Spring 2020

False Beliefs in Dogs

Sydney Rowley

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Illinois Wesleyan University

Abstract

Compared to many other species, including non-human primates, dogs perform exceptionally well on social reasoning tasks such as locating a hidden object by following a human point. One such task, understanding false beliefs (FB)--that another individual may possess a belief contrary to both one's own belief and reality--serves as a pinnacle in understanding social reasoning. Humans understand FB but whether nonhumans do remains controversial. We predicted that dogs, given their unusual social savvy, may understand FB. We presented dogs with a stage and a duck resting on it. The dog and researcher watched the duck move inside one of two boxes positioned on either end of the stage. An occluder then obscured the researcher so they could not see events on stage. While the researcher's vision was occluded, the dog watched as the duck moved to the opposite box. The occluder dropped to reveal the researcher, who then reached either toward the box where they had last *seen* the duck (as animals possessing FB understanding would expect) or to the box where the duck *actually was* (as animals possessing FB understanding would find unusual). Results suggest that dogs do not look longer (an indicator of surprise) when the researcher searched the unexpected box, suggesting that, contrary to our predictions, dogs may not understand FB. However, an alternative explanation is that we did not have enough statistical power to detect a significant difference in looking time due to COVID-19 and the unanticipated global shutdown.

Introduction

Humans, even from an early age, quickly and accurately process and understand complex social situations. For example, Minnie, Mickey, and Goofy went out for dinner to celebrate. When Minnie left the table to speak to her friend, Mickey became momentarily aggressive towards Goofy over a work-related conflict and yelled at him. When Minnie comes back, adults would expect Minnie to still act kindly towards Mickey since she did not see the aggression. Instead, if Minnie stayed for the outburst, adults no longer would expect her to still act kindly toward Mickey due to her new knowledge.

Even 13-months old infants can infer how varying experiences affect relationships between people. Infants watched as two puppets, Jack and Jill, interacted positively by wiggling and swaying together. When Jill left the room, Jack hit a third puppet, Bert. Upon Jill's return, infants seemed to expect Jack and Jill to continue to interact positively. However, if Jill instead observed Jack hit Bert, infants were surprised when Jack and Jill continued to interact positively. Presumably, infants were able to take Jill's perspective into account when predicting how she would react to Jack. In the first case, infants recognized that she did not have the information about Jack's misdeed, but in the second case, they seemed to predict that Jill's new perception of Jack possessing unforeseen anger may lead to a change in her behavior (Choi & Luo, 2015). Therefore, even young infants demonstrate fairly sophisticated levels of complex social reasoning, but this form of social reasoning is by no means the only one.

Social cognition includes understanding and interpreting others' thoughts, emotions, beliefs, and goals (Lyons & Koenig, 2013). For example, upon meeting up with a friend for lunch, one immediately evaluates the mood and emotions of the other. If one finds their friend in distress, that typically becomes the topic of the interaction. If while that friend is in the bathroom, you switch tables due to a cold draft, your friend still believes she will return to the original table, and therefore she holds a different belief than you. When she starts walking to the other side of the restaurant, you understand her goal is to sit back down to continue lunch based on her different beliefs. You, therefore, interpreted her emotions, beliefs, and goals all in one lunch. Social cognition is used in nearly every interaction with another being.

One aspect of social cognition includes a set of skills termed Theory of Mind (ToM): the ability to understand the thoughts, beliefs, desires, intentions, and other mental states of oneself and others (Premack & Woodruff, 1978). On a spectrum of most basic to the most complex, Theory of Mind includes the recognition that oneself and others have goals, may imitate behavior, take differing visual perspectives, reflect on their own mental states (metacognition), and may possess false beliefs about the world. Recognizing goals involves tracking behavior to make an inference about the desired outcome. For example, if I am sitting at a table with my phone and my keys on it and I reach toward my phone, you may assume my goal is to pick up my phone. Even young infants seem to attribute goals to others in this way (Hernik & Southgate, 2012). Imitation involves copying behavior exactly so as to conform to perceived cultural norms. In a study involving infants, 14-month olds watched two situations: both where adults tapped a light with their heads but in one their hands were wrapped in a blanket and consequently unavailable to turn the light on and in the other situation they were free but not used (Gergely, Bekkering, & Király, 2002). When their hands were unavailable, the infants tapped the light with their hands, but when the adult’s hands were not tied, the infants tapped the light with the heads as well, presumably because the infants assumed they were being given cultural information about the mode of turning on lights -- with the head rather than the hand.

Visual perspective-taking involves inferring what other people see from their different points of view (Schurz et al., 2015). For example, if I look up at the ceiling, you also would likely look up at the ceiling to see what I am looking at. Young children also possess the ability of visual perspective taking. For example, 14-month-olds had time to play with a toy that the experimenter claimed to belong to them. During test trials, the child and experimenter now face two toys: an old one that belongs to the experimenter and a new one that has not been claimed. In one trial (the visible trial), the experimenter can see both the new and old toys. In another trial (the blocked trial), the experimenter cannot see the old toy but it remained visible to the infant. In this case only the new toy was visible to the experimenter. When asked to indicate which toy belongs to the experimenter, the infants look longer, indicating surprise, at the experimenter reaching for the new toy in the visible trial compared to the blocked trial (Sodian & Thoermer, 2007). This suggests that infants understood that the other person did not see the old toy in the blocked trial. Metacognition involves knowing what you do and do not know (Brown, 1977). When a college student is studying for finals, they know which subject to study the most because they can assume which class they lack the most knowledge for. When infants are given the opportunity to ask for help on a problem they do not know how to solve, they too ask for help, demonstrating metacognition even in young children (Goupil, Romand-Monnier, & Kouider, 2016).

Though young children develop many ToM skills early in development, the true hallmark of development of full ToM occurs when they demonstrate the ability to understand false beliefs

(FBs), the recognition that another individual may possess a belief both contrary to one's own belief and contrary to reality (Baron-Cohen, Leslie, & Frith, 1985). Most of the other ToM skills are relatively low-level and may be explainable by other, non-ToM mechanisms. For example, visual perspective taking is a ToM skill but on its own does not indicate a full ToM. One may state that if you were to look up at the ceiling after seeing me look up, you would possess a ToM since you possess this ability. However, you may have been conditioned to look up when someone else looks up, or this looking behavior may be driven by another simpler social explanation -- local enhancement -- and therefore this ability may not come from a ToM but instead from simple learning mechanisms. False beliefs, on the other hand, require more complex cognitive abilities and often cannot be explained by some other mechanisms so demonstrating a FB understanding remains the best indicator of possessing a full adult-human like ToM.

A classic example of a FB task is the Sally-Anne task (Baron-Cohen et al., 1985; Wimmer & Perner, 1983): Sally had a basket and Anne had a box. Sally placed a marble in her basket and then took a walk. While Sally was gone, Anne took the marble out of Sally's basket and placed it in her own box. Sally returned from her walk and wanted to play with the marble. The crucial question occurs when the researcher asks: Where will Sally look for her marble? Most adults (and children over 4) reply that Sally would search in her basket, where she last saw it, even though they know the marble truly resides in the box. In other words, most adults recognize that Sally has a false belief about the location of the marble.

While we now know a great deal about ToM development, and in particular, the developmental pathway to demonstrating FBs in humans, the notion of ToM was originated by researchers interested in learning more about how chimpanzees think of other minds (Premack &

Woodruff, 1978). A chimpanzee, Sarah, was asked to pair one set of cards depicting problems a human experimenter faced with another set of cards with potential solutions to those problems. For example, an experimenter presented a card with a shivering human and an unplugged heater next to them. Then they gave Sarah the option of three cards: a plug in the wall, a key entering a lock, or a hose being attached to a faucet. Sarah consistently chose the correct pairing: an unplugged heater with a plug in the wall, demonstrating, the authors argue, that she understood the goal of the human in the picture. Sarah continually correctly matched the problems and solution cards. According to the researchers, in order to solve this task, Sarah necessarily demonstrated an ability to recognize some aspect of the goals of the human protagonist and then act on those goals (Premack & Woodruff, 1978). However, Sarah often saw these exemplars paired in her life such as a zookeeper using a key in a lock. Sarah may have associated these through previous experience and had no concept about the goals of the human in the story (Savage-Rumbaugh, Rumbaugh, & Boysen, 1978). She may, then, have seen an unplugged heater and recognized that the card that was most relevant was a plugged-in heater without reference to the mental states of the human actor.

Due to the very real possibility of alternative explanations, further examining the possibility of ToM in animals became a common topic due to its implications of how far cognition can reach in humans and other animals. FB work has been persuasively demonstrated in humans, but it remains controversial whether non-human animals possess it or not. Therefore, the following examines which species possess which components of ToM. First, we will examine what constitutes ToM and FBs in humans, then non-human primates, and finally we will turn to dogs.

Humans

As we saw in the Sally-Anne task, most FB tasks typically involve language. For example, in the Sally-Anne task outlined above, researchers verbally ask children where Sally thinks the marble resides: in Sally's basket (demonstrating FB understanding) or in Anne's box (lacking FB understanding). Children generally respond verbally: "in the box" or "in the basket". Evidence of this type of explicit understanding of false beliefs first seems to appear in children around the age of four (Grosse Wiesmann, Friederici, Singer, & Steinbeis, 2017). At this age, children correctly state Sally will search for the marble in her own basket, where she last saw it, and not in Anne's box, where the child knows it to be. Children three years of age and younger struggle with such explicit FB tasks and regularly predict that Sally will reach where the child herself knows the marble currently resides, in Anne's box instead of Sally's own basket where Sally last saw it (Grosse Wiesmann, Friederici, Singer, & Steinbeis, 2017).

Similar results obtain in another classic FB task, the Smarties task (Hogrefe, Wimmer, & Perner, 1986). In this task, two children were presented with a Smarties container, a British candy somewhat like M&Ms. Children were shown that the Smarties container did, in fact, contain smarties. One child, say, John, left the room and while he was gone the experimenter replaced the smarties inside the container with a novel object-- ribbons--while a second child, say, Jane, looked on. When John returned, the experimenter asked Jane what John thought resided in the container. As with the Sally-Anne task, children under four performed poorly. They stated that John believed ribbons would be inside the Smarties box, while adults and children over four stated John would believe Smarties were inside.

One explanation for why children under four perform poorly on these FB tasks -- the Sally-Anne task and the Smarties task -- is that they do not possess the ability to represent two different beliefs: the state that they know to be true, and the wrong belief held by the other person. That is, that they fail to recognize FBs. Other variations of this task lead to the same conclusions (Gopnik & Astington, 1988). Thus, typically developing children over four consistently perform well on explicit FB tasks, tasks requiring verbal question-and-answer scenarios, and can use their FBs knowledge to make predictions about behavior in social interactions.

However, this is not the only reason children younger than 4 years of age may perform poorly. For example, executive function and impulse control (Drayton, Turley-Ames, & Guajardo, 2011) increases between the ages of three and four and correlates with ToM tasks (Hughes, 1998). Children under three-years-of-age have underdeveloped executive function, resulting in an inability to inhibit their own knowledge about where the marble is or what’s in the Smarties box to answer the question from another’s point of view. Because they know where the marble is or what’s in the box they cannot inhibit this knowledge, therefore leading them to respond with their own knowledge and consequently fail the explicit FB tasks. Not only might executive function contribute to the difference in FB understanding between three- and four-year-olds, but even adults have also shown their own knowledge can jeopardize their ability to understand another’s beliefs and make predictions of their actions (Birch & Bloom, 2007). Therefore, executive function poses a plausible alternative explanation as to why young children may fail verbal FB tasks.

Another potential explanation for young children's failing to demonstrate FBs comes from their language skills. Perhaps young children fail FB tasks not because they lack the understanding that one may indeed hold a false belief, or because they cannot inhibit their own knowledge, but, rather, because they do not possess sophisticated enough language skills to either understand the question or answer it correctly. Evidence supports this notion: performance on explicit false belief tasks correlates with the development of language (Grosse Wiesmann et al., 2017).

Taken together, poor executive functioning and language skills may impact children's ability to explicitly demonstrate their true understanding of false beliefs. Therefore it is not clear whether the performance of three-year-old children on FB tasks like the Sally-Anne and Smarties tasks represents a true lack of FB understanding, a lack of executive function, or unsophisticated language skills.

Interestingly, when given an implicit false belief task, one that does not involve language either in any way, children much younger than three can perform successfully on FB tasks (Grosse Wiesmann et al., 2017; Onishi & Baillargeon, 2005). These implicit false belief tasks usually rely on the violation of expectation paradigm of studying cognition, a paradigm that relies on children and infant's tendency to look longer at events that surprise them compared to mundane events (Bogartz, Shinskey, & Speaker, 1997). Using a violation of expectation procedure, infants watched an event that looked very much like the Sally-Anne task: an experimenter watched as a ball entered box A. A screen then occluded the experimenter's face and the ball moved to box B. The screen was removed, revealing the experimenter once again. Next, the experimenter either reached into box A (where she last saw the ball) or into box B (where the ball really was). If infants could represent the experimenter's belief, false though it may be, they should have expected the researcher to look into box A (where she last saw the ball) and not box B (where it actually was). Infants would demonstrate such expectations by looking longer when she reached into box B (where the ball had moved) than when she reached into box A (where she last saw the ball).

Twenty-five-month old toddlers (Southgate, Senju, & Csibra, 2007) and 15-month old infants (Onishi & Baillargeon, 2005) looked longer at scenarios when the actor reached for box B (where the object actually resided) demonstrating an understanding that the experimenter possessed a false belief about the location of the ball. Even children as young as 10-months old consistently looked longer at the unexpected reach towards box B, showing an understanding of implicit false beliefs (Lou, 2011). Some have found that decreasing the demands on executive function of children by changing tasks from explicit to implicit increases performance on similar types of tasks (Diamond, 1985). Therefore executive function may cause children under four to fail explicit tasks while passing the implicit ones. In contrast, explicit false belief task performance correlates with language development (Grosse Wiesmann et al., 2017). Either reason could explain why 3-year-olds do not pass explicit FB tasks.

Humans perform exceptionally well on implicit tasks, become capable of understanding explicit tasks around four years of age, and perform nearly perfectly as adults. The Sally-Anne task seems extremely simple to adults and unfathomable to think one may think otherwise. Thus, we can be confident that human adults possess ToM and, in particular, FBs. But what about non-humans? Is this a uniquely human skill? As we have seen with Sarah, the question of whether non-human animals possess this FB understanding or ToM, in general, remains ambiguous.

Non-human primates

Understanding some aspects of social cognition is not a uniquely human ability. For example, chimpanzees cooperate together in group hunts, which requires a great amount of understanding of each member's roles and making predictions about the movements and activities of others. Nonhuman primates have also been known to take others' perspectives into account, for example, by initiating mating only when out of sight of the alpha male (Byrne & Whiten, 1988). They even conform to social norms (Whiten, Horner, & de Waal, 2005) and cultural traditions (Whiten et al., 1999).

In the lab, nonhuman primates reliably demonstrate an ability to recognize human intentions. Capuchin monkeys (Phillips, Barnes, Mahajan, Yamaguchi, & Santos, 2009) and chimpanzees (Call, Hare, Carpenter, & Tomasello, 2004) differentiate between a human unwilling to give them food (for example, holding the food but refusing to give it to the animal) and a human willing to give food but unable to do so (for example, because they are clumsy and drop the food and it rolls away). That is, animals consistently leave the testing area sooner when the human is unwilling to provide the food than when they are unable to do so.

Not only can non-human primates understand intentions, but, under the right circumstances, they appear to understand basic communicative cues such as gazing and pointing. In a now classic task, the object-choice task, researchers gave chimpanzees a choice of two cups to search for food. Though the chimps did not see which cup the food was hidden under, researchers gave them social cues such as pointing, gazing, and vocalizing. Chimpanzees used both head bobbing and vocalizing to locate the hidden food, showing that they understand the communicative goal of the human to direct their attention (Itakura, Agnetta, Hare, & Tomasello, 1999). Apes, following the human gaze as an indicator in an object-choice task, also choose the correct tube or barrier with food. However, when a barrier occluded the human from the object, the apes did not use human gaze to find the food. (Call, Hare, & Tomasello, 1998). This indicates an understanding of visual gaze following. In addition to the object-choice task, great apes (chimpanzees, orangutans) follow the gaze of an experimenter by looking to the ceiling when the experimenter looks above them. Thus, great apes demonstrate perspective taking which requires them to interpret that another being has a different view than their own, affecting their actions.

Though non-human primates can perform well in some social cognition tasks, they do not always perform well. For example, great apes oftentimes struggle with simple gazing in the absence of paired cues. That is, when a human gestures toward a container or vocalizes in its direction, great apes can predict which of the containers holds food, but they cannot use a simple human gaze alone to interpret the food's location (Itakura et al., 1999). Further, apes are not able to use pointing at all to find hidden food (Itakura et al., 1999).

Non-human primates may understand some aspects of ToM such as recognizing goals and some aspects of communicative intent, but whether they can demonstrate the more complex aspects of ToM such as imitation, visual perspective taking, metacognition, and false beliefs is more controversial (Kano, Krupenye, Hirata, Tomonaga, & Call, 2019; Krupenye, Kano, Hirata, Call, & Tomasello, 2016; Premack & Woodruff, 1978). For example, when an ape experiences an opaque barrier in real life, they predict that the barrier always remains opaque and therefore a human cannot see past the barrier as well during a false belief task similar to the Sally-Anne task.

They must, therefore, rely on locations of objects where they last saw it, contrary to the object's current location. In the same task, when an ape experiences translucent barriers in real life, they expect humans to look for an object where it currently lays since they assume the human also possesses the ability to see through the barrier to the object's current location (Kano et al., 2019). In this case, the task only works if apes have had past experience with opaque and transparent barriers. Therefore, the apes use their previous knowledge of whether the barrier is opaque or translucent to predict where a human looks for an object. This knowledge uses their ability of visual perspective taking, an example of possessing ToM.

In a task similar to the Sally-Anne task, bonobos and orangutans watched a scenario in which a person in all black hid a stone that the human experimenter wanted under one of two boxes. When the experimenter person turned away, the person in all black moved the stone to the opposite box. The apes looked in the direction they expected the experimenter would approach and knew the object last to lay, even though the apes knew the object had been moved somewhere else. The authors interpreted this to mean that the apes could understand FBs at an implicit level (Krupenye et al., 2016). In another alternative method of this task, an experimenter watched an assistant place a toy in a locked box. In the true-belief condition, the experimenter stayed and watched while the assistant moved the toy to the other box. In contrast, in the false-belief condition, the experimenter left and did not witness the assistant moving the toy before returning for the rest of the experiment. In both conditions, the experimenter attempted to reach toward the box in which the assistant first placed the toy. The apes unlocked the correct box (the one with the toy) in the false-belief condition more often than in the true-belief condition. This difference in performance between conditions showed the apes did hold an understanding of FBs (Buttelmann, Buttelmann, Carpenter, Call, & Tomasello, 2017). These animals all demonstrated a general understanding of false-beliefs.

While these results seem to indicate that some nonhuman primates perform well on FB tasks, other studies suggest that nonhuman primates do not possess the ability to understand FBs. In a study using rhesus macaques, an apple moved from one box to another as in the Sally-Anne task, while both the monkey and a human watched. Four experimental trials were randomly presented. Macaques looked longer when the apple's location violated their own belief -- that is, the monkey thought the apple was in location A but really it was in location B. However, monkeys looked the same amount of time regardless of the human's belief -- if the human thought the location was in location A but really it was in location B. Therefore the belief of the experimenter did not affect macaques looking time, suggesting that they do not understand others' false beliefs (Martin, & Santos, 2014).

Even when researchers used a simple method that did not require the monkeys to use language or demonstrate executive function, monkeys failed to choose correctly. Rhesus macaques viewed the true beliefs and false beliefs components of the previous study while experimenters added another condition: a true belief with occlusion condition (Marticorena, Ruiz, Mukerji, Goddu, & Santos, 2011). This new condition allowed researchers to examine whether the momentary time lapse during which the occluder covered the person's face could explain why they failed to demonstrate understanding FBs. In the true belief condition, the experimenter sat behind a stage while watching a lemon move to the left box. The person continued to watch as the lemon then moved to the right. The person reached either to the right box where the experimenter knew the lemon currently resided (expected) or the left box which the experimenter knew was empty (unexpected). In the false belief condition, the person watched the lemon move to the right again, but then an occluder raised while the lemon moved to the left box, so the person did not see it move. The occluder then was removed and the person reached again to either box, with the right box now being unexpected and the left box considered expected. In the new condition, the true belief with occlusion, the person watched the lemon move to the left. Then the occlusion raised and fell again. The lemon did not move during this time. The human then reached to either the left (expected) or right (unexpected) box. Researchers found that the rhesus macaques still looked longer at the unexpected box than the expected one for the true belief with occlusion condition but did not look significantly different at either expected or unexpected for the false belief condition, leading to the conclusion that monkeys can understand other's knowledge, but they fail to understand their beliefs. Though monkeys deviate further from the human evolutionary lineage, great apes, closer relatives to humans, also perform inconsistently on FB tasks.

In a FB experiment with chimpanzees and orangutans, a hider placed an object in one of two places without showing the great ape where. A different person, the helper, watched this occur and then left the room. At this point, the hider switched the two locations. When the helper returned, they marked the location where they believed the object to lay using a token that the subject could see. The task required the ape to understand that the location the helper chose was incorrect because she held a false belief due to the switching of the locations. Therefore, they should have chosen the container the helper did not indicate. However, the apes failed to represent this understanding and consistently chose the marked location. (Call, & Tomasello, 1999).

These methods of exploring FB understanding in great apes often use cooperative skills, like working with the experimenter to retrieve the food inside the correct box, but chimpanzees are naturally much more competitive than cooperative. For example, animals face competition when searching for food and generally only females cooperate with each other, specifically, when foraging with their young offspring. However, even when researchers adjusted the methods to make the task competitive, apes failed the false belief task (Krachun, Carpenter, Call, & Tomasello, 2009). While in a typical false belief task, the animals work cooperatively with an experimenter to retrieve food, but in a competitive task, the experimenter attempts to retrieve the food before the participant. In the true belief condition, the competitor watched the food placed into one of two containers. Then both the competitor and the participant watched the containers switch. In the false belief condition, the competitor “became distracted” and turned around while the containers switched while only the participant watched. The competitor then turned back towards the containers. In both, the competitor reached for one container to retrieve food but could not reach it because of lacking the ability to reach far. The participant was then allowed the opportunity to access either container, again not knowing where the food originally was placed. However, they could make an inference from where the competitor reached. For the true belief, the participant should reach towards the same container as the competitor but for the false belief, the participant should reach towards the opposite container since the competitor did not see the switch. Instead, the chimpanzee did not reach according to FBs while five-year-old children did (Krachun et al., 2009). This study, along with the aforementioned others, suggests that non-human apes do not possess the understanding that others have thoughts and beliefs different from their own.

As with many social cognition tasks, many reasons may explain the contradictory results on FB tasks with nonhuman primates. In the competitor false belief task, the apes had to distinguish between what the competitor saw and what they themselves saw. They may have failed because they found the competitors reach toward a box so compelling that they only paid attention to the reaching cue (Krachun et al., 2009) or due to a possible lack of executive function (Drayton et al., 2011). Some chimpanzees pass some tests but not others, further suggesting that other aspects of cognition may play a part in different tasks (Call & Tomasello, 2008). Researchers cannot yet eliminate the hypothesis that other species possess a ToM because many different cognitive mechanisms may contribute to one's understanding and the literature lacks research teasing apart these mechanisms (Meunier, 2017). Understanding whether other animals possess FB understanding and in what way may help researchers better separate the mechanisms and better understand ToM as a whole. Considering non-human primates produce inconsistent results, dogs are a more promising species to explore due to their consistently better performance on social cognition tasks.

Dogs

Dogs, including puppies, are more successful in social cognition tasks than other canids (wolves) and chimpanzees (Hare, Brown, Williamson, & Tomasello, 2002), demonstrating their ability to use cues such as gazing, physical makers, and pointing to predict locations of objects in the object-choice task (Hare & Tomasello, 1999; Riedel, Buttelmann, Call, & Tomasello, 2006). Many explanations have been posited for dogs' success on social cognition tasks, and the debate relies on differing opinions of whether these abilities are innate or learned (Reid, 2009). If dogs learn these capabilities in their lifetime, then, with enough experience, other species likely would be able to develop them as well. For example, human-socialized wolves have learned to follow human gestures and excel in object-choice tasks (Udell, Spencer, Dorey, & Wynne, 2012). Instead, if they are innate, then dogs may possess exemplary social cognition skills that may not be replicated in other species other than humans. Even when wolves were hand-reared, they did not display the same social cognitive skills as dogs (Gácsi, Vas, Topál, & Miklósi, 2013). Whether success on social cognition tasks in dogs is innate or learned remains an ongoing debate.

This debate is complex, but it seems likely that the process of domestication has enhanced social cognition skills over time. Three lines of evidence support this. First, puppies also possess these skills, suggesting that these skills are innate and that dogs are not likely to develop them with experience over their lifetime (Hare et al., 2002). Second, these social cognition skills are unique to dogs, and are not present in their closest evolutionary relatives (wolves), supporting the notion that they evolved through domestication (Hare et al., 2002). Third, domesticated foxes outperform wild-type foxes on social reasoning tasks, further supporting the notion that domestication can shape social reasoning (Hare et al., 2005). Therefore, dogs seem to possess exceptional social cognitive abilities compared to both nonhuman primates and other canid species (wolves).

Since dogs perform more consistently in social cognition tasks than non-human primates, we predict that they are likely to perform more consistently on false belief tasks. No published experiments have conducted false belief tests with dogs to date. I hypothesize that dogs will perform well in an implicit false beliefs test using a violation of expectation method. In other words, they will look longer when an experimenter acts contradictory to their understanding of false beliefs.

Method

Subjects

The subject pool of dogs (13 males, 14 females, M_{age} = 8.37[1] years) was recruited from the Bloomington-Normal community (see Table 1 for demographics). Ten dogs were excluded due to errors including the dog failing to watch critical components of the presentation ($N = 5$), a distraction from the owner ($N = 3$), experimental error ($N = 1$), and lack of ability to see the dog's eyes in coding due to hair ($N = 1$). The decision to remove a dog from the experiment in real-time was made by the cameraperson since they were blind to the condition.

Owners registered their dogs online where they answered questions about breed, age, temperament, and allergies (for future studies involving food). These owners received an email with a link to an online scheduling website where they could select a day and time to visit the lab for this study. An ad was also posted on the IWU Dog Scientist Facebook page. Owners filled out consent forms. This research was approved by the Illinois Wesleyan University IACUC.

Materials[2]

The materials included a visually appealing blue rubber duck, a screw connected to the duck's underside that acted as a handle for the experimenter, and a stage made of foam core. The foam core stage contained a screen on the front to cover the entire viewing area, and a platform with a horizontal track cut into it. The blue rubber duck could be moved along the horizontal

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[1] Dog age based only on the dogs included in the online database. Other ages had yet to be entered in the database and were in the lab that we lack access to.
[2] Dimensions of materials not included due to the building containing the lab being closed due to COVID-19 before measurements were taken.

track via a screw the researcher could manipulate from the underside of the platform. Two foam core boxes, large enough to occlude the duck, sat on either end of the platform. A second screen connected to the back of the stage could be lifted to occlude the researcher. To record the dog's looking time, a cameraperson held a Sony HDR cx430v High Definition Handycam Camcorder. The computer program MPEG Streamclip allowed researchers to view the videos of the dogs frame-by-frame (at thirty frames per second). Due to COVID-19 shutting down campus resources, data analysis used Google Sheets.

Procedures

We based our methods off of the procedures used by Onishi & Baillargeon (2005) who studied 2-year-old human toddlers on a false belief task. The experiment took place in a 4.67 m x 3.19 m room at Illinois Wesleyan University in the IWU Dog Scientists lab. Owners brought their dogs into the lab and consented to the experiment after receiving an explanation of the study. Subjects entered the room one at a time and roamed the room for up to one minute. The dog holder obtained the dog and held the collar to keep the dog in a specified area indicated by a line of tape on the floor. The dog holder then looked away from the presentation so they did not watch it therefore remained blind to the conditions. After the dog was in position, recording and trials began. The screen in front of the platform descended between each trial to indicate the start of a new trial. The cameraperson remained blind to the condition because they only looked at the dog and could not see what the researcher presented on the stage. This person decided when to exclude a dog from the experiment. This researcher also kept track of the time by announcing when 11 seconds passed after each trial started.

Familiarization Trials. In the familiarization trials, the screen dropped to reveal the duck sitting in the middle of the stage (Figure 1a). The researcher watched as the duck moved on the track to the right box (Figure 1b). When the researcher reached for the duck in the right box, they announced “now” and the time began (Figure 1c). Their head remained down during this pause as to remove any biases that looking at the dog may produce. The camera stayed focused on the dog’s face and the camera person announced “stop” after 11 seconds passed. The screen then rose, occluding the stage, and the duck returned to the middle of the platform. In the second familiarization trial, the same thing occurred except the duck moved from the middle to the left box. The researcher reached toward this left box, head down, and again announced “now” and held for 11 seconds. This terminated the two familiarization trials.

Experimental Trials. In the experimental trials, the researcher presented two different trials, an unexpected trial and an expected trial. We use a within-subject experimental design and randomly assigned dogs to the order in which unexpected or expected trials are first presented.

The expected trial began the same as the first familiarization trial. The screen dropped to reveal the duck sitting in the middle of the stage (Figure 1d). The researcher watched as the duck moved on the track to their right (Figure 1d). This trial differed from the familiarization trials as a moveable screen next arose to cover the researcher’s face so they could no longer watch the scene. Once this occurred, the duck then moved to the left, out of the box where the researcher had just seen it and into the other box (Figure 1f). The occluder then dropped to reveal the researcher’s face and they reached toward the right (where they last saw the duck; Figure 1g) with their head down. The researcher then said “now” and the cameraman said “stop” after 11 seconds. The screen then covered the stage to reset. This was expected because the researcher did not see the duck move to the left and therefore should reach to the right to obtain it.

The unexpected trial proceeded exactly the same except for that when the screen revealed the researchers face, they reached toward the left (where the duck actually was, not where the researcher last saw it; Figure 1h) with their head down. This was unexpected because the researcher did not see the duck move to the left and therefore it would surprise us if they somehow knew it moved. This concluded the four trials presented to the dogs, who then returned to their owners.

Coding and Analysis

One researcher coded the looking time for the dogs following the conclusions of the experiment. A research assistant blind to the hypothesis and the condition also coded for a reliability check. The two coded independently using MPEG Streamclip for all four trials with time beginning when the experimenter stated "now" and ending 10 seconds later. A Cronbach's Alpha test showed excellent interrater reliability between the coders, $\alpha = 0.920$.

Results

Using Google Sheets, a single-tailed paired t-test was conducted comparing the looking time between the unexpected and the expected trials of the 17 dogs included. Dogs did not look significantly longer in the unexpected trial ($M = 3.45$, $SD = 2.59$) than the expected trial ($M = 2.56$, $SD = 1.88$), $p = 0.13$[3] (Figure 2). Familiarization 1 ($M = 3.61$, $SD = 3.21$) and familiarization 2 ($M = 2.90$, $SD = 1.58$) were not included in the analysis, though they did show the expected pattern of decreased looking over the familiarization trials.

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[3] Only the p-value is provided as that is all that Google Sheets provides in the output. We had initially planned to use SPSS but were unable to do so due to COVID-19.

Ideally, we would have also conducted a Wilcoxon-Signed Ranks test, a nonparametric test that controls for small sample sizes. However, without access to SPSS, we were unable to do so.

Discussion

This experiment investigated whether dogs possessed the capability to understand false beliefs by comparing the difference in looking time between the unexpected and the expected trials for each dog. In the expected trial, the researcher reached toward the box in which they last saw the duck move, the right one. The researcher acted in line with her false belief but contrary to reality. In contrast, when the researcher reached to the left, this contradicts our knowledge that she last saw it on the right but is in line with where the duck really was. The analysis found no significant difference between the two, failing to support the research hypothesis that dogs would look longer at the unexpected outcome than the expected outcome. Therefore, dogs did not show an understanding of FBs. Even so, the dogs looked almost one second longer at the unexpected condition compared to the expected condition. Typically, a study of this nature includes about 40 dogs in their comparison, though this current one only had 17. If the total of 40 dogs were included, it is possible that the analysis could have produced significant results.

This study contributes to the current literature supporting that other non-human animals do not understand FBs and therefore do not possess the complete set of skills involved in Theory of Mind. No monkeys to date have shown any supportive evidence of FBs (Marticorena et al., 2011; Martin, & Santos, 2014) while nonhuman apes have shown contradictory results: some supporting FB understanding (Buttelmann et al., 2017; Krupenye et al., 2016) and some calling into question that apes understand FBs (Call & Tomasello, 1999; Krachun et al., 2009). On balance, most research leans towards a lack of false belief understanding in non-human animals.

Even so, dogs remain good candidates for social cognition and ToM tasks. They perform consistently better than non-human primates (Hare et al., 2002; Hare & Tomasello, 1999; Riedel et al., 2006) so they seem the most likely nonhuman species to perform well on FB tasks. Therefore, future research with dogs on ToM tasks continues to remain relevant.

In contrast, humans consistently perform well on both explicit and implicit false belief tasks. Children over four years old have continually shown an understanding of explicit FB tasks (Gopnik & Astington, 1988; Hogrefe, Wimmer, & Perner, 1986) while children as young as ten months old perform equally as well on implicit tasks (Grosse Wiesmann et al., 2017; Lou, 2011; Onishi & Baillargeon, 2005; Southgate et al., 2007). Whether this shift is due to executive function (Drayton et al., 2011) or language development (Grosse Wiesmann et al., 2017) remains unclear. Dogs possess some level of executive function and some even suggest that larger dog breeds possess better executive functioning than smaller breeds due to their larger brain size (Horschler et al., 2019). Thus, comparing false belief capabilities with different dog breeds might provide better evidence as to whether FB can be attributed to executive functioning.

A small sample size encompasses the main limitation of the study. Due to unforeseen environmental disruptions, data collection could not continue through its entirety. The sample size remains quite small compared to ideal circumstances and so the small sample size and large variance likely overshadowed any small effect size that may have been present. Since the p-value was .13, a larger sample size may have increased the power enough to detect even a small but significant difference.

Future work on FBs with dogs should include both true belief and ignorance conditions. Other experiments with nonhuman primates have included a true belief condition to better understand if the results truly are a measure of false beliefs and not something else (Marticorena et al., 2011). In a true belief condition, the experimenter would watch the duck move to the other box. This contrasts the false belief condition in which an occluder blocked the experimenter from seeing this transition. Therefore when the experimenter reaches towards the box in which the duck finally moved to, the dog would find this expected for the true belief (in which the experimenter watched it move) and unexpected for the false belief (in which the experimenter did not see it move to). This distinction between a true belief and a false belief condition would allow researchers to examine if dogs possess the ability to differentiate between the two, providing further support to claim dogs understand FBs.

An ignorance condition, as previously conducted with rhesus macaques (Horschler, Santos, & MacLean, 2019), would allow researchers to differentiate between a false belief understanding and misrepresentation of other's knowledge. This previous experiment conducted a true belief test in which an occluder still covered the person's view momentarily while either the object moved out and then back into the same box or the box itself lifted to reveal the object. In both, the object concluded in the same box that the person last saw before occlusion. They found that the monkeys differentiated between the person reaching toward the correct and incorrect box in the condition that the box moved. Instead, when the object moved out and back in, the monkeys looked just as long at both conditions, suggesting that they can understand each other's knowledge through awareness relations but this understanding is disrupted by spatial movement. Monkeys struggled to understand the person's ignorance. Therefore, this experiment may not be a test of false beliefs, but instead a test of understanding ignorance. Moving forward, it remains imperative to include both these conditions.

Overall, our findings suggest that dogs, and, through extension of previous research, other non-human primates, do not possess the ability to understand false beliefs while human children as young as 10 months old do. FBs remain an important component of ToM for two reasons. First, they involve the most complex cognitive reasoning of all the ToM tasks and the least likely to be explained by alternative explanations. If an organism understands FBs, then we can definitively state they possess ToM. Second, FB understanding can correlate with prosocial behavior towards others. When a child understands others' beliefs, thoughts, and perspectives, they empathize and engage in prosocial behavior more (Ornaghi, Pepe, & Grazzani, 2016). Understanding FBs also correlates with the ability to make persuasive arguments (Slaughter, Peterson, & Moore, 2013). Some groups lack the ability to demonstrate prosocial behavior or generate coherent arguments, and these deficiencies may arise from ToM related problems. For example, some children with autism lack ToM and therefore have an inability to understand other's beliefs based on their different experiences (Baron-Cohen et al., 1985). Understanding ToM, prosocial behavior, and language remain vital to understanding social cognition and human capabilities as well as the capabilities of other animals.

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Table 1.
Dog Demographics

Dog name	Sex	Age (yr)	Breed
Hildegard[a]	F		German Shepherd
Tex[a]	M		Lab, Basset, Otterhound, etc
Walker	M		Lakeland Terrier
Tilly	F	8	Beagle, German Shepherd
Layla	F		Standard Poodle
Lucky[a]	M	7	Golden Retriever
Max[a]	M		Golden Retriever
Shiloh[a]	F	9	Terrier
Maggie	F		Poodle
Hobbes	M		
Mason[a]	M		West Highland White Terrier
Finley	M		
Comet	M		Bertanee, German Shepherd
Steve	M		Terrier Mix
Zannie	F		German Shepherd, Rottweiler
Harry	M		Corgi
Audi	F		Poodle
Sweet Dee[a]	F		Boxer, Pitbull, Bulldog
IsaBella	F	10	American Cocker Spaniel
Ginger	F		Labrador, Pointer
Cody	M	12	Labrador, Great Pyrenees
Enzo[a]	M		Beagle
Roxy	F	8	Papillon

Maddie[a]	F		Papillon
Riley	M		Maltese, Poodle
Rizzo[a]	F	6	Golden Retriever
Wrigley[a]	F	11	Golden Retriever

Note. [a] = excluded from data analysis.

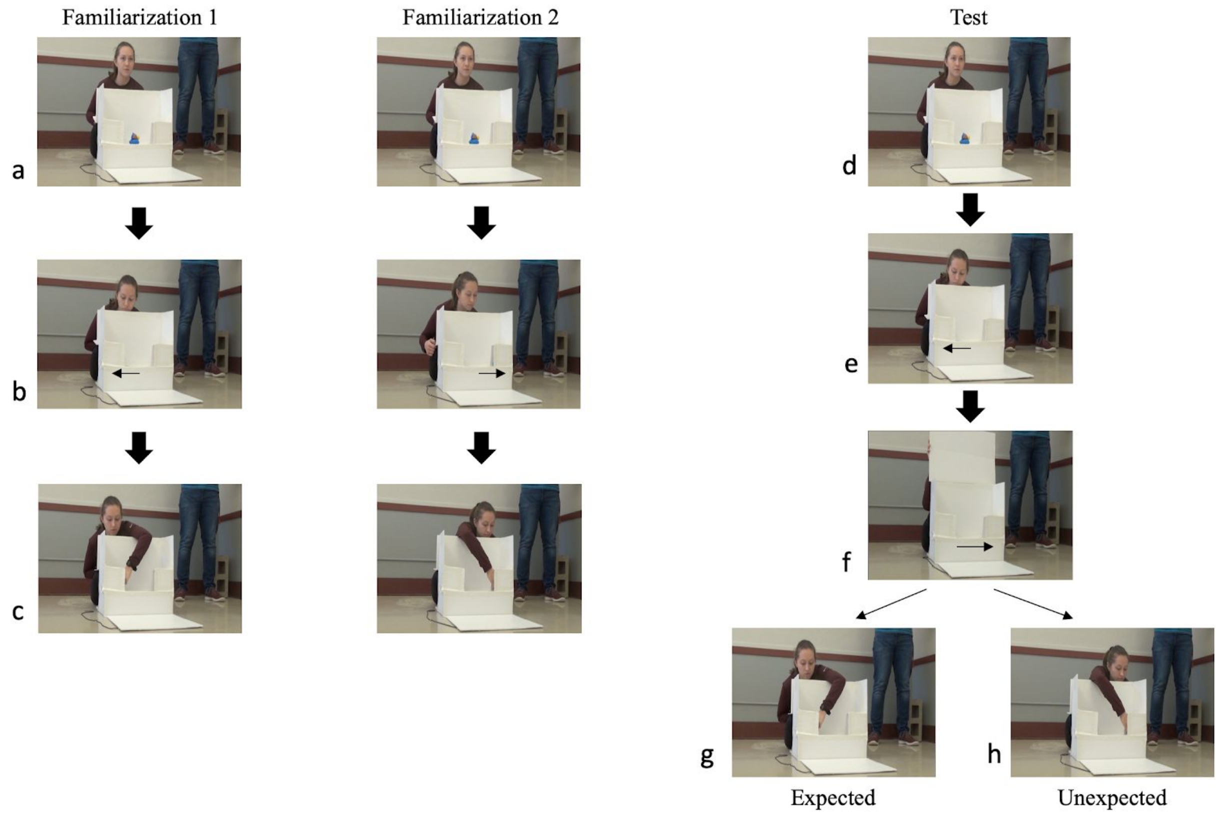

Figure 1. The two familiarization trials and the two test trials presented to the dogs.

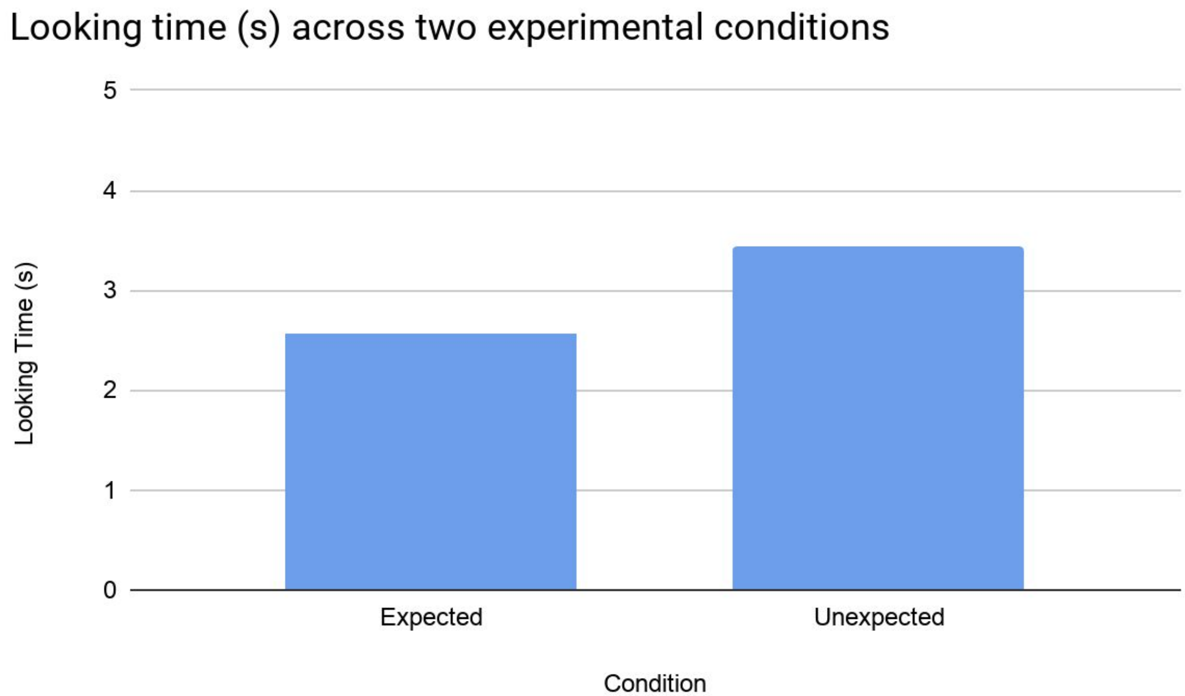

Figure 2. The difference in looking time between the Expected condition [95% CI: 3.45 ± 1.27] and the Unexpected condition [95% CI: 2.56 ± 0.92].