UNIVERSITÀ DEGLI STUDI DI PADOVA

Department of Comparative Biomedicine and Food Science

First Cycle Degree (BSc) in Animal Care L-38

Disentangling Factors Affecting Dogs' Performance in Object Permanence Visual Tasks

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Abstract

This thesis investigates what guides dogs’ choices in object permanence tasks, with the aim of disentangling the relative influence of motion, spatial bias, and proximity. Eight dogs participated in a series of three tasks, a transposition task and two control conditions, one testing the role of motion and the other examining the effect of distance from the dog. The findings indicate that motion significantly impaired the dogs' performance, suggesting it acts as a limiting factor in their ability to track the hidden object. When motion was removed and the setup made stationary, the dogs' performance improved; however, a strong spatial bias emerged. Further testing revealed that this bias was related to proximity: when the influence of distance was controlled for the spatial bias disappeared. This suggests that dogs tend to approach the location closest to them, even when they had visually tracked the object being hidden elsewhere.

1.Introduction

1.1 Canine Visual Perception

Vision plays a critical role in how animals interact with their environment, and for domestic dogs (*Canis lupus familiaris*) understanding visual perception is essential for interpreting their behavior and cognitive capabilities. Dogs are frequently anthropomorphized, viewed as if they perceive the world in the same way humans do, but their visual experience is shaped by distinct anatomical and physiological features. To design effective experiments, especially those involving visual cues which happen to be the most frequently used in dogs (Bensky et. al, 2013), it is crucial to develop a more thorough understanding of the underlying mechanisms of canine vision.

Vision is not just the reception of light; it requires complex processing that begins in the retina and continues in the brain. In dogs, photoreceptor cells in the retina convert light into electrical signals that are sent via ganglion cells to the visual cortex. However, the retinal architecture—and therefore visual perception—varies significantly across breeds. Some dogs have a visual streak, a horizontal band with a high density of ganglion cells that enhances panoramic vision (McGreevy et al., 2004), while others, particularly brachycephalic breeds, have an *area centralis*, allowing for greater acuity in a focused region of the visual field (Byosiere et al., 2017). These differences are linked to variations in skull shape, nose length, and eye placement, which also affect the field of view and can cause visual obstructions from the dog's own muzzle (Roberts et al., 2004). This means that two dogs may see the same visual scene in different ways. While these observations highlight variability in visual experience between breeds, more research is needed to fully understand how these anatomical traits might translate into perceptual differences.

Color perception is another key area where canine vision diverges from ours. Dogs are dichromats, possessing only two types of cone opsins that are most sensitive to wavelengths in the blue and greenish-yellow spectrum. As a result, they have limited color discrimination, particularly in distinguishing reds from greens (Gelatt et.al., 2021). Additionally, dogs have fewer cone cells overall compared to humans, only about 3% of their retinal cells, making their color vision less acute. (Peichl, 1992).

Instead, dogs have a better scotopic vision than us since they are better suited to low-light environments due to a higher density of rod cells. These cells are highly sensitive to light and are complemented by a unique reflective layer in the eye called the *tapetum lucidum*, which enhances vision in dim conditions by reflecting light back through the retina (Gelatt et.al., 2021). This scotopic adaptation allows dogs to see in both bright and dark environments, although it comes at the cost of reduced visual acuity. Studies suggest that dogs' visual acuity is four to seven times lower than that of humans (Miller and Murphy, 1995). Visual acuity is the minimal detection power of the eye, meaning that it is a measure of how well an object can be seen from a certain distance. Photopigment dynamics, particularly involving rhodopsin in rod cells, may affect dogs' vision under changing light conditions. After exposure to bright light, rhodopsin undergoes a process called photobleaching and requires time to regenerate. This could result in a temporary decline in visual sensitivity when dogs transition from bright outdoor environments to indoor or dimly lit spaces. Recent research has suggested that the time they need to regenerate the pigment is longer than in humans (Byosiere et al., 2017). This is an important aspect to consider when designing an experiment and considering how much light to make available.

Taking these different aspects, of visual perception in dogs, into consideration is key when designing a visual task. Despite the fact that there might be some breed and individual specific differences in perception previous experiments have already proven them to be insignificant in displacement tasks so this is not something that must be considered when designing an experiment such as the present one (Gagon and Doré, 1993). You need to consider their visual color range and pick an object that will be salient for them. You need to consider their visual acuity when considering how complex or small the stimulus you are showing them is. You should consider the lighting of the room, and whether it is conducive to dogs performing at their best. You should consider whether you need to accommodate for a change between the outdoor environment from which the dog is entering to the indoor experimental environment. All of these features should be considered and closely monitored in order to get reliable replicable results throughout your experiment.

1.2 Canine Cognitive Mechanisms Used in Visual Tasks

All visual tasks start with the ability to see and recognize the objects involved in the task. How dogs are able to see an object is discussed above, however the object that the dog sees, despite being the same object, can be perceived as different under different circumstances (lighting, distance, orientation, etc.) and this is where object recognition comes in. Object recognition is the ability to recognize individual objects despite perceived differences (Jitsumori and Delius, 2008), and it was proven that dogs learn to identify objects by using visual, olfactory, and other information (Dror et al., 2022). The ability to identify objects includes the ability to understand that an object still exists when you cannot see it anymore. This particular aspect is called object permanence and implies the ability to represent objects as distinct spatial elements of the environment. This means that the subject is aware that the objects continue to exist even if they are out of sight and can represent the world outside of what is directly perceived by them (Piaget, 1967; Gagon and Doré, 1993). Dogs, as well as their evolutionary predecessors, wolves, have been shown to possess object permanence in past experiments (Fiset et al., 2014).

It is clear that object permanence comes with the requirement of being able to remember where the object was, relying hence on the subject's memory. There are different types of memory that one might think animals use in a visual experiment. Spatial memory, the kind of memory that encodes and stores information about the environment and the subject in that environment (Madl et. al., 2015). Episodic memory, or the capacity to store and retrieve memories of specific past events (Ghetti and Bunge, 2012). Semantic memory, which refers to the capacity to recall information, and general knowledge (Rzezak et. al., 2014). However, many of these memory theories have definitions which are tailored to humans, which makes it difficult to attribute to animal subjects. For example, episodic memory is hard to define in animals because they are not able to communicate their conscious recollection of a specific event (Carrillo-Mora et. al., 2009). There is also varied evidence of whether or not dogs possess these different kinds of memories. For example, there are studies which say that they possess episodic memory (Fugazza et al., 2016) while other sources describe it as something uniquely human (Tulving, 2002). This is why I will not be discussing these in detail as related to dog cognition although a mix of these kinds of memory is likely used when performing visual tasks.

One of the more well studied and explored concepts in animal memory is working memory, it is defined by the American Psychological Association as "a temporally based representation of an object, stimulus, or spatial location that is used within a single trial of an experimental session to guide behavior." (American Psychological Association) Working memory can have different lengths in dogs but it has been shown that dogs perform above chance when their working memory is tested within intervals of up to 240 seconds. Here dogs were tested by being shown a target object "rubber toy" being hidden behind a screen and then having their sight of experimental area obscured by an opaque screen, the dog was then released and rewarded if it found the hidden object. The dog's performance was above chance on all trials up to 240 seconds of retention, although their performance did decrease when the retention time was longer (Fiset, 2003). A key concept within working memory is updating, this is when information which was maintained within working memory is replaced with new information (Nyberg and Eriksson, 2015). For example, when a new trial begins and the dog sees the object being hidden behind a different screen than in the first one this updates their working memory. We can be sure of this as the dogs perform above chance on the trials and do not go to the location in which the object was previously hidden. Joseph Perner is a psychologist who introduced the potential need for secondary representation when solving tasks requiring object permanence. Representation of the world can be of two types: primary or secondary. Primary representation is when you can represent and keep in mind only what you can perceive, and your environment is continuously updated with the new actual information. Secondary representation allows for more than one world view: you perceive what is in front of you, but you can integrate that with information about what was there before, while not being able to perceive it directly (Gagon and Doré, 1993; Suddendorf and Whiten, 2001).

1.3 Displacement tasks

A key area of interest in animal cognition, as mentioned above, is object permanence - the understanding that objects continue to exist even when they are out of view. This cognitive ability can be tested through a series of tasks: invisible displacement, visible displacement, and transposition tasks.

The invisible displacement task was originally created by a Swiss psychologist named Jean Piaget, who created a system of classifying the cognitive development of children. The first stage of development is marked by gaining understanding of object permanence, it is known as the sensorimotor stage and is divided into 6 substages (Rabindran, 2020). The sixth substage marks the transition into representational thought for the child (Ramsay and Campos, 1978). Representational thought is explained as the ability of an individual to evoke the thought of an object using “signifiers” or symbols instead of visualizing the object itself (Piaget, 1972). Different types of displacement tasks, as mentioned above, were created to show this ability in human children, and when these tests were shown to be successful, they were adapted to determine whether animals had the same cognitive capabilities.

The invisible displacement task is based on showing a desired object to the subject then hiding it, using a displacement device that is an apparatus designed to hide and transport the object from one hidden location to (behind a screen, inside a box, etc.). After this, the displacement device is shown to the subject revealing that it is now empty giving a clue that the object was deposited in the last location visited by the displacement device (Collier-Baker et.al., 2004). To successfully pass the invisible displacement task the subject must possess object permanence and be able to predict the location of the object using the visible movement of the device and the invisible (not directly perceived) movement of the object (Gagon and Doré, 1993).

In visible displacement tasks the object of interest is not hidden and is moved in full view of the subject. At the end of the movement, it is hidden (i.e. behind a screen) just as in the invisible displacement but without the use of a displacement device (Gagnon and Doré, 1993). This is the easiest task out of the three types of tasks mentioned here and dogs manage to do it in the same study they performed at above chance levels in visible displacement trials (Gagnon and Doré, 1993).

Transposition tasks are a type of invisible displacement task in which the participant is shown the target object, then it is placed underneath a displacement device, usually an opaque container, and hidden. In this type of experiment, there are other empty containers which are moved around alongside the one containing the hidden object. This movement occurs in full view of the subject (Wrape and Hammonds, 2019). These kinds of tasks require attention, working memory, and spatiotemporal cognition (Pepperberg et al., 1997). Depending on the trial the movement of the containers can be different. The most basic type of movement is when the containers that are manipulated move to one side together and end up in new locations and the location in which the hidden object was first located is left empty (Figure 1). Dogs perform very well in these trials. The movements can become more complex, having the containers crossing each other and switching positions, or crossing each other and occupying two new positions, etc. as illustrated in Figure 1.

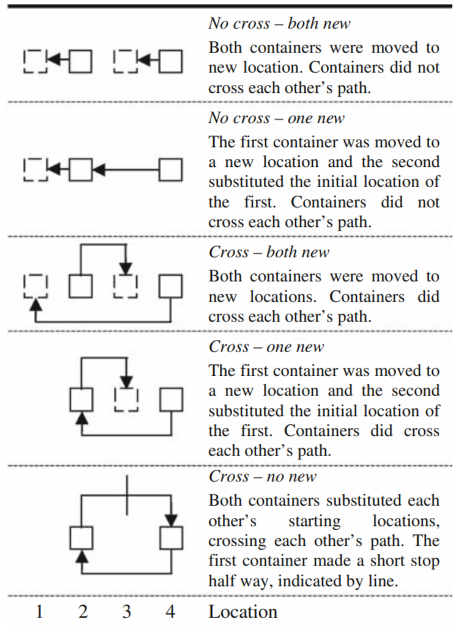

Fig. 1 Schematic representation of the 5 different transposition conditions performed in this study accompanied by a text explanation from experimenter 1 point of view. The arrows represent the manipulations performed. Location numbers 1, 2, 3 and 4 refer to the start and final locations of the containers during the trials. In all conditions the start locations were 2 and 4. In all conditions the left container was moved fist

Figure 1: Illustration of possible patterns of movement in transposition tasks (Rooijakkers et. al., 2009).

Invisible displacement tasks are aimed at understanding object permanence capabilities to see if there is representational thought in the subject (Collier-Baker et.al., 2004). The trajectory of the object in this task must indeed be represented in the mind of the subject in order to infer the object's location (Call, 2001). Passing the test is one of the key points to show secondary representation in the subject (Perner, 1991). However, what kind of reasoning animals use to pass the tasks, whether associative learning Collier-Baker et. al., 2004) or object permanence and secondary representation, is still questioned. Two different kinds of possibilities have been identified for passing the invisible displacement task. The first is the representational solution, while the second is nonrepresentational (Natale et. al., 1986). A representational solution is when the subject reconstructs the path travelled by the hidden object and correctly identifies the final hidden location. A nonrepresentational solution is when the animal picks up other cues from the environment to solve the task such as going to the screen touched last by the experimenter. These types of strategies are usually referred to as using local rules (Gagon and Doré, 1993).

Many species have been tested for invisible displacement like dolphins (Doré et. al., 1991), cats (e.g., Doré, 1986; Dumas, 1992), hamsters (Thinus-Blanc and Scardigli, 1981), multiple species of monkeys (e.g., de Blois et. al., 1998; Natale et. al., 1986), and, except for gorillas and orangutangs, there is no clear evidence of secondary representation (Collier-Baker et.al., 2004). There is some evidence showing that psittacine birds, like the grey African parrot, and dogs are able to understand this (Collier-Baker, et.al, 2004.). However, more recent studies have proved that dogs specifically use local rules instead of true secondary representation to solve the task (Collier-Baker et.al., 2004). What type of local rules, unvoluntary social cueing or associative learning, were used by dogs is still uncertain, which makes it difficult to understand the mechanism underlying performance and improving future assessment.

2. Aim

The aim of this study was to investigate the environmental cues and local rules that dogs rely on when solving object permanence tasks. Previous research has suggested that dogs may use proximity-based strategies, such as adjacency rules or the closeness of the experimenter, as described above. However, this study eliminates potential social cues by ensuring the experimenter remains out of sight of the dog. Instead, we focus on the influence of environmental factors, particularly the distance between the dog and the cups, which was controlled for to assess its impact on the dogs' choices.

3. Materials and methods

3.1 Experimental Subjects

The sample for this experiment consisted of eight pet dogs, recruited on a volunteer basis. The owners were either students or employees of the University of Padova, or volunteers who had registered in the Laboratory of Applied Ethology database. The requirements for participation were such: being at least one year old; being in good health with no particular visual or locomotory problems; being easily habituated to new environments; displaying no aggressive behavior towards humans; and being food motivated. Prior to the start of the experiment, all the owners were asked to fill out a questionnaire about their dog's habits, behaviors, and food preferences. This preliminary screening ensured that the dogs chosen for the experiment were suitable and helped identify the most effective food-based motivator for each individual.

Given that the study focused on visual perception there were no strict restrictions on age, since this ability should remain relatively stable throughout a dog's adult life. Due to difficulties in assessing age-related visual decline we relied on the owner's assessment to ensure that the dogs had no apparent visual impairments. Dogs younger than one year were excluded due to typically shorter attention spans and potentially lower motivation. To minimize confounding factors, dogs with known locomotory issues were excluded. To reduce stress in the lab setting and ensure cooperation, only dogs that were calm, non-aggressive, and adaptable to new environments were selected. Finally, food motivation was essential to maintain task engagement, without it poor performance might reflect lack of interest rather than an inability to complete the task. No restrictions were placed on breed, as the study required only basic visual discrimination and minor inter-breed differences in visual acuity were not expected to influence the results.

The final sample can be seen in Appendix 1. The ages of the dogs ranged from two to ten years old, with a mean age of five years. Out of the eight participants, one was a mixed breed and seven were pure bred, six were females and two were males.

3.2 Experimental Setting

The experiment was performed in a 4.2 x 3.0 m room (Figure 2). A white panel (2 x 1 m) was placed 70 cm in front of the wall, as seen in Figure 2. The panel was placed on two stands (15 cm) to raise it off the floor and allow for the experimental cups (height = 10 cm) to slide underneath the panel. The panel was necessary so the experimenter could hide and manipulate the setting without being visible and possibly influencing the dog's choice. A white sheet was draped over the panel to cover the space created by lifting the panel off the floor, ensuring the dog cannot see the experimenter while they manipulate the apparatus. The sheet was held in place with one clip on either side of the panel. The floor was covered by a plastic carpet to prevent unwanted visual orientation and maintain a neutral testing environment. There were eight other white panels placed on either side of the main panel (four on each side) to create a symmetrical geometrical area in the middle of the room and cover distracting elements like curtains, doors, sockets, etc.

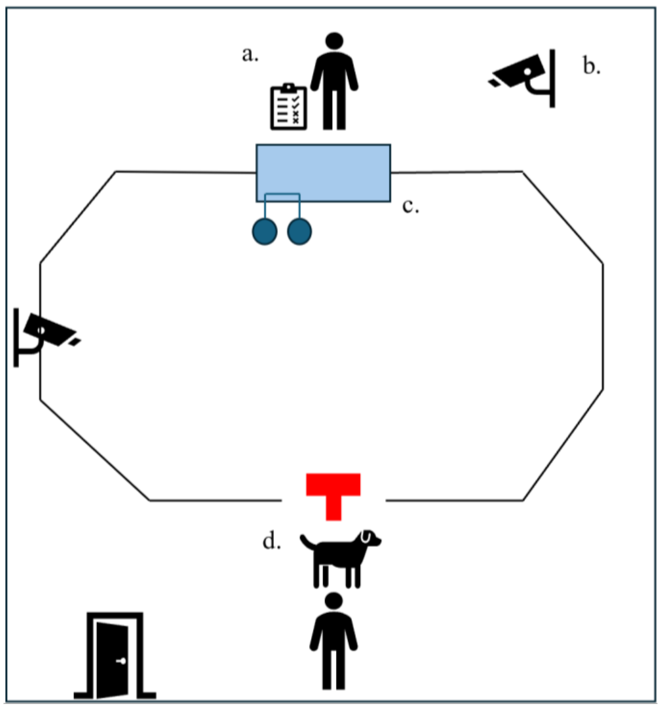

Figure 2: Diagram of the experimental setup showing: (a.) the position of the experimenter, (b.) the positioning of the two cameras, (c.) the panel and sheet which cover the experimental apparatus, (d.) the position of the handler when holding the dog in the starting position, on top of the red “T”.

The moving cups apparatus was slid underneath the panel into the central area created by the panels. This apparatus was created by attaching 2 cups to a rectangular piece of plastic so that they were 30 cm apart, as seen in Figure 3. This allowed the cups to be moved smoothly and simultaneously during each experimental phase. Each of the cups had a metal wire attached to the top which allowed the experimenter to open and close them without being visible to the dog. In every trial, underneath the baited cup, there was a yellow plastic cap where the food was placed to increase the food visibility to the dog.

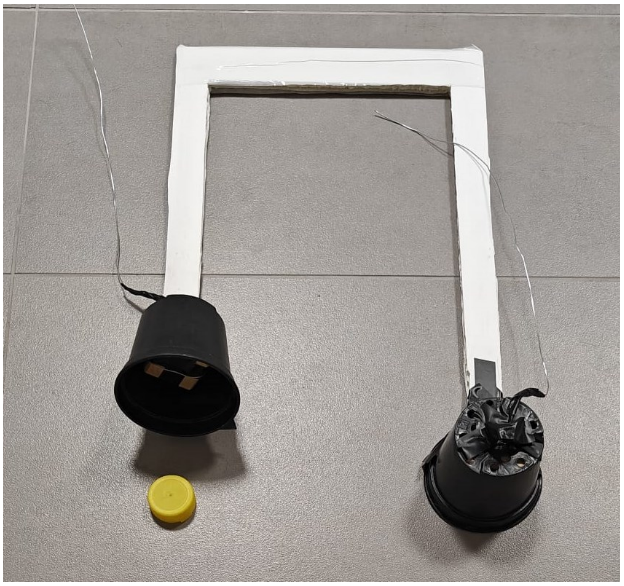

Figure 3: Photo of the cups apparatus showing the cups themselves and how they are attached to one another, as well as the system of wire which allows them to open and the yellow cap underneath (where the food will be placed).

Across from the apparatus was the location in which the handler sat with the dog. The location was marked with red tape on the floor in the shape of a "T" to delineate the optimal position of the dog (Figure 2). The distance between the horizontal line of the "T" and the apparatus was 2.0 m. The dog's head was positioned on the horizontal line of the "T" while its torso was located in the middle of the vertical line. The handler then sat behind the dog and gently held the dog by the shoulders while being as neutral as possible, i.e., no petting or talking.

Each phase of the experiment was recorded using two cameras (AVer TR311HWV2, Taipei, Taiwan), allowing for verification of the data collected directly by the experimenter throughout the trials. One camera was mounted on the left wall of the room, facing the panel behind which the experimenter was hidden. This camera captured the movement of the cups apparatus and clearly documented which cup the dog selected. The second camera was positioned behind the experimenter, facing toward the dog. This setup allowed for a clear view of the dog's face, making it possible to determine the direction of its gaze and whether it observed the stimuli presentation.

3.3 Experimental Procedure

This experiment required a pre-phase, which allowed the dogs to get accustomed to the apparatus as well as get used to properly approaching the cup of their choice, and a testing phase.

3.3.1 Pre-phase

In every part of the pre-phase the cups were stationary. In every trial, the dog needed to clearly select one of the two cups (moving in a straight line towards it and not hesitating between the two cups) and clearly indicate it by touching the chosen cup with their nose.

The dog had to complete several preliminary steps before being ready to participate in the testing phase. The criteria for passing each of the pre-phase steps was that the dog performed the task correctly four times in a row.

The pre-phase is where the role of the handler becomes important. The handler is the person who is in charge of keeping the dog still and well positioned during the trials as well as verbally rewarding the dog when it chooses correctly during the trials. Since the experiment was performed in such a way that the experimenter is behind the panel and could not see the dog, the verbal reward serves two functions; the first is giving positive reinforcement or positive punishment to the dog and the second is allowing the experimenter to understand if the dog chose the baited cup or not.

a. Food Motivation Assessment

This initial assessment was created to assess to what extent the food motivates the dog. The handler and the dog enter the room, and the handler positions the dog in the starting position. The experimenter walks in front of the panel with food in their hand. The food was previously chosen either by the dog after having been given a choice between three different kinds of food or by the owner via the initial questionnaire. The experimenter places the food on top of the plastic yellow cap and backs away, after which they signal to the handler to release the dog. The dog is released to evaluate how freely and quickly it approaches the food. The dog is called back by the handler and, if the dog does not return once called upon, the handler is allowed to take the dog back to the starting position. If the dog was not sufficiently motivated, the food was changed, and the trial was repeated until the dog promptly approaches the food and eats it on its own.

b. Procedural training

The aim of this phase is to teach the dog the experimental procedure. The experimenter is hidden behind the panel and slides one cup with a piece of food hidden under it into the sight of the dog. The experimenter lifts the cup to show the food to the dog, the food remains exposed for two seconds, and then the cup is lowered. If the dog is not looking at the cup while the food is being presented, the dog is called by the experimenter behind the panel to draw their attention back in. After the cup has been lowered, the dog is released. If the dog approaches the baited cup, it is raised so that the dog can eat the food underneath. This training continues until the dog approaches the cup and touches it with its nose every time.

If the dog does not promptly approach the cup or if it does not eat, additional trials are conducted for the dog to get accustomed to the experimental procedure.

c. Discrimination training

In this phase the moving apparatus with two cups is introduced to the dogs. This training aimed to teach the dog that it has to make a clear choice between one of the two cups presented. The cups are slid underneath the curtain, so they become visible to the dog and then the baited cup is revealed (Figure 4). The food is uncovered for 2 seconds and then the cup is closed again. The handler releases the dog after the cup is closed. The dog is then free to approach the cups. If it makes a clear choice by indicating the baited cup with its nose, the cup is lifted by the experimenter and the dog is allowed to eat the food. If the dog chooses correctly, the handler vocally rewards the dog which signals the experimenter to lift the cup and let the dog eat. If the dog indicates the unbaited cup, the handler vocalizes that the dog has made the wrong choice and proceeds to call the dog back.

Correction trials are allowed if the dog does not choose correctly or if it does not make a clear choice.

Figure 4: Photo of the discrimination training setup showing the panel with the sheet behind which the experimenter is hidden as well as the cups apparatus underneath, which hides the stimulus and food from the dog.

3.3.2 Testing Phase

During the testing phase, after the location of the food under one of the cups in the cups apparatus was revealed the cups either remained stationary or were transposed from left to right and vice versa. In the stationary trials, cups could be arranged in two positions: inclined, which makes the cups equidistant to the dog, or aligned which makes the internal cup closer to the dog. Moreover, regardless of the condition, the positioning of the cups was such that there was always a cup which was more lateral and another which was more central with respect to the dog. As a result, the exact distance of the cups from the dog and the wall of the room is different depending on the condition. The external cup was 40 cm and 205cm away from the wall and the dog respectively, and the internal cup was 60 cm and 195 cm from the wall and the dog respectively in the aligned trials. The distances are the same for the stationary aligned and the transposed trails. In the inclined trials the external cup and internal cups were 50 cm and 70 cm away from the wall respectively and both were 205 cm from the dog. For simplicities sake, the position of the cups (Appendix 2) is referred according to their position from the dog's point of view from here on.

The position of the food was counterbalanced between the internal and external cup, as was the starting side position of the apparatus under the panel (either the right or left side). This gave rise to 12 different types of trials which were used during the testing phase (Table 1). Each dog underwent 5 sessions consisting of 12 trials each.

Trial	Movement	Orientation of the Apparatus	Starting Location of the Baited Cup	Final Location of the Baited Cup
1	Transposed	Aligned	Internal Right	External Left
2	Transposed	Aligned	Internal Left	External Right
3	Transposed	Aligned	External Right	Internal Left
4	Transposed	Aligned	External Left	Internal Right
5	Stationary	Aligned	Internal Right	Internal Right
6	Stationary	Aligned	Internal Left	Internal Left
7	Stationary	Aligned	External Right	External Right
8	Stationary	Aligned	External Left	External Left
9	Stationary	Inclined	Internal Right	Internal Right
10	Stationary	Inclined	Internal Left	Internal Left
11	Stationary	Inclined	External Right	External Right
12	Stationary	Inclined	External Left	External Left

Table 1: Overview of trial characteristics presented to each dog. The columns provide detailed information for each trial, including: whether the baited cup was transposed, whether the cups were equidistant to the dog (inclined) or not (aligned), the initial position of the baited cup (starting location), and its final position after the transposition (end location).

The general procedure of each test trial was the same. The experimenter slides the cups under the curtain, either to the left or to the right depending on the trial, to reveal them to the dog. The food is then uncovered; the cup stays open for 2 seconds and then is closed again. Then the cups apparatus remains in this position (stationary aligned and inclined trials) or is moved to the opposite side of the panel (transposed trials), causing the cups to switch positions in the dog's point of view (internal becomes external). Once the cups reach their final position, the handler releases the dog. If it approaches the correct cup, the cup is lifted, and the dog is rewarded vocally and with food. Correction trials are not allowed and the experimenter notes down the dog's performance based on the vocalizations of the handler.

3.4 Data Collection and Analysis

All data was collected manually by the experimenter during each session. The experimenter determined whether the dog selected the baited cup based on verbal confirmation from the handler. To ensure data accuracy, all observations were independently verified through video recordings of the sessions, resulting in 100% concordance.

The data obtained was arranged into three data sets based on the experimental condition: Transposed, Stationary Inclined, and Stationary Aligned. Each dataset contained three variables: Dog ID, Choice, Position. The choice variable was treated as a numeric binomial variable, with a correct choice (selecting the baited cup) being coded as 1, and an incorrect choice being coded as 0. The position variable referred to the final position of the baited cup from the dog's point of view and was categorized as internal or external.

To investigate whether the choices of the baited cup were significantly different from chance level, a series of intercept only logistic regression models were fitted. Each dataset was analyzed with a separate model to allow for condition specific interpretation. The response variable was the choice. To account for individual differences and repeated measures, dog ID was included as a random effect.

To investigate whether the choice was dependent on the position, a separate set of logistic regression models were run. The position of the baited cup was included as a fixed effect, and the Dog ID still included as a random effect. The choice remained as the response variable. To further assess whether the choice of the internal vs external cup was significantly different from chance, a hypothesis test comparing the estimated means to a null probability of 0.5 (chance level) was carried out.

All the statistical analyses were performed using R (v4.5.0; R Core Team 2025), in RStudio (v. 2024.9.0.375; Posit Software, PBC, Boston, MA). The significance level was set at $\alpha = 0.05$.

4. Results and Discussion

4.1 Descriptive Analysis

All the dogs successfully passed the pre-phase and completed all experimental sessions. Out of the 160 transposition trials the dogs correctly identified the baited cup 76 times (47.5%), out of which 61 (80.3%) were internal and 15 (19.7%) were external (Figure 5).

Out of the 160 stationary aligned trials the dogs correctly identified the baited cup 127 times (79.4%), out of which 78 (61.4%) were internal 49 (38.6%) were external (Figure 6).

Out of the 160 stationary inclined trials the dogs correctly identified the baited cup 135 times (84.4%), out of which 71 (52.6%) were internal and 64 (47.4%) were external (Figure 7).

4.2 Statistical Analysis and Discussion

4.2.1 Transposition Condition

Choices of dogs in this condition are represented in Figure 5. The intercept only logistic regression model exploring the dogs' success in the transposition trials showed that their choice distribution was not significantly different from chance level ($z = -0.63$ and $p = 0.53$). However, the position of the baited cup did influence the dog's choice ($z = 6.77$, $p < 0.001$) with dogs choosing the corrected baited cup more often when internal (estimated mean ± SE = 0.76 ± 0.05), compared to when the baited cup is external (0.19 ± 0.04). Finally, the corrected baited cup was chosen more often than chance when located internally ($z = 2.53$, $p = 0.01$), while it was chosen less often than chance when located in the external position ($z = -6.87$, $p < 0.001$).

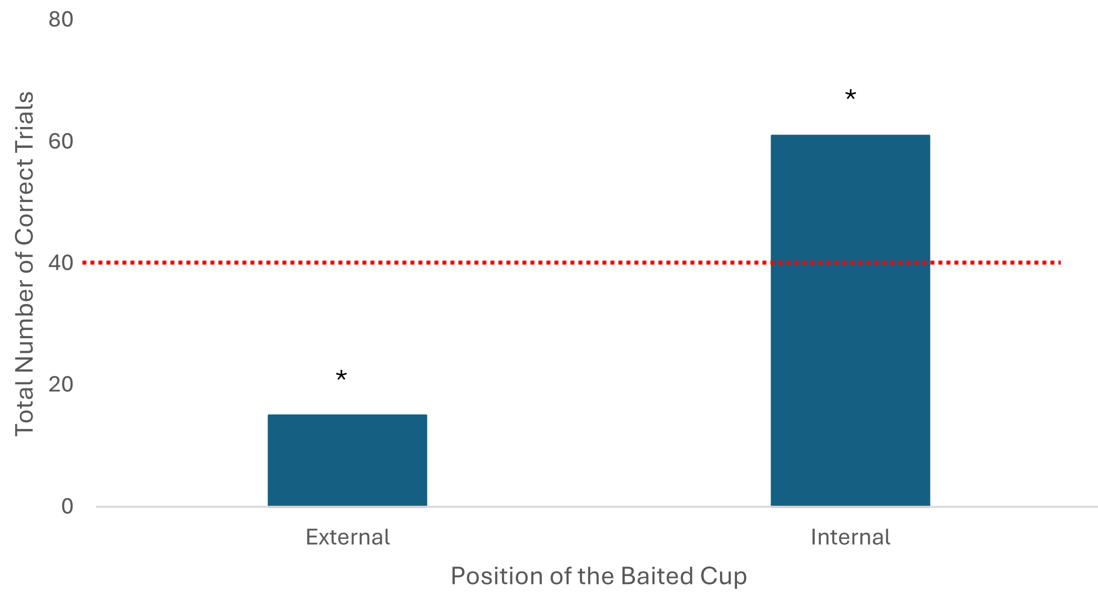

Figure 5: Bar chart showing the total number of correct choices made by the dogs in the transposition condition, separated by the position of the baited cup (Internal vs. External). The red dotted line represents the chance level, set at 40 correct choices, as each position condition (Internal and External) included 80 trials. Asterisks indicate whether performance in each position was significantly different from chance.

The results indicate that dogs were unable to solve the transposition condition, performing below chance levels. This outcome is surprising given that prior studies have demonstrated above-chance performance in transposition tasks involving the apparatus occupying 2 new locations after transposition which mirrors the design of the current experiment where the cups apparatus transposed both cups to new locations.

For instance, a paper from 2009 found that dogs could successfully locate hidden food when transposition device, consisting of two opaque containers, one of them hiding the food was moved together to occupy a new location (Rooijakkers et. al., 2009). Similarly, in an earlier study, dogs were tested in three kinds of transposition tasks involving three panels arranged in a semicircle. Dogs succeeded in conditions where only an adjacent panel was moved while the panel hiding the object remained stationary (motion control), where the panel hiding the object and another adjacent panel were transposed together to two new locations, and where the panel hiding the object was moved from next to one fixed panel to a new position next to other fixed panel (Doré et. al., 1996) In all these successful cases, the original hiding location was left empty, possibly providing a cue for the dogs. They failed, however, in trials where the object's hiding location was occupied by another panel, especially when the panels crossed paths. Another study further support the ability of dogs to succeed in transposition tasks. Here dogs of three age groups (3, 6, and 11 months) were tested on transposition tasks involving two opaque cups and a hidden dog toy. The 11-month-old group, considered as juvenile, in a paper about age grouping in dogs, which means that their attentiveness and cognition is not fully developed (Harvey, 2021), performed above chance in trials where the two cups were moved to new positions. However, they failed in more complex variants, one where only the cup containing the object was moved (with the decoy left in place), and another where the two cups crossed paths, trading locations (Lazarowski et. al., 2020).

These findings suggest that while dogs can succeed in certain transposition tasks, they often struggle when it comes to invisible displacement, another kind of task testing for secondary representation. This aligns with the broader literature on invisible displacement, where dogs typically perform poorly unless aided by social cues, associative rules, or inferential reasoning, rather than demonstrating Piagetian Stage 6 object permanence, which requires secondary representation. Evidence for this comes from a 1993 study which tested dogs under four displacement conditions. Dogs performed near perfectly in visible displacement trials (97.6%), moderately well when the object's movement was visible but its transfer behind a screen was hidden (64.2%), and significantly worse in classic invisible displacement trials (48.2%; Gagnon and Doré, 1993). Notably, eye-tracking analysis showed that in 93-99% of invisible displacement trials and in 97-99% of visible displacement trials, dogs lost visual fixation on the relevant screen, suggesting dogs were not visually tracking the object as their primary strategy. This evidence clearly shows as stated in the paper that "the invisibility of the object during its movement toward the target screen is another factor that makes discrimination or retention of the hiding location more difficult" (Gagnon and Doré, 1993). While this study claims that dogs performed above chance on a second set of invisible displacement tasks a more recent paper, published in 2004, using a similar approach, controlled for potential spatial cues that the original study did not check for, and found that dogs were not using a representation of the hidden movement of the object but rather simpler strategies to solve the task. This 2004 paper also showed that dogs were able to perform above chance on an invisible displacement task. However, once the controls were introduced, such as removing the displacement device from in front of the screens or manipulating its spatial relation to the hiding box to test for associative reasoning the dogs were unable to solve the task. In the task where they removed the displacement device the researchers saw that, "Removing the displacement device did not "push" dogs into using a representational strategy; in fact, their performance was diminished," (Collier-Baker et al., 2004) still showing a bias towards the screen which was adjacent to the displacement device before its removal. In tasks where they tested whether dogs used the adjacency principle to solve tasks the researchers consistently found that the dogs picked the screen adjacent to the displacement device consistently more than the non-adjacent one (Collier-Baker et al., 2004).

In the current study, although the dogs failed to locate the correct cup in the transposition condition, their responses were not random. They exhibited a significant bias toward the internal side, choosing the cup positioned closer to the center of the array. A similar centrality bias was observed by Rooijakkers and colleagues (2009), who attributed it to the proximity of the central cups to the experimenter. However, in our study, the experimenter was fully hidden, ruling out that explanation.

4.2.2 Stationary Aligned Condition

Choices of dogs in this condition are represented in Figure 6. In the stationary aligned trials, the intercept only logistic regression model showed that the distribution of the dog's choices was significantly different from chance ($z = 4.31$, $p < 0.001$). The fixed effect of the position also turned out to be significant ($z = 4.45$, $p < 0.001$), with dogs choosing the corrected baited cup more often when internal (estimated mean = 0.99 ± 0.01) than when external (0.64 ± 0.11). The corrected baited cup was also chosen more often than chance levels when located in the internal position ($p < 0.001$), while when located externally it was chosen at chance level ($p = 0.91$).

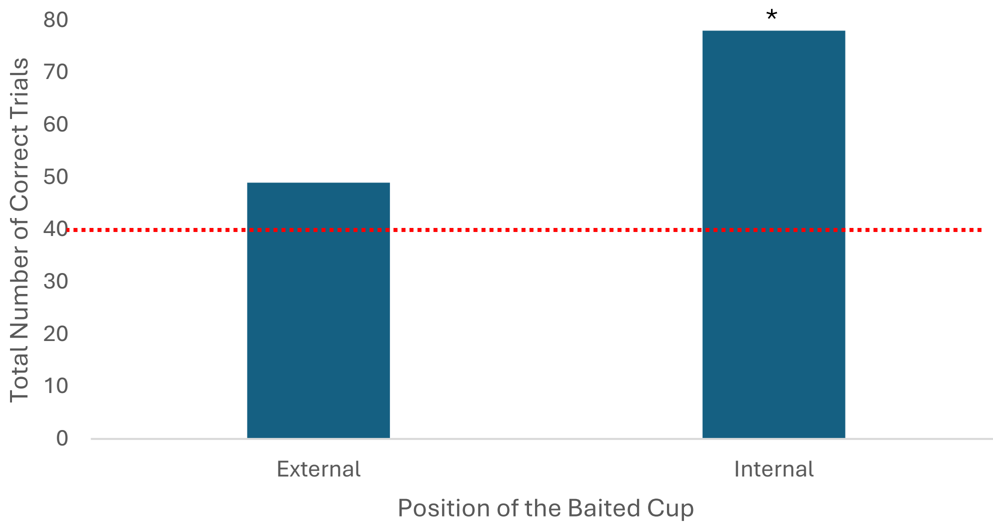

Figure 6: Bar chart showing the total number of correct choices made by the dogs in the stationary aligned condition, separated by the position of the baited cup (Internal vs. External). The red dotted line represents the chance level, set at 40 correct choices, as each position condition (Internal and External) included 80 trials. Asterisks indicate whether performance in each position was significantly different from chance.

The results indicate that dogs performed significantly above chance in the stationary aligned, demonstrating improved accuracy when the cups are not transposed. This suggests that working memory may help their performance allowing them to retain the location of the baited cup, as well as the fact that they possess some kind of object permanence seeing as they understand that the food that vanished is still under the cup. The dog's success in this stationary condition supports the idea that dogs use primarily egocentric information to orient themselves, meaning that they rely on cues about the location of objects with respect to their own location, and this information becomes irrelevant when the absolute position of the cups with respect to the dog changes (Fiset et al., 2003).

Despite their success, bias towards the internal cup persists in the stationary aligned trials. When the baited cup is internal, they can consistently perform above chance but when the baited cup is external, they do not consistently pass the trial and choose correctly only at chance level. This type of central bias, which was observed also in the transposition condition, is shown to exist in other canine cognition contexts as well. For example, in a paper where dogs were presented with a tube and had to pick the location where an object dropped inside a vertical curved tube would fall, dogs exhibited a significant middle location bias no matter the starting side of the tube or where the gravity bias location was. In this study, however, proximity to the dog was not a determining factor. When controlled for the dogs still showed a central location bias (Tecwyn and Buchsbaum, 2019). In the present experiment the persistence of an internal position bias raises an important question: is the bias due to the proximity of the position to the center or due to the proximity of the position to the dog? To disentangle this information, we created the next condition (stationary inclined).

4.2.3 Stationary Inclined Condition

Choices of dogs in this condition are represented in Figure 7. For the stationary inclined trials, the intercept only model showed that there was a significant difference between the dog's choices and chance ($z = 3.23$, $p = 0.001$). The model with the position of the baited cup included as a fixed effect showed no significance of the position related to the dogs' choices ($z = 1.66$, $p = 0.10$).

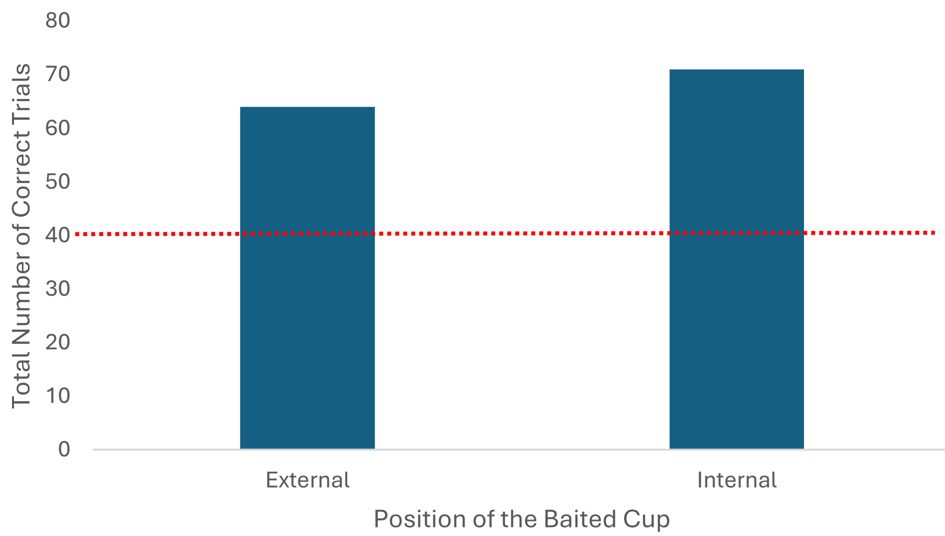

Figure 7: Bar chart showing the total number of correct choices made by the dogs in the stationary inclined condition, separated by the position of the baited cup (Internal vs. External). The red dotted line represents the chance level, set at 40 correct choices, as each position condition (Internal and External) included 80 trials.

In the stationary inclined condition, the dogs chose the correct baited cup significantly higher than chance levels (Figure 7). The position of the cups did not come out to be significant in the model, suggesting no positional bias, hence, both positions were chosen significantly above chance levels. In this condition, the inclination of the cups apparatus ensured that both cups were equidistant from the subject, effectively controlling for proximity. This means that the positional bias in the previous trials was not due to the central position of the cup but to the fact that it was more proximal to the dog.

5. Conclusion

The present study provides evidence that two key factors significantly influence dogs' performance in object permanence tasks: movement and spatial proximity. First, dogs performed significantly worse in trials involving movement of the target object, suggesting that transpositions are more difficult to process. Second, and more importantly, our findings highlight a proximity bias: dogs exhibited a consistent preference for selecting the cup closest to them. While previous research has attributed similar biases to the spatial positioning of the experimenter or to simple local rule strategies, our experimental design controlled for these variables, by hiding the experimenter, and manipulating the spatial arrangement of the cups. This allowed us to isolate distance from the dog as the key determinant. When cup positions were adjusted to be equidistant, via the inclined position, dogs' accuracy improved, indicating that proximity was a primary factor interfering with correct choice behavior.

This proximity bias may reflect reduced impulse control in the presence of nearby food rewards. This interpretation aligns with findings from a literature review of the detour task, where dogs are more prone to making errors when the goal object is in close proximity (Kabadayi et. al., 2018). Accordingly, another detour task study (Brucks et. al., 2017) found that individuals who were better able to inhibit direct approaches to the reward tended to create more distance between themselves and the object, supporting the idea that proximity to the possible reward location impairs inhibitory control. This evidence can be used to better understand our study, and make the supposition that dogs, when the distance between them and the cups is unequal, will go to the closest cup because they cannot inhibit their impulse to go to the nearest possible location of the food. When the cups were inclined and were, hence, equidistant, the dogs could process the visual information presented and correctly choose the baited cup.

Future studies should investigate the role of equidistance in transposition tasks to determine whether controlling for proximity can reduce the hardships observed in moving trials. This could offer insights into the hierarchy of cues that dogs rely on and how these interact with their abilities to solve object permanence tasks.

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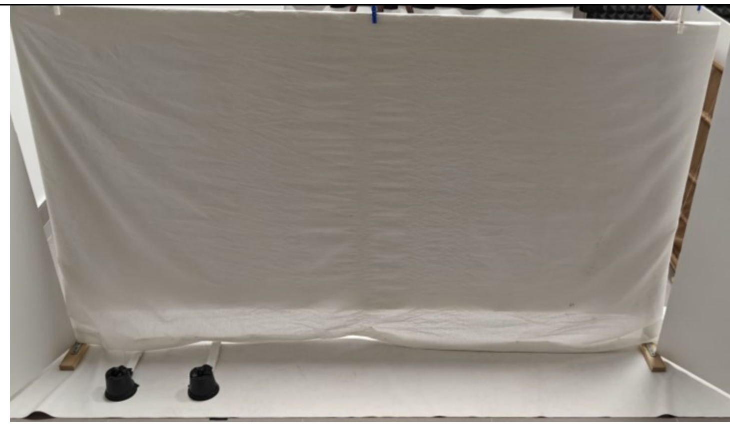
7. Appendices

Participant Number	Sex	Breed	Age
1	Female	Labrador Retriever	2 years
2	Female	Lagorai Retriever	3 years
3	Female	Whippet	10 years
4	Male	Mixed Breed	2 years
5	Male	Australian Kelpie	4 years
6	Female	Border Collie	6 years
7	Female	Shetland Sheepdog	8 years
8	Female	Mixed Breed	8 years

Appendix 1: Table of the Characteristics of the Participating Dogs

Aligned Right	

Inclined Right	
Aligned Left	
Inclined Left	

Appendix 2: Setup of the Inclined vs Aligned Trials