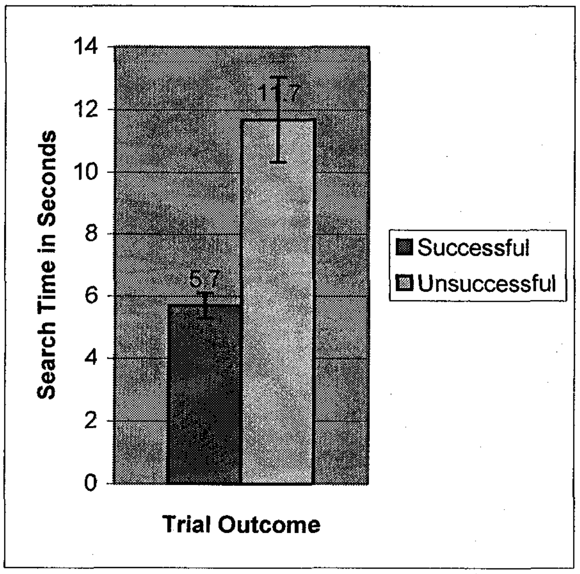

Figure 3. 4: Overall Difference in Search Times Between Successful and Unsuccessful Trials

Second, I invisible displacements had a greater proportion of unsuccessful trials than did visible displacements. It was possible the observed difference between successful and unsuccessful trials was due to the level of difficulty inherent in invisible displacements. I compared mean search time of visible displacement ($\overline{X}$ = 6.35 s, SE = 0.53 s) to mean search time of invisible displacement ($\overline{X}$ = 6.38 s, SE = 0.66 s; $p = 0.48$, unpaired t-test, N = 506). All active searches were included in this comparison, regardless of outcome.

Third, individual variability in search time could account for some of the difference in the effect observed in Figure 3. I analyzed this potential effect by comparing the highest level successful task and the subsequent unsuccessful task for the same dog (Figure 4). The two tasks compared were individual to each dog, for example: 5a and 5b for one dog and 6a and 6b for another. Recall, the tasks were presented in random order, so the next cognitive stage was not necessarily the next presented task. This comparison addresses differences observed in concrete cognitive stages. There was a significant difference between search times in the last successful stage ($\overline{X}$ = 4.02 s, SE = 0.55 s) and the first unsuccessful stage ($\overline{X}$ =13.7 s, SE = 2.01 s; $p < 0.001$, paired t-test, N = 88).

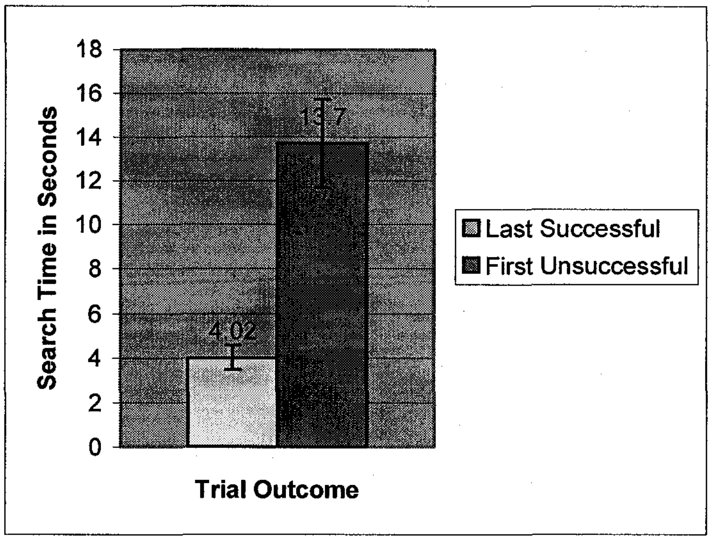

Figure 3. 5: Search Times Between the Highest Successful Displacement Task and the Subsequent Unsuccessful Task

Missing Data and Excluded Animals

There were five dogs (2 Labrador Retrievers, 1 American Bulldog, 1 Giant Schnauzer, and 1 Scottish Terrier) that qualified as participants but were not included in the data set because of owner or health issues. Additionally, there were a total of 51 dogs excluded from further testing due to behaviors exhibited during the acclimation period or during the initial assessment of motivation. Behaviors that prompted this decision were grouped into four main categories: aggression, fear, hyper-attachment, and no interest or lack of motivation (Appendix II).

Discussion

Assessment of Object Permanence

My study is the first to explore object permanence in dogs while simultaneously controlling olfactory cues, the major source of sensory perception in dogs. I also eliminated confounding variables of learning and previous experience. All of these cues and variables are present in previous studies, which demonstrated uniformity in object permanence across all domestic dogs investigated (Gagnon & Dore, 1992, 1993, 1994; Dore et al., 1996; Dumas, 1998; Fiset et al., 2003; Pasnak et al., 1988; Triana & Pasnak, 1981). In contrast, while my study does indeed support the existence of object permanence in dogs, I found significant variability in the degree to which it is expressed in individual dogs.

This variability may well reflect the more rigorous controls in my study design, or it may reflect other issues (see "Breed and Age Influences" below). Regardless, given the importance of olfaction in canine perception, it is difficult to argue that an object permanence task ignoring such cues could truly represent canine cognitive states. If olfaction is the major perceptual tool of a test species, and if olfactory cues are not controlled, then the object in question is never beyond the perception of the subject; the object's visual status is irrelevant. Indeed, Willis-Jamtgaard (2005b) has shown that dogs do not use vision as a primary searching tool until olfactory cues are compromised.

Breed and age have been examined as possible factors that affect performance (Gagnon & Dore, 1992, 1994). Sex was also examined as a variable in my study but was not found to be significant. Breed and age are concrete variables that are easy to assess, but these alone do not encompass all possible reasons for differences in stage acquisition.

Due to the large number of domestic dog breeds, assessing performance differences among breeds is difficult. Gagnon and Dore (1992) analyzed breed differences in their study, but they were limited to a small number of dogs, which were almost all terriers. They found no significant difference in performance between breed groups, but only compared terriers and sporting dogs. To better address diversity, I included dogs of all seven AKC breed groups in my experiment. My analysis examined differences among both individual breeds and AKC breed groups, and found no significant difference in overall performance. However, numbers of individuals within breeds were still small in my study, with the largest number of individuals in closely related breeds [Labrador Retrievers (13) and Golden Retrievers (9)]. Because of apparent breed differences in suitability for testing (Appendix II), some breeds are over-represented in my excluded group, resulting in unfortunate and unavoidably small samples of these breeds. In addition, I was limited in soliciting individuals from particular breeds if those individuals were not regular daycare participants. I found in a pilot study that such dogs had to be universally excluded from testing because of separation anxiety from their owners and a failure to perform. Even so, my study has the largest number of dogs and the most diverse range of breed groups of any study to date.

Age could affect performance in one of two ways: young dogs might not have fully developed object permanence, while the visual and cognitive abilities of older dogs may deteriorate. Gagnon and Dore (1994) performed the only study that addressed the development of object permanence in the domestic dog. [Other studies on domestic dogs only included subjects that were over one year of age (Dore et al., 1996; Dumas, 1998; Fiset et al., 2003; Gagnon & Dore, 1992, 1993; Pasnak et al., 1988; Triana & Pasnak, 1981). While puppies as young as eight weeks were able to solve visible displacements, dogs did not succeed at invisible displacements until one year of age (Gagnon and Dore, 1994). In contrast, my results show that puppies as young as four months display stage 6b object permanence (3 of 3 puppies at 4 months). However, theirs was a cross sectional study (Gagnon & Dore, 1994): a true longitudinal assessment has yet to be performed. The groups used in their study were made up of seven to nine individuals, and given the variability among the species, that number may not have been sufficient to show abilities of puppies at different ages.

Other variables that may account for differences in performance are enrichment provided in early development, home environment, level of training received, and temperament (see also Scott & Fuller, 1965). These factors are interrelated and difficult to investigate individually and/or in contrast. As a result, their effect on performance has yet to be examined.

Ordinality

Gagnon and Dore (1992) found that half of the subjects tested at the sequential invisible displacements exhibited the preservative error of searching at the last known location of success. In subsequent trials, this effect went away. Dogs performed better when they had been presented tasks in order (Gagnon & Dore, 1992). Both of these pieces of evidence demonstrate that order of presentation and repetition can lead to a learning effect. All other studies in dogs presented tasks multiple times, in order, or allowed trial and error learning to occur within one trial by recording the dog's last choice instead of their first (Dore et al., 1996; Dumas, 1998; Fiset et al., 2003;Gagnon & Dore, 1992, 1993, 1994; Triana & Pasnak, 1981). All of these procedures confound the testing of cognition with possible learning effects. I controlled for that by presenting each task once and recording only the first choice in searching which allowed me to investigate the hypothesis that each animal operates by a set of schema determined by their cognitive stage (Piaget, 1954/1937). According to this idea, each individual should acquire all the stages in a particular order, with no stage out of order. Since my study is the only study to assess cognitive stages in single task presentation in random order, it most rigorously examines ordinality. My results confirm that ordinality of stage acquisition is overwhelmingly preserved. Further elucidating this principle led me to analyze stage appropriate mistakes and search behavior.

Search strategies and mistakes

If ordinality exists as Piaget originally observed, then I expected to see clear categorical mistakes of those dogs that did not achieve stage 6b. When I analyzed the type of incorrect choice for dogs in stage 5b and 6a during the 6b task, a significant trend emerged. Dogs at stage 5b chose the container significantly more often than dogs in 6a. This corresponds to stage 5 search behavior, which is demonstrated by a reliance on immediate perception. Dogs in stage 5 searched at the last place the object was seen, where the object disappeared in to the container prior to displacement behind the screens. Dogs at stage 6a chose the first screen more often than the container. This corresponds to stage 6 search behavior, which demonstrates the ability to at least partially infer the manipulation of the object invisibly, without the aid of perceptual cues. The inability to mentally follow the transfer of the object from the first screen to the second would correspond with their level of success, in that this task was the one they failed to perform. These dogs can succeed at sequential but not successive displacements. This is the first evidence of its kind to support not only the achievement of stages of object permanence according to underlying operational schema, but that mistakes made by the animals are also indicative of these schema. My results are also further evidence for concrete cognitive structure and ordinality.

Search times

Gagnon and Dore (1992) concluded that invisible displacements were more difficult to solve than visible displacements due to increased search latencies which they attributed to a longer information processing time . When they compared only successful trials, invisible displacement search latencies were significantly longer than those of visible displacements (Gagnon and Dore, 1992). While my results also show that fewer dogs were successful at invisible displacement tasks, overall mean search times were the same between visible and invisible displacements when both successful and unsuccessful trials were included. This finding makes it unlikely that the difference observed between unsuccessful and successful trials is due to the inherent difficulty of invisible displacement tasks.

I found a significant difference in search times between successful and unsuccessful trials when I analyzed the search times of all trials. My result demonstrates that dogs take more time to search when the outcome is unsuccessful. In theory, it should take the same amount of time to make a right choice as to make a wrong choice, since the screens are equidistant from the starting point. However, in my study behavioral differences exist between searches with different outcomes. The term search latency was used to describe search time differences by Gagnon and Dore (1992), but in my study that term cannot completely describe the reason for the difference between successful and unsuccessful outcomes. While I observed that some dogs did self-impose an actual delay in searching, many proceeded more slowly towards their choice, often hesitating or changing direction. These results allude to the presence of metacognition. If interpreted in this way, the dogs were behaving differently and taking longer to make a choice because they knew they did not know how to solve the problem.

To investigate whether time differences were present as soon as the dog's cognitive threshold was reached, I compared times from the highest order task with the next sequential task. The results mirrored what was found when overall mean times were compared; unsuccessful search times were significantly slower than successful search times. This means that dogs were equally slow at all unsuccessful tasks. Since tasks were presented in a random order, this effect is especially convincing because it was not comparing sequential trials but sequential stages. This is an important finding because it provides evidence that dogs operate at a concrete level of cognition, and above that level higher order tasks are equally confusing. Dogs in unsuccessful trials displayed what could be called "confusion behaviors" such as fear, social referencing and giving up. Again, this may be evidence for metacognition, in that dogs may have known they did not know the correct search location.

Conclusion

This is the first study to assess object permanence in dogs using the olfactory control method described by Willis-Jamtgaard (2005) and also to control for potential learning effects. Other studies have demonstrated success at stage 6b tasks in the absence of olfactory cue control (Dumas, 1998; Fiset et al., 2003; Gagnon & Dore, 1992, 1993, 1994). My findings are in general agreement with conclusions of other studies, in that at least some dogs achieve a fully developed object concept. However, my results differ from those other studies in major ways. First, I found that dogs can achieve fully developed object permanence by 4 months of age, in contrast to a previous study which concluded that dogs were not capable of this until one year of age (Gagnon & Dore, 1994). Second, my method of robustly testing ordinality through random presentation allows me to confidently conclude that ordinality is highly conserved. Third, my method of single trial presentation of tasks, recording only the animal's first choice, shows that dogs demonstrate complete object permanence and that it is not due to learning. The learning effect was an important point confounding previous studies. Fourth, I found evidence that search behavior and mistakes made by dogs provides evidence that they are able to represent displacements at concrete cognitive stages, and do display stage 5 and stage 6a search behavior appropriate to their cognitive level. Fifth, I observed differences in search times that correlated with outcome, meaning that dogs performed differently when the outcome was successful than when it was unsuccessful. I observed a strong effect here, which may indicate that dogs possess metacognition, an aspect requiring further study. Last, domestic dogs possess the species potential for object permanence, but differences in specific case histories may influence the achievement of this potential. Investigation of these differences should be explored in future work. In summary, my method of testing object permanence provides a clear, biological approach to analyzing cognition. It is easily applicable to studies in other species where similar controls are needed to effectively interpret cognitive test results.

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Appendix I: An Overview of the Stages of Object Permanence in Humans (modified from Piaget, 1954/ 1937)

Stage/Substage	Milestone	Description of Response
1	None	Eyes fail to track a moving object
2	Visual Tracking	Eyes can follow object to point of disappearance; no search behavior
3	Partially Occluded Object	Subject can retrieve objects if they are touched prior to disappearance; mental reconstruction of object from a partial visual cue
4a	Single Visible Displacement	Subject can retrieve a completely occluded object if search behavior is initiated before disappearance
4b	Single Visible Displacement	Subject can retrieve a completely occluded object even if search behavior is initiated after the disappearance
4b	Sequential Visible Displacement	Subject fails to retrieve displaced object hidden at one location during previous trials; now hidden at a novel location; searches at previously successful location, classical mistake called A-not-B error
5a	Sequential Visible Displacement	Subject can retrieve an object hidden at one location during previous trials now hidden at a new location; relies on perceptual information over previous success: no presence of A-not-B error
5b	Successive Visible Displacements	Subject can follow successive disappearances and reappearances of object in the same trial; searching only in the place of the last disappearance
5b	Single Invisible Displacement	Subject can follow the disappearance of an object first visually occluded, then displaced at another location; relies on logical inference of perceptual cues
5b	Sequential Invisible Displacement	Subject fails to follow serial invisible displacements at one location, then at a novel location; A-not-B error resurfaces in this task at this stage
6a	Sequential Invisible Displacement	Subject can retrieve the invisibly displaced item hidden at a novel location; no presence of the A-not-B error
6b	Successive Invisible Displacement	Subject can follow the multiple disappearances of an invisibly displaced object,; relies on logical inference of perceptual cues

Appendix II: Breeds excluded from object permanence testing and the reason for exclusion

Breed	Breed Group	Number Excluded	Total Number Tested	Percent Excluded	Reason(s)
Australian Shepherd	Herding	6	9	66.7%	Fear (3), No interest (2), Attachment (1)
Belgian Terveren	Herding	2	3	66.7%	Attachment (1), No interest (1)
Border Collie	Herding	1	2	50%	Fear
Corgi (Pembroke)	Herding	2	5	40%	Aggression
German Shepherd Dog	Herding	7	8	87.5%	Fear (6), No interest (1)
Shetland Sheepdog	Herding	2	2	100%	Fear (1), No interest (1)
Great Dane	Working	1	1	100%	Fear
Great Pyrenees	Working	1	1	100%	No interest
Greater Swiss Mountain Dog	Working	1	1	100%	Fear
Rottweiler	Working	1	1	100%	No interest
Siberian Husky	Working	1	8	12.5%	No interest
Golden Retriever	Sporting	2	11	18.2%	Fear (1), No interest (1)
Labrador Retriever	Sporting	11	24	45.8%	No Interest (6), Aggression (2), Fear (2), Attachment (1)
Sharpei	Non-sporting	1	1	100%	Attachment
Basset Hound	Hound	1	1	100%	No interest
Greyhound	Hound	3	5	60%	No interest (3)
American Staffordshire Terrier	Terrier	2	3	66.7%	Fear (2)
Boston Terrier	Terrier	1	1	100%	Fear
Jack Russell Terrier	Terrier	1	3	33%	Fear
Miniature Schnauzer	Terrier	2	3	66.7%	Aggression (1), Fear (1)
American Eskimo	Toy	1	1	100%	Fear