

Belief Contagion: Susceptibility to Others' Beliefs in *Canis familiaris*

By Katherine Garvey

Advised by Laurie Santos, PhD  
Professor of Psychology  
Yale University

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**Abstract**

Young infants' successful performance on false belief tasks has led researchers to argue there may be a core knowledge system for representing the beliefs of other agents. One way to investigate this purported core belief representation system is to examine whether other species share such a system. Belief representation and theory of mind has traditionally been investigated in nonhuman primates, particularly chimpanzees and rhesus macaques. However, non-primate species, such as domesticated dogs, are also viable candidates for such a cognitive capacity, as dogs share humans' social environment and have developed special cognitive abilities due to their co-evolution with humans via domestication. Prior research in canine theory of mind is limited, with inconclusive and contradictory results. Little work has explored how canines perform on more automatic measures of belief representation and processing. To address this issue, this study aimed to investigate theory of mind in dogs using a searching time paradigm as part of a novel false belief task. Kovacs et al.'s (2010) test of automatic belief representation was modified to examine whether domesticated dogs (*Canis familiaris*) automatically represent and are influenced by agents', specifically their owners', beliefs when tracking an object's location. Dogs and their owners observed a sequences of events in which treats were place in or removed from a bucket filled with shredded paper. By blocking visual access to the treat's movement for either the dog, the owner or both, the dogs' belief (true or false) and owners' belief (true or false) about the final number of treats in the bucket were manipulated. No statistically significant main effect of dog belief, no main effect of owner belief and no interaction between dog and owner belief were found. These findings suggest automatic belief representation and contagion may be an aspect of core knowledge unique to humans.

## ***Introduction***

Humans are guided by internal mental states, such as goals and beliefs. People understand others' behavior as the result of these unobservable mental states. Without the ability to infer others' mental states, human society would not be possible as social interactions depend on the ability to infer others' intentions and beliefs. Developmental psychologists often debate when and how humans acquire the ability to represent such unobservable mental states and recognize these mental states can be different from one's own (Heyes, 2014). This "mindreading" capability is often referred to as a theory of mind, the ability to attribute mental states—thoughts, knowledge, beliefs, emotions, desires—to oneself and others and to understand that others have beliefs, desires, intentions and perspectives that differ from one's own (Premack & Woodruff, 1978). It is common to explain people's behavior on the basis of their minds: their knowledge, beliefs and desires. When there is a conflict between belief and reality, it is a person's belief, not the actual state of reality, that determines their behavior (Frith & Frith, 2005). Through theory of mind, one can recognize and understand that another person's knowledge, beliefs, desires, etc. are different from one's own. Given their importance for all aspects of social life, the question of how these critical theory of mind capabilities emerge and develop is intriguing and important.

## ***Human Theory of Mind***

Developmental transitions in theory of mind are often assessed using "false-belief tasks" (Baron-Cohen et al., 1985). Up until the late 1990s, most psychologists believed that children became capable of mindreading around the age of 4 years, because that is when

most typically developing children begin to pass tests assessing their ability to identify someone's mental state (Wellman et al., 2001). In these tasks, children have to predict a person's behavior based on the person's false belief while disregarding their own true belief. For example, children are presented with a situation in which a child named Anne places a ball in a basket. In Anne's absence, another child named Sally moves the ball from the basket to a box. When Anne returns, children are then asked where she will look for the ball. Very young children, under the age of 4 years, fail to take into account that Anne does not know the toy is in the box and must (falsely) believe the ball to be in the basket. In contrast, older children and adults take into account Anne's false belief and predict she will search in the basket. Wimmer & Perner (1983) conducted the first systematic investigation of false belief understanding in children and found that children begin to correctly predict a story figure's mistaken action based on a false belief around the age of 4 years. When asked the critical false belief question, 3-year-olds generally do not answer correctly. However, 40-80%, depending on the test condition, of 4- to 5-year olds answer correctly (Wimmer & Perner, 1983). In contrast, younger children tend to make reality-based action predictions and fail to attribute false beliefs to other persons. Other researchers have also suggested that at about 4 years of age a fundamental change occurs in children's understanding of others' behavior. Specifically, children begin to realize that mental states are not direct reflections of reality but representations, which many or may not be accurate (Flavell et al., 1990; Astington & Gopnik, 1991; Gopnik & Wellman, 1994).

Some have suggested that theory of mind is present much earlier in development, and that young children's difficulties with false-belief tasks arise from the linguistic, computational and other task demands (Leslie, 1987; Chandler et al., 1989; Fodor, 1992;

Premack & Premack, 1995; Bloom & German, 2000). In other words, children possess theory of mind abilities earlier in development that are masked by the slower development of other abilities involved in such tasks, such as inhibition (Friedman & Leslie, 2004) or problem solving (Fodor, 1992). Under this view, infants and young children may be able to represent others' beliefs but unable to correctly predict what an agent will do without inhibitory abilities, as this involves inhibiting their own belief when predicting the agent's behavior. All of these claims are supported by evidence that 3-year-olds and some 2-year-olds succeed at a modified false-belief task (Clements & Perner, 1994; Garnham & Ruffman, 2001). In this version of the false-belief task, children are simply probed by the experimenter to look where the first character will search for the object upon return. Most children look to the correct location, suggesting that they possess some implicit understanding that others may have and act upon false beliefs. More recent research suggests that theory of mind abilities are present in infants and younger children when simpler testing procedures are used (Onishi & Baillargeon, 2005; Surian et al., 2007). Using a nonverbal task, Onishi & Baillargeon (2005) examined 15-month-old infants' implicit understanding of false belief. The investigators employed a looking-time, violation-of-expectation paradigm. The idea behind this experimental method is that infants should look longer at surprising, unexpected events as compared to familiar or expected events. For this experiment, looking time was measured and used as an indicator of infants' beliefs and expectations. Infants observed an actor hide an object in either a green or yellow box. Next, infants saw the actor disappear, during which time the object moved to the opposite box. Infants then observed one of two outcomes. In the congruent test trial, the actor then reached into the box where she had left her object, but in the incongruent test trial, she

reached into the box where the object actually was. If the infants expected the actor to search for her toy on the basis of her belief about its location, rather than the object's actual location, then the infants should look reliably longer when that expectation was violated. Thus, when the actor had a true belief that the toy was hidden in the green box, infants should expect her to reach into that box and they should look reliably longer when she reached into the yellow box instead. Conversely, when the actor had a true belief that the toy was hidden in the yellow box, infants should look reliably longer when she searched in the green as opposed to the yellow box. When the actor had a false belief about the toy's location the same predictions held; infants should look longer at the actor searching in the yellow box when the actor falsely believed that the toy was hidden in the green box. Similarly, infants should look longer at the actor searching the green box when she falsely believed the toy was hidden in the yellow box. In each case, the infants should look reliably longer when the location the actor searched was inconsistent with her belief about the toy's location. Onishi & Baillargeon (2005) found that infants looked significantly longer when viewing the incongruent outcome as compared to the congruent outcome. Infants expected the actor to search on the basis of her belief about the toy's location, indicating they have some understanding that people's actions should depend on what they have experience rather than on what is actually true. This finding suggests that 15-month-old already possess at least a rudimentary and implicit form of theory of mind. Infants around this age are also able to take false beliefs into account when inferring an agent's preferences (Luo, 2011) and deciding how to help an agent (Tomasello, 2009; Knudsen & Liszkowski, 2012). Furthermore, it appears as though almost all human beings, excluding those with autism spectrum disorder (Baron-Cohen, 2000), develop theory of mind despite

having different socio-cultural environments or having been diagnosed with language disorders or mental disabilities (Baron-Cohen, 1997). This has led researchers to theorize and argue humans may be equipped with an early emerging system for representing others' beliefs. In other words, theory of mind may be an innate, universal human capacity (Tomasello, 1999; Baillargeon et al., 2010).

It is particularly remarkable humans can infer and understand other's beliefs even when those beliefs contradict with one's own, as this leads to the complex problem of simultaneously holding two conflicting representations in mind. Interestingly, research in human theory of mind suggests humans may not encode and store one's own and others' perspectives as separate versions of reality. When inferring what someone else sees, feels, wants, believes or thinks, an individual often holds a different point of view themselves. The ability to set one's own perspective aside is a fundamental facet of the ability to read other people's minds. The encoding of others' experiences seems to be able to interfere with the encoding of one's own experience of an event. For example, Samson et al. (2010) asked adult participants to judge their own or someone else's visual perspective in situations where both perspectives were either the same or different. They found that reaction times were slower when the number of objects presented to a human adult subject and an avatar were different (Samson et al., 2010), suggesting the subject was also computing the scene from the avatar's perspective and had to overcome and disregard this representation to make the correct judgment. A particularly interesting aspect of these results was that adults were slightly faster to judge others' perspectives than they were to judge their own, possibly because someone else's perspective may be more important than or prioritized over one's own under certain conditions (Samson et al., 2010). Thus, what

another person could see was computed spontaneously even when it was not relevant to the task. This information helped participants make explicit judgments about the other person's perspective as easily as, and sometimes even more easily, than explicit judgments about their own perspective.

Investigations into the automatic encoding and representation of others' beliefs have also been conducted with human infants. Kovacs and colleagues (2010) conducted a series of studies with 7-month-old infants using a task with no executive demands beyond those involved in attending to a video. As such, it was a very simple mindreading task. Kovacs et al. (2010) showed infants an animated scenario in which a ball moved behind an occluder, emerged again and either left the stage or returned behind the occluder. Some of these sequences took place while an agent was present, and in some cases the agent left the scene before the ball reappeared from behind the occluder and left the stage (thereby giving rise to a false belief about the location of the ball). Kovacs and colleagues found that the infants looked longer when the occluder dropped to reveal the absence of a ball, thereby violating the agent's false belief (despite the fact that the infants themselves knew the ball would be absent). In this looking-time task, the infants did not need to make a prediction about the agent's behavior, but infants still looked longer when the agent falsely believed the ball was behind the occluder compared to when the agent also knew the ball was not there. Thus, infants' looking times were influenced by both their own beliefs as well as the agent's beliefs. Kovacs et al. (2010) concluded that humans automatically compute other's beliefs and hold them in mind as alternative representations of the environment. As a result, others' (false) beliefs influenced infants' behavior similarly to their own (true) beliefs. The authors asserted these powerful mechanisms for computing

others' beliefs may be part of a human-specific "social sense" and one of the cognitive preconditions for the evolution of the uniquely complex and elaborate social structure in human societies (Kovacs et al., 2010).

These aforementioned studies indicate that humans, including human infants, seem to consider others' perspectives on the world. Infants appear to understand that others' experiences determine their subsequent behaviors. While there are many ways in which this understanding might differ from adult theory of mind capabilities, infants certainly seem to track and understand others' belief states from a very young age. This evidence from human infants and adults is consistent with the view that there may be a core knowledge system for belief representation. The proposal that infants possess an early emerging system for representing others' beliefs fits with "core knowledge" accounts of infant development (Kinzler & Spelke, 2007; Kovacs et al., 2010). These core knowledge accounts argue that infants begin life endowed with a set of domain-specific systems for making sense of the physical and social world. Core systems are thought to be older cognitive systems, designed to rapidly solve domain-specific learning problems that human ancestors faced throughout their evolutionary history. Importantly, because core knowledge systems are thought to be phylogenetically ancient, they are likely to be shared by closely related nonhuman primates (Martin & Santos, 2014). As such, to test this core knowledge view, one must explore whether these same theory of mind capabilities are unique to humans or shared with other species.

### ***Nonhuman Primate Theory of Mind***

While evidence from human infants and adults suggests there may be a core

knowledge system for belief representation, there is less consistent support for this theory when considering nonhuman primates. This taxonomic group is a logical one in which to test whether other animals share this potential core-knowledge system of belief representation and theory of mind abilities. Since the late 1990s, experimenters have been finding better ways to experimentally determine what nonhuman primates know about the psychological states of others (Call & Tomasello, 2008). This generally involves designing experiments that more closely model situations nonhuman primates routinely encounter in their natural environments, yielding many more positive results.

Many of the nonhuman primate theory of mind studies run to date were conducted with chimpanzees or rhesus macaques as test subjects. Chimpanzees are likely candidates for possessing theory of mind cognitive capabilities because they are humans' closest primate relatives. Humans and chimpanzees' most recent common ancestor was approximately 5-8 million years ago (Patterson et al., 2006), and humans and chimpanzees share almost 99% of their genes (Enard et al, 2002). Much like humans, rhesus macaques are very social primates and exhibit a highly complex social system. They have a despotic, linear dominance hierarchy for which abilities such as perspective taking and understanding the beliefs and knowledge of others is extremely relevant and useful for avoiding conflict (Drayton & Santos, 2016). In a more general sense, rhesus macaques are valuable subjects when interested in understanding the evolution and conserved nature of a cognitive capacity (Hecht et al., 2012). Humans and old world monkeys (which includes rhesus macaques) most recent common ancestor was approximately 25 million years ago, and humans have approximately 93% of their DNA in common with rhesus macaques (Gibbs et al., 2007). If a human cognitive ability is observed in rhesus macaques, it is

possible to infer this ability is especially important and potentially highly conserved throughout evolution. This is all to establish the principle that studying animals can enhance understanding of human social cognition (Hecht et al., 2012) as well as determine if a particular cognitive capacity is unique to humans.

Several studies have demonstrated chimpanzees understand other individuals have perception and knowledge. Chimpanzees successfully follow the gaze of an experimenter (Tomasello et al., 1998; Call et al., 1998; Tomasello et al., 1999; Tomasello et al., 2001; Brauer et al., 2005; Tomasello et al., 2007) and understand gaze stops at an opaque barrier (Okamoto-Barth et al., 2007). When competing with others for food, chimpanzees consider what their competitor can and cannot see and what the competitor does and does not know (Hare et al., 2000; Hare et al., 2001; Hare et al., 2006; Melis et al., 2006; Brauer et al., 2007). Hare et al. (2006) had chimpanzees compete for food with a human competitor who was situated inside a glass booth. Chimpanzees preferentially chose to approach the food that was on the side of the booth with an opaque barrier through which the human could not see them approaching. Chimpanzees seem to comprehend what the human could and could not see, demonstrating they were imagining and understood the perspective of the human. In a review of chimpanzee theory of mind, Call & Tomasello (2008) asserted that chimpanzees, like humans, understand what others see and know.

Despite evidence that chimpanzees can understand the perceptions and knowledge of others, there is little experimental evidence chimpanzees understand others' false beliefs (Call & Tomasello, 2008). Call & Tomasello (1999) conducted a study examining false belief task capabilities of children and great apes, namely chimpanzees and orangutans. Using a nonverbal task of false belief understanding, two experimenters conducted a series of

finding games in which the first experimenter hid a reward in one of two identical containers. The second experimenter observed the hiding process and attempted to help the participant by placing a marker on the container believed to hold the reward. In the false belief trials, the second experimenter watched the hiding process and then left the area, at which time the first experimenter switched the location of the containers. The second experimenter then returned and marked the container at the location where they had seen the reward hidden, which was incorrect. The chimpanzee was then allowed to find the reward. No ape succeeded in the nonverbal false belief task even though they succeeded in all of the control trials, indicating understanding and ability to perform task demands (Call & Tomasello, 1999).

Furthermore, Hare et al. (2001) investigated performance on two versions of a chimpanzee competition task. In one version, the dominant chimpanzee either witnessed (informed) the location of where the food was placed or did not witness the location of the food (uninformed). In the other version of the task, the dominant chimpanzee always witnessed the initial location of the food but then the food was moved to a second location. In some trials the dominant chimpanzee witnessed the movement (informed), while in others the chimpanzee did not (misinformed)—creating a false belief in the dominant chimpanzee about the food's location. If the subjects understood that in the misinformed condition their competitor had a false belief, they should have performed perfectly and been able to predict the competitor will go to the wrong location. However, if the subjects simply understood their competitor was ignorant of the food's location, they should not perform as well. Although the chimpanzees appeared to distinguish between the informed and uninformed conditions, they did not distinguish between the uninformed and

misinformed conditions (Hare et al., 2001). This indicated they were able to understand their competitor's knowledge versus ignorance but provided no evidence for understanding that their competitor had a false belief. This lack of understanding is quite striking given the accumulating evidence that very young human children attribute beliefs to others and have some understanding of false beliefs.

These studies provide convincing evidence that chimpanzees understand the perception and knowledge of others. Moreover, they understand how these mental states produce intentional action. However, chimpanzees probably do not understand others in terms of a fully human-like theory of mind in which others are understood to have mental representations of the world that drive their actions even when their mental representations do not correspond to reality. Why chimpanzees fail understand false beliefs, or if there might be certain situations in which they do understand false beliefs, is a topic of current and future research.

Researchers have conducted similar theory of mind tasks with rhesus macaques, often with similar results. Flombaum & Santos (2005) developed a competitive foraging task, similar to the one used by Hare et al. (2000). Free-ranging rhesus macaques on the island of Cayo Santiago were presented with two similar looking experimenters each holding a grape. The experimenters simultaneously placed the grapes on small platforms on the ground. One of the experimenters then positioned themselves such that he could see the grape while the other experimenter was positioned such that he was unable to see the grape. The subject was then allowed to approach and take one of the grapes. If the monkeys understood that one of the experimenters could not see the grape, the monkey should prefer to steal the grape from this experimenter. Overwhelmingly, this is exactly what the

monkeys did (Flombaum & Santos, 2005). Monkeys were sensitive to the role of the head and eyes in perception. In one experiment, monkeys discriminated between an experimenter holding a small occluder over his eyes versus an experimenter holding an occluder over his mouth. These results suggest the monkeys understood how objects occlude visual perception. The overall pattern of performance reported in Flombaum & Santos (2005) suggests rhesus macaques understand that agents perceive objects in their line of sight and fail to perceive objects when visual access is blocked. These experiments provide evidence that monkeys comprehend visual perception and what others can see (Drayton & Santos, 2016).

But do rhesus macaques track what an agent has previously seen? To explore this capacity, Marticorena et al. (2011) used a looking-time method modeled after Onishi & Baillargeon (2005). Marticorena et al. (2011) presented monkeys with a stage that had two opaque boxes on either side. In an initial study, monkeys saw the experimenter watch as a lemon moved into one of the two boxes. Once the lemon was inside the box, the experimenter reached into the box where she had just seen the lemon hidden or into the other box. If monkeys expected the experimenter to act on the basis of what she had recently seen, then they should be surprised (as indicated by longer looking-time) when she searched in the wrong box. Indeed, monkeys looked longer at the stage when the experimenter searched in the box that did not contain the lemon. Thus, like chimpanzees, rhesus macaques understand others' behavior is guided by previous perceptions (Drayton & Santos, 2016).

However, tracking what others have and have not seen does not necessitate the ability to represent or understand false beliefs. Demonstrating sensitivity to the false

beliefs of others is usually considered the most powerful way to demonstrate mindreading capacities (Drayton & Santos, 2016). To test whether monkeys demonstrate false belief understanding, Marticorena et al. (2011) conducted another looking-time experiment in which the experimenter had a false belief about the lemon's location. In this experiment, monkeys saw the experimenter watch a lemon go into one of the boxes on the stage. Then, while the experimenter was hidden behind an occluder, the monkeys saw the lemon move into the other box. If the monkeys attribute false belief to the experimenter, they should expect her to search in the original box for the lemon and look longer if the experimenter fails to act in a manner consistent with this belief. The monkeys were found to look equally long at the display when the experimenter reached into either of the two boxes (Marticorena et al., 2011). This pattern of results suggests the monkeys did not make any prediction about where the experimenter should look for the lemon, showing no evidence of attributing a false belief to the experimenter.

Monkeys seem to understand that others have perceptions but not that they have beliefs (Drayton & Santos, 2016). It is possible that monkeys might be able to track the experimenter's belief in a simpler task than the one used in Marticorena et al. (2011). As mentioned above, Kovacs et al. (2010) used a simpler false belief task with 7-month-old infants. Martin & Santos (2014) investigated whether rhesus macaques would represent false beliefs when tested with this simpler Kovacs et al. (2010) experimental method. Martin & Santos (2014) presented monkeys with a series of events in which an experimenter observed an apple move across a stage between two boxes. The presentation ended when when one of the boxes was revealed to be empty. In different conditions, the reveal of the empty box either violated the belief of the monkey, the experimenter or both.

Manipulating whether the monkey and the experimenter had a true or false belief about the contents of the box allowed Martin & Santos (2014) to assess whether monkeys' looking times were affected by only their own belief or also by the belief of the agent. Martin & Santos (2014) found the agent's belief did not influence monkeys' looking time, suggesting again that monkeys do not track or represent others' beliefs.

Taken together, research with chimpanzees and rhesus macaques supports the hypothesis that nonhuman primates' failures on false belief tasks reflect a limitation in their theory of mind capabilities. The more complex theory of mind observed in humans, including human infants, may be a uniquely human cognitive capacity and part of a human-specific core knowledge system. However, it is worthwhile to search for theory of mind in other animal species, beyond nonhuman primates—specifically canines.

### ***Canine Theory of Mind***

As evidenced by the research reviewed above, theory of mind has traditionally been investigated in humans and nonhuman primates. However, non-primate species, such as canines, are also viable candidates for possessing a theory of mind. Domestic dogs (*Canis familiaris*) were the first species to be domesticated (Byrne, 2005; Wynne, 2004), with likely selection for sensitivity to human cues and human-like cognitive abilities (Kaminski & Marshall-Pescini, 2014). Due to the close evolutionary association between humans and dogs, domesticated dogs are likely candidates for finding evidence of theory of mind in a nonhuman animal (Kaminski & Marshall-Pescini, 2014). Dogs typically spend their lives in the elaborate social environment of humans, and it is reasonable to hypothesize that the emergence of specific cognitive abilities may be dependent on the richness of one's social

environment. The combination of these factors makes dogs an excellent candidate for having theory of mind.

Comparative cognition researchers are increasingly using dogs as a model species to provide insight into human and nonhuman cognition. Several researchers have developed the hypothesis that dogs might have evolved special social behaviors and skills as a result of living with humans and adapting to the human environment. The social behavior and cognitive skills of dogs are rooted in their heritage from their wild ancestors, but these behaviors and skills have evolved within their new social environment with humans (Kaminski & Marshall-Pescini, 2014, p. 250). An important aspect of dogs' domestication was the ability to understand the communicative cues of humans (Brauer et al., 2006). Csanyi (2005) suggests that, through domestication, dogs acquired mental traits that "resembled those of humans in many respects." More recently in the evolution of dogs, there has likely been selection for social skills, suitable for dogs' roles in human society (Cooper et al., 2003). Studying this interaction and co-existence between two highly social species is intriguing and raises many questions. Within the context of this study, the relevant question is: are dogs able to attribute mental states to others, such as knowledge and beliefs? More generally, do dogs have theory of mind and how is it similar to or different from human theory of mind?

Research on perspective taking investigates whether dogs are sensitive to the perspective of others (humans and dogs), and evaluates evidence that dogs behave differentially dependent on the perspective of others (Topál et al., 2006). Hare et al. (1998) demonstrated that dogs preferred to drop an object in front of a human experimenter, and would maneuver to do so if the human's back was to them. This provides evidence of dogs'

knowledge of human's visual perception. Call et al. (2003) observed the behavior of dogs that were verbally forbidden to eat a food reward by the experimenter. The experimenter's attention toward the dog varied throughout the experiment: eyes open and focused on the dog, eyes open and not focused on the dog, eyes closed, and experimenter having his back turned. Call et al. (2003) found dogs ate significantly less food after being verbally forbidden to do so when the experimenter's eyes were open and focused on the dog than in the other conditions. This pattern of results suggests dogs understand what humans can see and perceive signals known to reflect human attention-states. Human attention-states have also been found to alter dog command responses and begging behaviors (Gacsi et al., 2004; Virányi et al., 2004; Udell et al., 2011). Brauer et al. (2004) found that dogs approached a forbidden treat more when the barrier effectively blocked the experimenter's view of the treat. While these results do not necessarily confirm human perspective taking by dogs, they suggest dogs understand human perspectives and use them to guide their behavior.

Dog-to-human communication research has attempted to investigate whether dogs are able to incorporate the knowledge states of others into their decision-making processes and behavior. The "Ignorant-Helper" paradigm has been used to investigate whether dogs are able to recognize humans' states of knowledge or ignorance depending on what they have seen, also known as knowledge attribution (Topál et al., 2006; Virányi et al., 2006). This paradigm requires the dog communicate with a human helper in order to obtain a reward that is inaccessible to the dog. The dog is able to see the location of a hidden reward and the location of a tool necessary to access the reward. The human helper's knowledge of where either of these items is located is manipulated within the experiment. The dog's

behavior is measured to determine if the manipulation of what the human helper knows results in the dogs adjusting how they interact with this person. Virányi et al., (2006) found dogs were much more focused on the hidden reward, rarely signaling toward the location of the object necessary to access the reward in any of the conditions. However, the dogs did appear to signal the location of the tool significantly more when the human helper was unaware of the reward's location. In this way, dogs appeared to show behavior that corresponded with the human's knowledge state.

Thus, dogs have been shown to differentiate their actions based on cues associated with visual attention and use others' perspectives to guide their behavior. However, there is little agreement about whether current evidence is sufficient to conclude dogs take human perspectives into account (Bensky et al., 2013). There are many different ways in which animals might understand the psychological functioning of others (Call & Tomasello, 2008). A more informative approach is to ask specifically which psychological states domesticated dogs understand and to what extent. Research focused on developing novel experimental paradigms and tasks that can more conclusively determine which perspective taking and theory of mind capabilities dogs possess is needed (Horowitz, 2011).

### ***Experiment***

Based on Kovacs et al.'s (2010) exploration of theory of mind in 7-month-old human infants as well as Martin & Santos's (2014) experiments in rhesus macaques using a similar experimental paradigm, the experiment presented here aimed to investigate whether dogs automatically encode others' beliefs and if these beliefs have similar effects on their behavior as the dogs' own beliefs. Rather than using a looking time paradigm as in human

infants and monkeys, this experiment employs a searching time paradigm (Santos et al., 2002). In a typical searching time task, the experimenter places treats into an opaque bucket filled with shredded paper. The amount of time that dogs spend searching in the bucket can be used as an indication of how many treats the dogs believe are in the bucket. For example, if a dog saw the experimenter place two treats in the bucket and then remove one treat, the dog should spend time searching in the bucket for the missing second treat. Whereas, if a dog saw the experimenter place two treats in the bucket and then remove two treats, the dogs should spend little to no time searching in the bucket for treats. Using this searching time paradigm, dogs' beliefs and the beliefs of their owner (the agent) were modulated and searching time was measured as an indicator of how many treats the dog believed to be in the bucket. Within this experimental paradigm, longer searching time indicated the dog believed there were more treats in the bucket, and shorter searching time indicated the dog believed there were few or no treats in the bucket (Santos et al., 2002). Dogs' searching time was measured and compared between conditions to determine if owners' beliefs about the number of treats in a bucket influence the amount of time dogs spend searching for treats in the bucket.

This experimental design is unique and goes beyond previous work in that it only requires an automatic representations of others' beliefs. Many previous tests of human, nonhuman primate and canine theory of mind and belief reasoning required subjects to predict or interpret the agent's behavior on the basis of the agent's false beliefs. These tasks require more than a mere understanding of an agent's beliefs. This study investigates belief representation without the need to predict or interpret the agent's behavior. As such, it is a liberal test of theory of mind and belief attribution.

## **Methods**

**Dog subjects.** We tested 40 dogs (19 males,  $M_{\text{age}} = 4.52$  years;  $SD_{\text{age}} = 2.82$  years) of varying breeds (see Table 1). Twelve additional dogs were tested but excluded due to lack of motivation (3), experimental error (3) or owner error/interference (6). All dogs were pets whose owners volunteered for participation by entering their dogs' information in an online database. Subjects were required to show no aggressive tendencies, be up to date on all vaccinations and be older than 6 months of age. Before participation in the study, all dogs visited the center at least once before testing to become familiar with the center.

**Apparatus and testing setup.** We used two opaque, rectangular plastic buckets (large bucket: 7 in width x 11 in length x 5 in height; small bucket: 6 in width x 10 in length x 2.5 in height) for all trials (see Figure 1). The smaller bucket was only used when the dog was too small or short to search in the larger bucket. Each bucket was made opaque by covering the sides of the buckets with purple duct tape. The buckets were filled with shredded paper to block visual access to the treats (in line with previous research, e.g., Santos et al., 2002)). Treats were 1 cm<sup>3</sup> cubes of Natural Balance beef sausage. However, in cases in which dogs were allergic to the ingredients in the treats, we used alternate treats of the same size provided by their owner.

Dogs were tested in the presence of their owner and two experimenters, with one experimenter conducting the trials and the other serving as a handler for the dog. Dogs were tested in a large room (3.5 m x 5.15 m) at the Canine Cognition Center at Yale University. During testing, the handler sat in a chair with their head down and eyes closed and held the dog's leash until instructed to release the subject by the experimenter. A

standard leash clipped to a built-in hook in the wall was used for every dog. The owner and dog were positioned diagonally across from each other, 63.5 in apart. The bucket was oriented lengthwise between the dog and owner, positioned 38 in from the dog when using the large bucket and 39 in away from the dog when using the small bucket and 15 in from the owner's chair (see Figure 2).

**Design and procedure.** All subjects participated in *two testing trials*. In the first test trial, dogs and their owners observed treats being placed into and removed from the bucket by the experimenter, with the exact events depending on the condition randomly assigned to the dog (see below). After the presentation, the experimenter left the room and the dog was released to search in the bucket. Each subject then participated in a second trial, in which one treat was placed in the bucket and the dog was allowed to search for the treat once the experimenter had left the room. The goal of this second test trial was to ensure each dog received a treat from the bucket before concluding the experiment, so the dogs understand what was placed in the bucket remained there. For both test trials, the dog was allowed to search in the bucket until another experimenter, who was blind to the experimental condition, determined the dog was finished searching. This experimenter considered the dog was “done searching” when the dog oriented itself away from the bucket.

**Experimental conditions.** Each dog was tested on one of four test conditions. Across conditions, the amount of information the dog and owner knew about the number of treats in the bucket was manipulated in order to create either a true or false beliefs in the dogs and their owners. Table 2 summarizes which beliefs were elicited by the different experimental conditions.

At the start of each testing trial, the experimenter left the testing area and returned with the bucket full of shredded paper, which was placed in the bucket out of the subject's view. The experimenter provided instructions to the owner before the start of trial and throughout the experiment. The owner was instructed to sit in a chair, facing forward with his eyes open. The owner was told he would observe the experimenter place treats into and remove treats from the bucket. The owner was asked to exaggeratingly watch the experimenter place treats in and remove treats from the bucket, following the trajectory of the treats with a wide-eyed facial expression. Then, when instructed by the experimenter, the owner was asked to close his eyes and turn his back to the dog at a particular point of the test trial to clearly indicate to the dog he could not see the events taking place in the bucket. Eventually, the owner was asked to turn around and sit normally in the chair, facing forward with his eyes open. Towards the end of the test trial, the owner was handed the bucket by the experimenter and told to remove the first treat he could find, showing the treat to the dog. The bucket was then placed back in its original location by the experimenter. The owner then placed the treat from the bucket in the palm of his right hand and dropped his open hand to their side, displaying the treat. The owner was instructed to call the dog's name once upon hearing the door close. The handler was instructed to remain seated with her head down and eyes closed and release the dog upon hearing the door close. Then, the experimenter left the testing room.

The goal of condition 1 was to create a false belief in the dog and a true belief in the owner. In condition 1, the experimenter kneeled near the bucket, called the subject's name in a high-pitched, ostensive voice and established eye contact, saying, "Look!," while

holding a treat between the thumb and index finger of her left hand. Then the experimenter placed this treat in the bucket while both dog and owner were looking. The experimenter then told the owner to close his eyes and turn his back. The experimenter placed a second treat in the bucket while the dog was watching but the owner could not see what was occurring with the bucket. However, this treat was surreptitiously not placed in the bucket but rather removed by the experimenter without the dog's knowledge. The experimenter then asked the owner to turn around and open his eyes. The experimenter then waved her hand over the bucket to control for timing, using the same auditory cues as when placing a treat in the bucket (calling the dog's name in a high-pitched, ostensive voice and establishing eye contact, saying, "Look!"). The experimenter then handed the bucket to the owner and asked him to remove the first treat he could find. The bucket was returned to its original location while the owner showed the dog the treat he found without using any vocal cues. The owner then placed the treat in the open palm of his right hand and dropped this hand to their side, clearly displaying the treat. The owner was instructed to call the dog's name once upon hearing the door close and to allow the dog to search in the bucket without encouragement or interaction by the owner. The handler was instructed to release the dog upon hearing the door close. Then the experimenter left the room (see Figure 3a).

It was predicted the dog would believe there were two treats in the bucket while the owner would believe only one treat was in the bucket, based on what they had each seen. The dog saw two treats placed in the bucket and believed two treats were in the bucket. The dog also saw that the owner could not see when the second treat was placed in the bucket (and later surreptitiously removed). After the owner removed one treat from the bucket, the dog should think one treat remains in the bucket (false belief) while the owner

should think no treats remain in the bucket (true belief). Thus, in condition 1, the owner and dog held inconsistent beliefs about how many treats were in the bucket. If dogs automatically encode and represent their owner's beliefs in a manner similar to their own, they should search for less time, as compared to the experimental condition in which both the owner and dog have a true belief (condition 4), because the owner believed the bucket was empty. If dogs hold their beliefs as well as representations of their owners' beliefs in mind in a manner similar to human infants, the owners' true belief should interfere with the dogs' belief and subsequently influence the dogs' behavior, resulting in less time spent searching in the bucket.

The goal of condition 2 was to create false beliefs in both the dog and the owner. Condition 2 used a very similar procedure to condition 1 with a few important changes. After placing the first treat in the bucket while both the dog and owner were looking, the experimenter asked the owner to close his eyes and turn his back. While the owner was not looking, the experimenter waved her hand over the bucket to control for timing. The experimenter then asked the owner to turn around and open their eyes. The experimenter placed a second treat in the bucket while both the owner and dog were watching. However, this treat was surreptitiously not placed in the bucket but rather removed by the experimenter without the owner or dog's knowledge (see Figure 3b). Thus, both the dog and owner were lead to believe there were two treats in the bucket. After the owner removed one treat from the bucket, the dog and owner should think one treat remains in the bucket. Thus, in condition 2, the owner and dog held consistent, false beliefs about how many treats were in the the bucket. If dogs automatically encode and represent their owner's beliefs in a manner similar to their own, they should search for a greater amount of

time for the second treat believed to be in the bucket, as compared to the experimental condition in which both the owner and dog have a true belief (condition 4), because the owner and dog share this false belief.

The goal of condition 3 was to create a true belief in the dog and a false belief in the owner. In condition 3, the experimenter placed a treat in the bucket while both dog and owner were looking, followed by placing another treat in the bucket in the same manner. The experimenter then told the owner to close their eyes and turn their back. While the owner was not looking, the experimenter removed one treat from the bucket and gave it to the dog. The experimenter then asked the owner to turn around and open their eyes. The experimenter waved her hand over the bucket to control for timing. The experimenter then handed the bucket to the owner and asked him to remove the first treat he could find (see Figure 3c). It was predicted the dog would believe there was one treat in the bucket while the owner would believe there were two treats in the bucket, based on what they had observed. After the owner removed one treat from the bucket, the dog should think no treats remain in the bucket. However, we expected the dog to search for more time, as compared to their baseline searching time, because the owner believed the bucket contained another treat. It was predicted the dog would believe there was one treat in the bucket while the owner would believe there were two treats in the bucket, based on what they had each seen. Both the dog and owner saw two treats placed in the bucket. The dog then saw one treat removed, believing only one treat remained in the bucket. However, the owner did not see this, believing two treats remained in the bucket. After the owner removed one treat from the bucket, the dog should think no treat remains in the bucket (true belief) while the owner should think one treat remain in the bucket (false belief).

Thus, in condition 3, the owner and dog held inconsistent beliefs about how many treats were in the bucket. If dogs automatically encode and represent their owner's beliefs in a manner similar to their own, they should search for more time, as compared to the experimental condition in which both the owner and dog have a true belief (condition 4), because the owner believed there was another treat in the bucket. If dogs hold their beliefs as well as representations of their owners' beliefs in mind in a manner similar to human infants, the owners' false belief should interfere with the dogs' belief and subsequently influence the dogs' behavior, resulting in more time spent searching in the bucket.

The goal of condition 4 was to create true beliefs about the number of treats in the bucket in both the dog and owner. Much like in condition 3, the experimenter placed a treat in the bucket while both dog and owner were looking, followed by placing another treat in the bucket in the same manner. While the owner was not looking, the experimenter waved her hand over the bucket to control for timing. The experimenter then asked the owner to turn around and open their eyes. The experimenter removed one treat from the bucket and gave it to the dog while the owner was watching (see Figure 3d). Thus, both the dog and owner believed there was one treat in the bucket. After the owner removed one treat from the bucket, the dog and owner should think no treats remained in the bucket (true belief). Thus, in condition 4, the owner and dog held consistent, true beliefs about how many treats were in the bucket. If dogs automatically encode and represent their owner's beliefs in a manner similar to their own, they should exhibit little to no searching in the bucket because the owner and dog share this true belief.

**Coding and analyses.** Searching time was coded by the experimenter from de-identified videos, making the experimenter blind to the dog's experimental condition. The

experimenter examined frame by frame searching (30 frames = 1 s) during the searching portion of each trial, using the program MPEG Streamclip. Searching time was defined as the amount of time the dog spent searching in the bucket—more specifically, the amount of time the dog spent with its head or snout in the bucket. A second blind coder coded 10 of the test trials to determine reliability of the coding. Reliability was high (Pearson's  $R=0.989$ ). Statistical analyses were conducted using IBM SPSS Statistics statistical software (Version 24.0.0.0, 64-bit edition).

### **Results**

A two-factor Dog Belief (True or False) by Owner/Agent Belief (True or False) ANOVA was conducted on subjects' test trial data. T-tests were also performed comparing the mean searching times for Dog Belief (True or False), Owner/Agent Belief (True or False) as well as Owner/Agent Belief stratified by Dog Belief. No statistically significant results were found. Specifically, we found no significant main effect of dog belief ( $F = 1.459$ ,  $p = 0.235$ ), no main effect of owner belief ( $F = 0.812$ ,  $p = 0.373$ ) and no interaction between owner and dog belief ( $F = 0.460$ ,  $p = 0.502$ ). However, there were several notable, interesting trends in the data. Although the pattern was not statistically significant, dogs searched longer during conditions in which they held a false belief (conditions 1 and 2;  $M = 14.352$  s,  $SE = 1.667$  s) as compared to conditions in which the dogs held a true belief (conditions 3 and 4;  $M = 11.503$  s,  $SE = 1.667$  s) (see Figure 4). Dogs also showed a trend of searching slightly longer during conditions in which the owner held a false belief (conditions 2 and 3;  $M = 13.990$  s,  $SE = 1.6667$  s) as compared to conditions in which owner held a true belief (conditions 1 and 4;  $M = 11.865$  s;  $SE = 1.667$  s) (see Figure 5). In

addition, examining the interaction between Dog Belief and Owner Belief, dogs searched the longest when both the dog and owner held false beliefs ( $M = 16.213$  s,  $SE = 2.358$  s) compared to when the dog had a false belief and the owner had a true belief ( $M = 12.490$  s,  $SE = 2.358$  s). When the dog had a true belief, searching time was slightly longer when the owner had a false belief ( $M = 11.7667$  s,  $SE = 2.358$  s) as compared to when the owner had a true belief ( $M = 11.240$  s,  $SD = 2.358$  s) (see Figure 6).

### ***Discussion***

Neither dog belief nor owner belief had a significant effect on dogs' searching time. This significantly limits the conclusions that can be drawn from the data. The most conservative interpretation of these results is that dogs might not have tracked the differences between the conditions. Another possibility is that dogs were able to track the differences between all four conditions, including experiencing belief contagion from their owner's beliefs, but this did not impact their searching time behavior. This would be consistent with developmental work in humans, showing that an understanding of false beliefs does not always translate to behavioral measures (Helming et al., 2014). Furthermore, work within the field of canine cognition has found dogs successfully complete some theory of mind tasks and fail others (Udell et al., 2011). If this were the case, it could mean dogs represent beliefs, both their own and those of others', in a fundamentally different way than humans, allowing others' beliefs to not interfere with their own based on this potentially different cognitive architecture. It is also possible that dogs simply fail to automatically represent the beliefs of others', which would be consistent with the results found by Martin & Santos (2014) in rhesus macaques. This would lend

further support to the argument proposed by Kovacs et al. (2010) that automatically representing the beliefs of others may be a unique to humans and part of a core, human-specific set of cognitive capacities.

However, "absence of evidence is not evidence of absence." The current study was underpowered, meaning the sample size of dog participants was too small to detect an effect. It is possible running additional dogs would make significant some of the currently non-significant results. Although not statistically significant, dogs appeared to search longer when they held a false belief than a true belief about the number of treats in the bucket. This pattern of results suggests dogs were attending to the events they witnessed. They seem to be tracking the location of the treats and searched longer when they believed more treats were in the bucket. Dogs also tended to search longer when their owner held a false belief than a true belief about the number of treats in the bucket. Thus, dogs exhibited different, although not statistically significantly different, searching times based on the owners' beliefs as well. If dogs were not representing or tracking their owners' beliefs, there should have been no difference in searching time according to the owners' beliefs. These findings very subtly suggest dogs may have understood and automatically represented their owners' beliefs, which subsequently influenced their searching time in this predictable manner.

Interestingly, dogs tended to search the longest amount of time when both they and their owner held a false belief and for the shortest amount of time when both they and their owner held a true belief. Dogs also searched for less time when they had a false belief and their owner had a true belief than when both the dog and owner had false beliefs. This pattern of results was expected, as dogs should search reliably longer when they

themselves hold a false belief, regardless of the owners' beliefs. However, when the dog had a false belief and the owner had a true belief (condition 1), searching time decreased. Owners' beliefs had the largest impact on searching time when the dog had a false belief. It is possible the dogs' false beliefs are more susceptible to influence by others' beliefs than the dogs' true beliefs. Consistent with this conclusion, dogs searched for slightly more time when they had a true belief and their owner had a false belief than when both the dog and owner had true beliefs. However, this difference in searching time was minimal and almost certainly due to chance. Overall, these trends and differences in searching time provide a hint that dogs may have automatically represented and been influenced by owners' beliefs in a manner similar to their own. This pattern of results was essentially consistent with the hypothesized results, despite lacking power and statistical significance. Therefore, it remains unclear whether dogs' beliefs were automatically influenced by the beliefs of their owners.

If this study were repeated with a larger sample size and statistically significant results were found, it would provide evidence that dogs possess theory of mind capabilities, or at least automatically represent and understand their owners' beliefs. Beyond this fascinating result, this finding would suggest sharing the human social environment and the co-evolution of humans and dogs via the domestication process likely endowed dogs with specific, sophisticated sociocognitive abilities—making dogs more cognitively similar to humans than some nonhuman primates. This conclusion would be consistent with other canine perspective taking and theory of mind research, as Maginitty & Grace (2014) found dogs' performance on a perspective taking task was superior to those of nonhuman primates in previous studies using a similar experimental paradigm.

Dogs have a remarkable sensitivity to cues related to human attentional and knowledge states, which may enable them to more successfully complete certain theory of mind tasks.

However, it is important to note the pattern of results obtained in this study could also be explained by owners' behavioral cues, both intentional and unintentional. For example, it is possible when owners believed more treats remained in the bucket they looked more at the bucket or exhibited body language that encouraged the dog to search longer. Similarly, when owners believed the bucket was empty, it is possible they no longer looked at the bucket or displayed behavioral cues indicating disinterest that decreased the dogs' searching time. Owners' behavior with respect to looking at the bucket and body position (leaning forward toward the bucket or sitting back in the chair) could be coded in order to determine if owners' behavioral cues might explain the pattern of results obtained here.

It appears as though the searching time method is a somewhat effective method for investigating theory of mind in dogs. Future studies should use this experimental paradigm with a larger sample of dogs to either confirm or refute the pattern of results found in this study. Future studies should also investigate if dogs' performance on this task changes when the agent is not the dogs' owners but rather an unfamiliar experimenter. It is possible this ability to automatically represent others' beliefs is specific to or most robust with dogs' owners. However, having the owners participate in the execution of the experiment introduces a great deal of inconsistency and variability between trials. It would be best for future studies to eliminate owner participation to decrease this variability and control for confounders.

It is clear from recent work that belief representation fulfills two of the main

features typical of core knowledge domains. Namely, it emerges early in human development (Luo, 2011; Kovacs et al., 2010; Surian et al., 2007; Onishi & Baillargeon, 2005) and can still be observed into adulthood (van der Wel et al., 2014; Low & Watts, 2013; Apperly, 2011). Research in nonhuman primates suggests they do not share humans' ability to automatically represent others' beliefs (Martin & Santos, 2014). The results reported here fail to indicate whether domesticated dogs share this ability with humans. Thus, automatic belief representation and sharing may very well be a uniquely human cognitive capacity that functions and evolved as part of a core knowledge system not shared with non-human primates or domesticated dogs.

Future work addressing canine theory of mind should also examine the possibility that dogs are unable to represent any mental states automatically. The ability to automatically represent others' mental states when such representations are irrelevant to one's own behavior might be specific to humans. Furthermore, it is possible that dogs do not represent the beliefs of agents outside of their own species. It would be interesting to conduct a two-dog study in which the agent is another dog rather than a human owner or experimenter. Such a study could determine if belief representation in other species is limited to intra-species belief representation while humans have a broader, more robust and flexible capacity for both intra- and inter-species belief representation.

Understanding the origin of the human mind presents an enormous challenge. Humans often marvel at the uniqueness of the human intellect and are simultaneously astonished at how similar other species' behaviors and understanding of the world seem to be. Like all human traits, the human mind is a product of evolution. Thus, it is critical to gain an understanding of the nature and evolution of cognition in both human and

nonhuman animals. To understand theory of mind more fully, it is necessary to understand the evolutionary origins of such a mental capacity and, in doing so, address the question whether theory of mind is a uniquely human capacity or one shared with other animals. Broadly, this study attempted to parse out precisely which cognitive capacities are unique to humans and which are shared more widely across species, thereby providing insight into the evolutionary origins of human's cognitive architecture. More specifically, this study used a novel experimental paradigm of searching time to investigate whether dogs automatically represent their owners' beliefs and encode these beliefs in such a way that they influence the dogs' own beliefs. Due to lack of statistical power and a small, potentially nonexistent, effect size, no significant results were found, so future research must continue this work.

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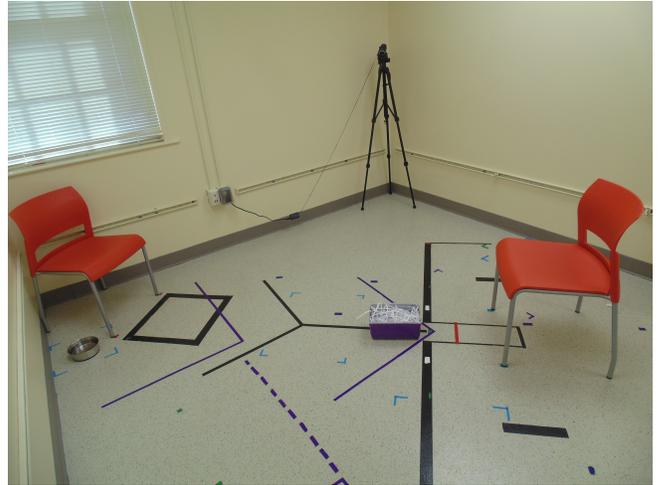
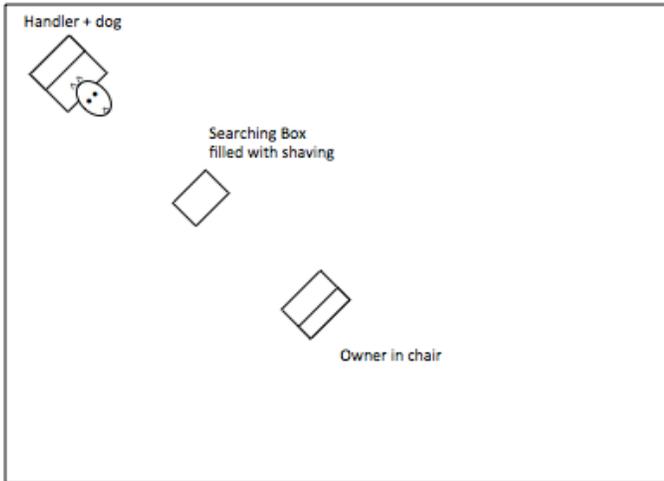
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<b>Name</b>	<b>Breed</b>	<b>Sex</b>	<b>Age</b>	<b>Condition</b>
Daisy	Goldendoodle	F	5	1
Indigo	Australian Shepherd	F	5	1
Blue	Golden Retriever	M	9	1
Angelia (Gigi)	Labrador Retriever	F	2	1
Annie	Labrador Retriever/Hound/Terrier mix	F	7	1
Flapjack	Labrador Retriever/Hound mix	M	7	1
Winston	Miniature Dachshund	M	1	1
Dora	Pembroke Welsh Corgi	F	6	1
Havalah	Cavalier King Charles Spaniel	F	8	1
Molly	Boston Terrier/Beagle mix	F	7	1
Sophie	Shepherd/Hound/Labrador Retriever mix	F	10	2
Cooper	Irish Setter/Poodle mix	M	2	2
Ovie	Border Collie/Miniature Poodle mix	M	2	2
Dallas	Cocker Spaniel	F	3	2
Duchess	Great Dane/Catahoula Leopard mix	F	4	2
Bob Barker	Dachshund	M	8	2
Luka	Standard Poodle	F	3	2
Gobi	Labradoodle	M	2	2
Matilda	Beagle/German Shorthair Pointer mix	F	4	2
Skye	Australian Shepherd	F	4	2
Oliver	Pembroke Welsh Corgi	M	8	3
Sadie	Bichon Frise/Poodle mix	F	8	3
Carlo	Labradoodle	M	1	3
Rosie	Pembroke Welsh Corgi	F	3	3
Jed	Brittany Spaniel	M	5	3
Noodle	Yorkie/Poodle mix	M	3	3
Annie	Catahoula Leopard/Border Collie/Cattle mix	F	2	3
Gatzby	Great Dane	M	4	3
Payton	Husky/Herding mix	F	3	3
Jacob	Australian Shepherd mix	M	6	3
Denver	Cockapoo	M	10	4
Adina	Labrador Retriever	F	4	4
Cyrus	German Shepherd	M	8	4
Lincoln	Standard Poodle	M	3	4
Giuliana	Havanese	F	1	4
Fyodor	English Shepherd	M	1	4
Markl	Pomeranian	M	3	4
Arrow	Labrador Retriever/Border Collie mix	F	1	4
Charlie	Maltese/Yorkie mix	M	3	4
Jo	Miniature Schnauzer	F	5	4

**Table 1.** List of dog subjects, indicating name, owner reported breed, sex (male/female), age (in years) and the condition each subject participated in.



**Figure 1.** Large bucket (left) and small bucket (right) filled with shredded paper.

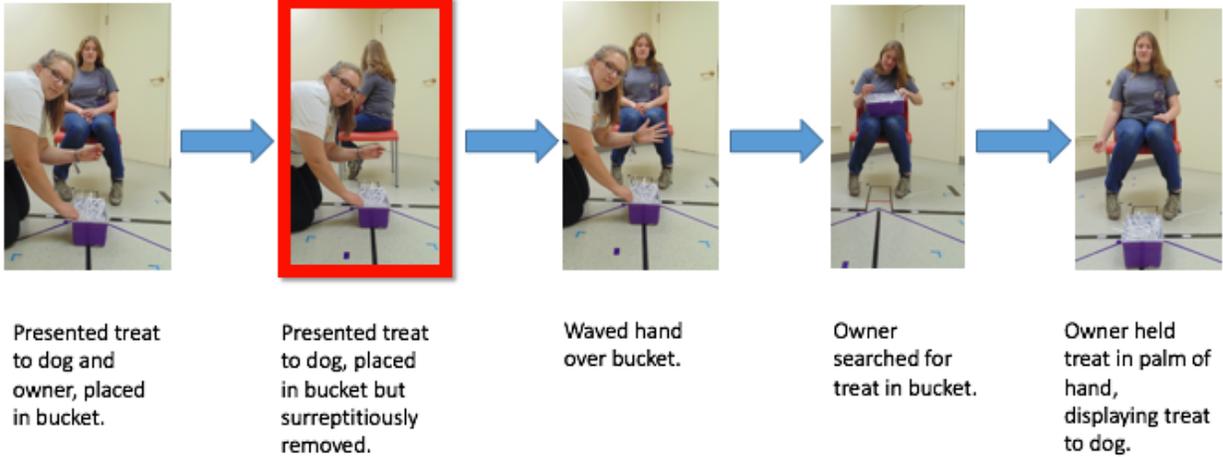


**Figure 2.** Set-up of testing room.

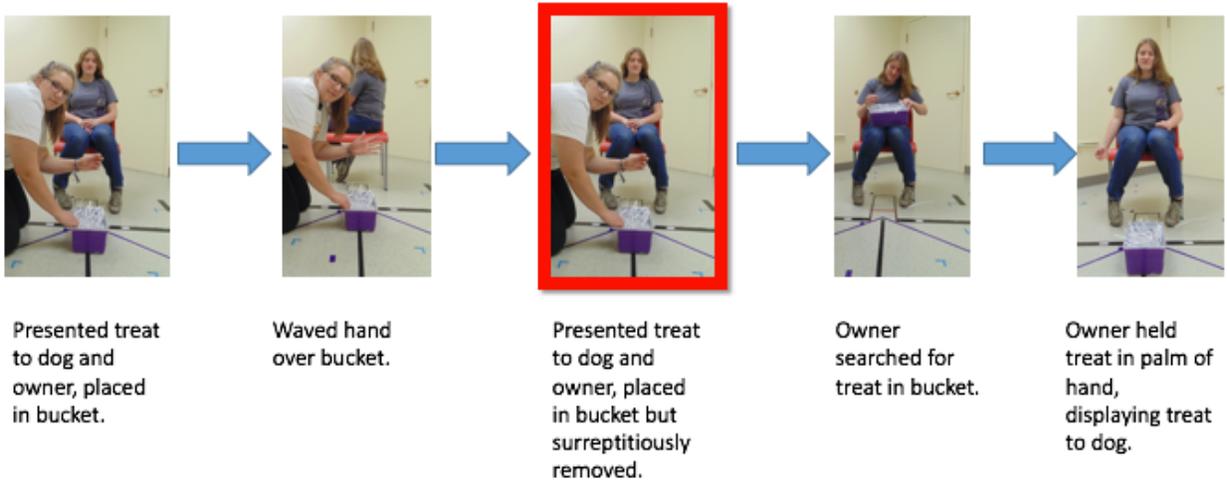
		<b>Owners' Belief</b>	
		True	False
<b>Dogs' Belief</b>	True	Condition 4	Condition 3
	False	Condition 1	Condition 2

**Table 2.** This table summarizes which beliefs were elicited in the dogs and owners by each experimental condition.

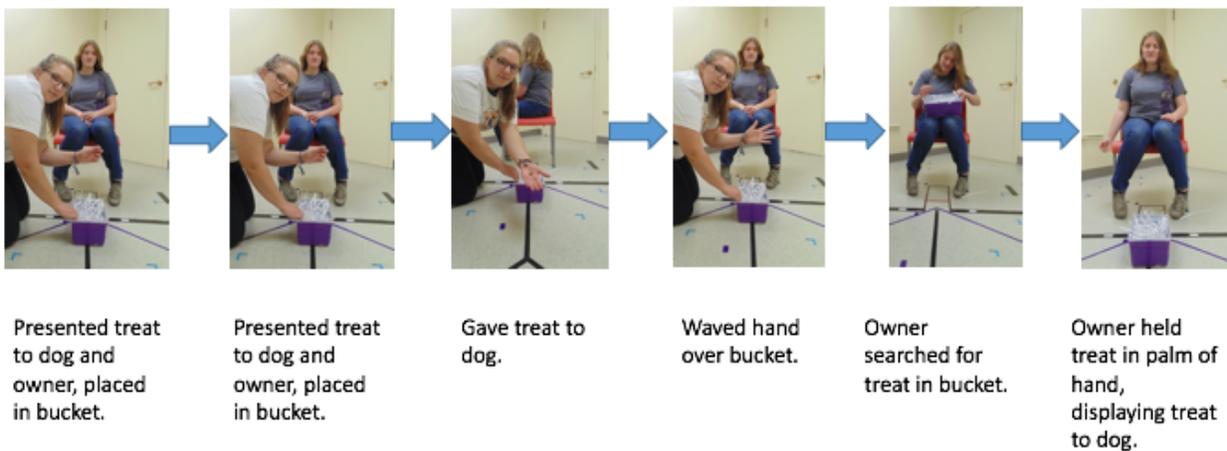
a. Condition 1: Dog FB/Owner TB

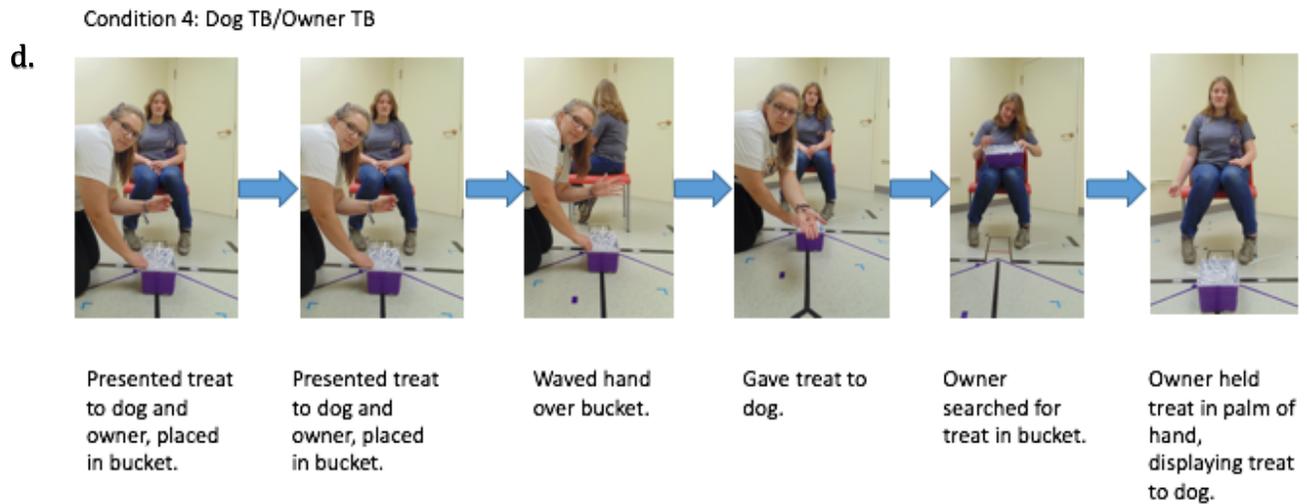


b. Condition 2: Dog FB/Owner FB

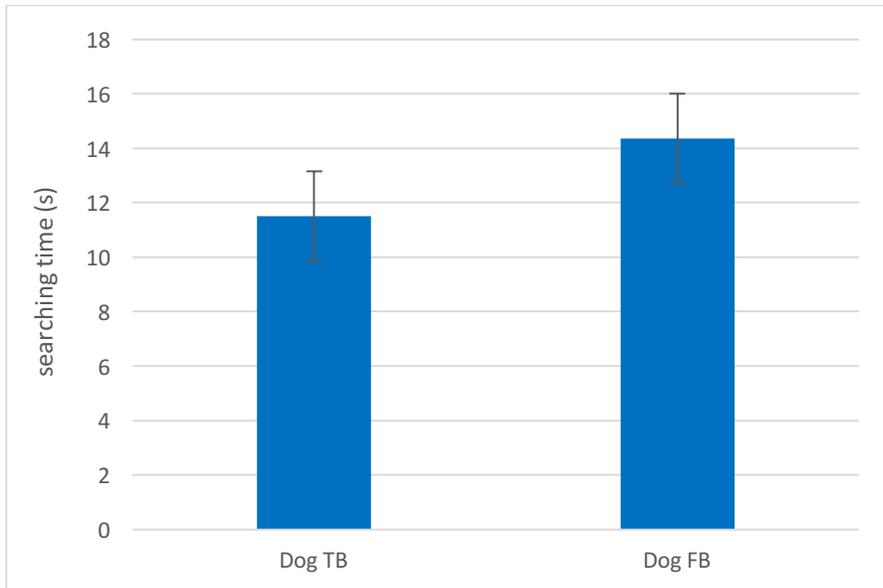


c. Condition 3: Dog TB/Owner FB

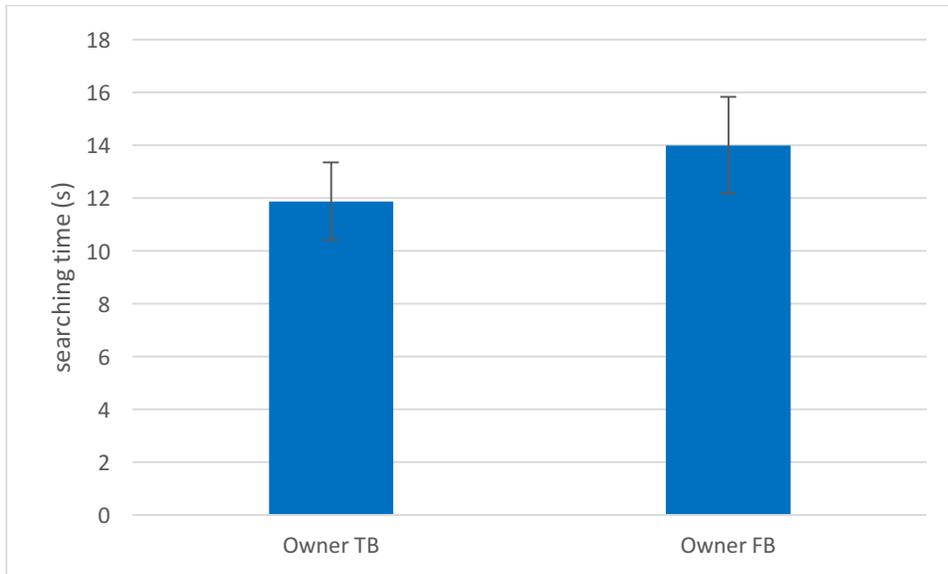




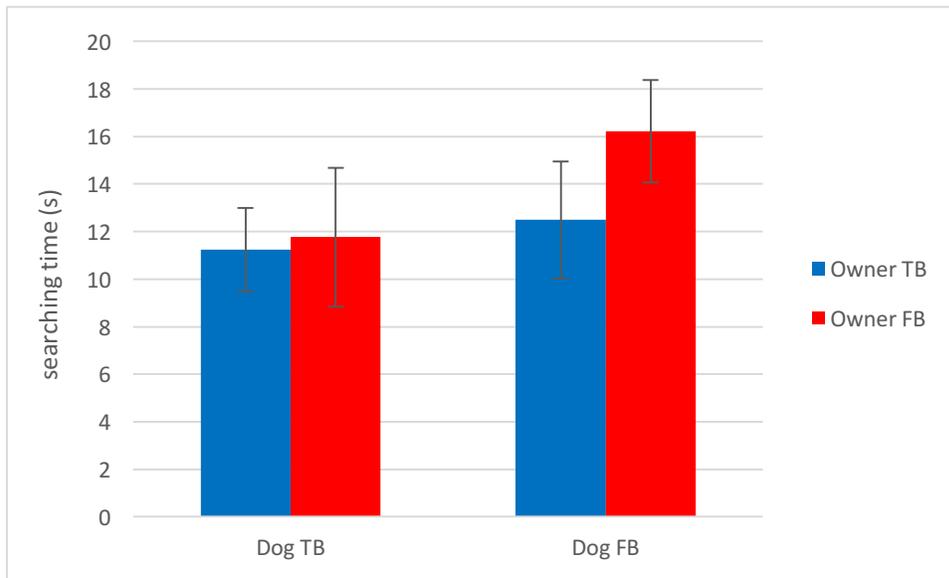
**Figure 3.** A depiction of the procedure across different conditions. The red boxes indicate the treat was presented to the dog or the dog and owner, placed in the bucket, and then but surreptitiously removed. The order of treat presentation and the visual access of the owner in the test trials varied by condition. After each trial, the experimenter left the room, and the dog was released by the handler.



**Figure 4.** Mean searching time (in s) +/- SEM across dog beliefs: Dog Belief (True or False).



**Figure 5.** Mean searching time (in s) +/- SEM across owner beliefs: Owner Belief (True or False).



**Figure 6.** Mean searching time (in s) +/-SEM across dog beliefs in each condition: Dog Belief (True or False) and Owner Belief (True or False).