

Wageningen University & Research, Behavioural Ecology research group (BHE)

Theory of mind in dogs

Assessing pet dogs' (*Canis Familiaris*) ability to understand false belief in humans



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Abstract

Theory of Mind (ToM) is the cognitive ability to attribute mental states, such as beliefs, desires and intentions, to oneself and others, enabling to predict and interpret others' behaviours. It encompasses an understanding that others have different perspectives from one's own and may hold false beliefs, facilitating complex social interactions. Dogs are social animals that have co-evolved with humans, which made them understand and predict many human behaviours. Research suggests the presence of at least some ToM abilities in dogs, but the degree of ToM in dogs remains a point of discussion. Therefore, we tested dogs for understanding false beliefs in humans, utilising an experimental setup modelled after the classical Sally-Anne task for measuring false belief in children. Fifty-nine pet dogs of various breeds and ages participated in a task where the dogs needed to predict the location of where an experimenter would search for an object, by timely meeting the moving experimenter at that location. The subjects were first trained to meet up with the experimenter for food rewards, by anticipating where he/she would go based on his/her knowledge about the location of an object of interest. The object of interest was (re)placed in one of two containers, as witnessed by the dogs and, depending on the condition, (not) by the first experimenter who would then move towards the assumed baited container. The dogs performed two true belief trials and two false belief test trials, in which the object was replaced by the second experimenter out of view of the first one. Twenty-eight dogs did not pass the training phase, leaving 31 dogs for data analysis. Dogs did not take the false beliefs of the experimenter into account when choosing a side, and typically went to the side where the object was currently hidden (38 out of 62 false belief trials, Binomial $p = 0.049$). During the control trials, they were significantly successful (45 out of 62 trials, $p < 0.001$). This suggests that dogs do not understand false beliefs of humans. The successes of the dogs in the true belief test trials support that the experimental setup was sound, though the required attention span, the complexity of the task, and environmental distractions may have impaired the dogs' performances. Further refinement of our experimental procedures is recommended to achieve more valid interpretations. Gaining further knowledge on social cognition in dogs will help us to create a better social environment and state of welfare for humans' beloved companions.

1. Introduction

Theory of Mind (ToM) is a concept that describes the complex cognitive abilities that enable individuals to perceive and interpret their own mental states as well as those of others (Duval et al., 2011). It is part of social cognition and underlies social behaviour (Bellerose et al., 2011; Beer & Ochsner, 2006). ToM has been considered to have a cognitive component, referring to the ability to understand others' intentions, knowledge and beliefs (Brothers & Ring, 1992), and an affective component, referring to the ability to understand others' emotions (Shamay-Tsoory et al., 2010). The level of ToM varies from basic understandings to more complex levels (Shamay-Tsoory et al., 2005), and at least the basic forms of ToM are not exclusive to humans (Wellman & Liu, 2004; Wellman et al. 2011). Animals with a first degree of ToM would understand that individuals other than themselves have desires, which serve as motives for their actions. At a second degree, one grasps that others have specific beliefs and behave in ways that logically align with these beliefs. A third degree of ToM is about understanding that others can possess knowledge acquired from (visual) experiences not shared by oneself. The fourth degree of ToM includes a second degree of understanding beliefs, like that others' beliefs can be false. The fifth degree is about understanding that individuals might display emotions that do not reflect their genuine feelings. In humans, these various degrees develop as an individual matures. Children usually show implicit awareness of others' perspectives from around 18 months old (Kovács et al., 2010; Rubio-Fernández & Geurts, 2013). They develop the necessary skills to pass false belief tasks, like the "Sally-Anne" test, between the ages of two and seven years old (Wellman et al., 2001; Wimmer & Perner, 1983). The Sally-Anne test assesses the understandings of other's beliefs and perspectives in children, by telling the subjects about the changing of the location of a personal item by one of two persons when the other is out of the room. The child is then asked where the absent person will look for the item upon his/her return. Individual differences are apparent in tests like these, which in part reflect the age of the individual (Brunsdon et al., 2019). Other determining factors are individual's socioeconomic status and education (Li et al., 2013), and individual differences in for example intelligence and executive functioning (Charlton et al., 2009; Cane et al., 2017). Psychopathologies, like autism or schizophrenia, associate with an impaired ToM (Brüne & Brüne-Cohrs, 2006; Frith, 1992; Bradford et al., 2018). Human ToM is a well-researched topic, yet research into the presence and development of ToM has focussed mainly on a few specific species. Nonetheless, there are reasons to assume that ToM is a widespread phenomenon under non-human animal species (Wellman & Liu, 2004; Wellman et al. 2011). As ToM is something humans heavily rely on for social interactions, it would be safe to say that other social animals would also benefit highly from it.

Research on ToM in non-human species has been done with great apes (chimpanzees, bonobos, and orangutans), which are closely related to humans and have complex social structures (McNulty, 2010; Meder, 2015). Great apes demonstrated an understanding of others' perspectives, meaning that they can follow the gaze of conspecifics and that of humans (Call & Santos, 2011). For instance, chimpanzees understood what another chimpanzee could see in an experiment where subordinate and a dominant individual were put into competition over two pieces of food. The dominant took the food to which it had visual and physical access, but subordinates managed to get some of the food when this was placed in such a way that only the subordinate saw it. They 'fooled' the dominant by inferring the other's perspective (Hare et al., 2000). Chimpanzees also deceived human experimenters, and thus obtain a food reward unseen, in a competitive experiment. Already in the first trial, chimpanzees used active, deceptive strategies for concealing their approach to the contested food (Hare et al., 2006; Melis et al., 2006), suggesting that they understood the human competitor's perspective. The same subjects preferred to pursue food that they could approach silently, so that a distracted human competitor could not hear them, as opposed to choosing food which involved making noise en route. These findings showcased the social cognitive abilities of great apes and spurred on further research with other species, including dogs.

Dogs originate from wolves, a pack animal with a complex social environment, and have co-evolved with humans (Benecke, 1987). They are raised by humans or live off human refuge, which makes them dependent on us, and pet dogs establish strong attachment-like bonds with humans (Gácsi et al., 2013; Karl et al., 2020; Topál and Gácsi, 2012). Dogs understand human emotions and different forms of communication and gestures (Bensky et al., 2013; Huber, 2016; Kaminski & Marshall-Pescini, 2014; Wynne, 2016). Even free-range dogs, with little to no socialisation, understand human pointing gestures (Bhattacharjee et al., 2020). Dogs communicate with humans in specific ways, like making eye contact when facing an unsolvable task (Lazzaroni et al. 2020). Dogs have shown

to direct help-seeking behaviour towards humans during difficult problem-solving tasks (Udell, 2015; Brubaker & Udell, 2018) and in unsolvable puzzle set-ups (D'Aniello et al., 2015; Marshall-Pescini et al., 2013). This help-seeking behaviour is seemingly something that evolved with the dogs, as it is rare in hand-raised socialised wolves (Miklósi et al., 2003).

Dogs are a social species with a degree of interspecific ToM, for example as demonstrated with a guesser-knower paradigm (Catala et al., 2017, Povinelli et al., 1990). The dog subjects watched as one experimenter, the knower, hid food behind a low barrier, in one of four cups, with the precise hiding location being invisible to the dog. A second experimenter, the guesser, waited outside of the room until the baiting was complete. Both experimenters then took position behind the four cups, each pointing to a different cup, after which the dog was allowed to choose (going to the baited cup earned the dog the food in it). The preference for the knower was at 67% of the trials and this indicates that the dogs were capable of knowledge attribution (Catala et al., 2017), meaning a third degree of ToM. Dogs have at least a rudimentary ToM (Horowitz, 2011), but findings on higher degrees have been limited and not conclusive, for example regarding dogs' ability to understand false belief. Lonardo et al. (2021) conducted a study with dogs on understanding false belief, using a modified version of the change of location paradigm (Wimmer & Perner, 1983). Food was moved from one container (A) to another (B), after the initial hiding, which was seen or not by an experimenter as witnessed by the dog. The experimenter would subsequently hint at the empty bucket, and dogs followed the hints significantly more in the false belief scenario. As Lonardo said: "the dogs might have viewed these misleading gestures as a mistake 'in good will' if the dog understood that the experimenter lacked relevant knowledge" (Lonardo et al. 2021). In another study on false belief, dogs were observed for the direction of their gaze during a staged act with violation of expectation (Rowley, 2020). The dog subject and an experimenter observed a toy duck being placed into one of two boxes, which was then replaced as witnessed by the dog only. The dogs would then experience an expected event, were the experimenter reached towards the box were they last saw the duck, or an opposite unexpected event. The dogs were expected to gaze longer at a box in apparent surprise if the experimenter acted contradictory to their false belief. However, this was not the case, but rather the dogs gazed equally at both boxes, causing Rowley to conclude that dogs do not understand false belief. The limited number of studies on false belief and tricky interpretations of earlier findings, leaves a knowledge gap. Initially, great apes were assumed to not understand false belief (Heyes, 1998; Karg et al., 2016), but views shifted with changes in methodologies. Using eye tracking technology, primatologists have found that great apes (Kano et al., 2017, 2019; Krupenye et al., 2016) and Japanese macaques (Hayashi et al., 2020) visually anticipate that an actor will search for an object where they falsely believe it to be. This showcases that we should stay open minded in the research towards ToM in dogs.

Tests that are designed to study difficult cognitive concepts, such as understanding of false belief in animals should be simple and reproducible to avoid complications with the interpretation of the results. We aimed to test dogs for understanding false belief in humans, using methods based on the Sally-Anne paradigm (Wimmer & Perner, 1983). Dogs had to predict where an experimenter with a true or false belief would search for a hidden object. If dogs understand human false beliefs, we expected them to be able to predict the movement of the experimenter to a cup where he/she believed the object was, even when that object was 'secretly' moved elsewhere. If dogs would not have an understanding of false beliefs, they would go to the cup holding the object, irrespective of the belief of the researcher.

Knowing the degree of ToM in dogs holds significant implications for various aspects of our interactions with them. Firstly, it could change the way we train and interact with dogs, prompting adjustments to training methods to accommodate their potential comprehension of others' beliefs and intentions. Secondly, it might open doors to improved communication between humans and dogs, enhancing our ability to convey information effectively and interpret their behaviour accurately. Lastly, from a broader scientific perspective, exploring canine cognition contributes to our understanding of animal intelligence and consciousness, enriching our knowledge of the complexities of the animal mind. Thus, delving into this question not only benefits our understanding of dogs, but also offers insights into fundamental aspects of cognition and human-animal relationships.

2. Methods

To study dogs' understanding of false belief, we created a set-up based on the Sally-Anne paradigm (Wimmer & Perner, 1983), where dogs had to predict the actions of a human researcher based on the view of the researcher. Dogs and their owners were invited to Carus research facilities, Wageningen University, the Netherlands, to participate in our false belief test.

2.1 participants

Fifty-nine privately owned pet dogs participated in the false belief test. The dogs were from a variety of breeds and backgrounds but were all kept as a pet. Participating dogs were recruited through an online questionnaire that was advertised online and in the area of Wageningen, the Netherlands. The questionnaire entries provided general background information about the dog and the consent of some participants to do on-site behavioural studies with their dog. Dogs were tested individually for understanding false belief, with their owner in the room. Owners with multiple dogs were asked to bring an extra person to watch the other dog(s) during tests.

2.2 Ethical statement

We prioritized the health and well-being of the dogs, alongside the safety of our research team. The dog subjects were securely leashed to a fixed point within the experimental room, allowing for the necessary restraint without compromising their comfort. The owners were always present in the room and were told to discontinue the test whenever they wanted to. Before the commencement of the study, all participants provided their informed consent. This consent also covered the approval for filming the sessions for research purposes, with a guarantee of confidentiality and ethical use of the data that were collected.

Continuous access to water was provided to ensure the dogs remained hydrated and comfortable throughout the experiment. Breaks with the possibility to walk outside were provided in between tests, and in cases of a dogs with allergies, the owner was asked to bring their own treats for food rewards. The training that was conducted involved solely out of positive reinforcement and no aversive procedures took place during any of the experiments. Due to all considerations and the nature of the test the ethical committee of Wageningen has deemed this test not to be an animal experiment as defined by Dutch law.

2.3 Experimental setup

The false belief test ran from 18-9-2023 to 1-3-2024, with a maximum of four dogs tested on a given day. Testing took place in a separate room of 6.5 by 6.3 m at Carus research facilities (Wageningen UR, Netherlands). The room was equipped with audio and video recorders and had a big one-way window for observations. A separate Go Pro camera (black 8) was fixed on the ceiling, to film the choices of the dog. The room had an exit door next to the starting place of the dog, leading to the corridor, and one next to the one-way window, leading to the observation room (Figure 2.1). During the false belief test, the dog was leashed to the wall and kept in its starting place by its owner, who took place on a chair behind the dog. On the floor, in front of the dog and owner, was a wooden barricade that forced the dog between choosing left or right during test trials. Behind and to the sides of the barricade, were two opaque cups, one on the left and one on the right side of the room (Figure 2.1). Two experimenters were opposite the dog, on the other side of the room. One experimenter, the chooser, held a bag of treats and looked at the dog. Behind the chooser, out of view of the dog, was the baiter, holding a ball. The identity of the chooser and baiter was decided randomly beforehand.

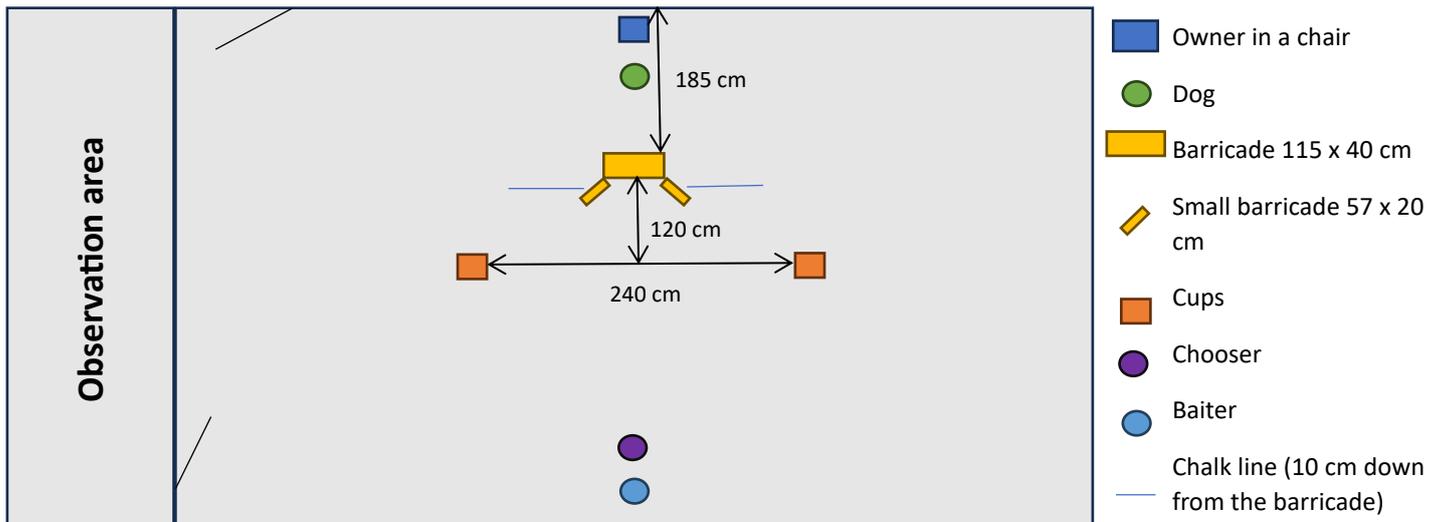


Figure 2.1: Experimental setup and dimensions of the false belief test in a 6.5 by 6.3 m room at the Carus research facilities.

2.4 Procedure

The dog and owner were given a minute off-leash together in the room to let the dog habituate to the experimental room. During this habituation, the barricade, cups and experimenters were not yet in the room. After the habituation, owner and dog left the room until the test started shortly after. At the start of the false belief test, the dog and owner walked into the room and took their positions, with the dog being leashed to the wall by the owner. The experimenters were already in the room and waited until the dog was seated in front of the owner and paid attention.

2.4.1 Training phase

The dogs were first trained to anticipate the movement of the chooser to gain a food reward. The chooser showed the dog a treat and then walked straight at one of the two cups where he/she waited for the dog. The owner was told to release the dog as soon as the chooser started walking, so the dog could meet the chooser at the cup. If the dog came to the chooser at the designated cup, it received the treat. This was repeated for at least four times, until the dog reached the chooser within five seconds, while alternating sides with a randomly selected start side. Next, the dog was taught that the chooser was searching for the ball and would thus always walk towards the cup he/she thought held the ball. The baiter now came from behind the chooser to place the ball under a cup, visibly for both dog and chooser. The baiter returned to his/her starting position and the chooser showed a treat to the dog, before walking straight towards the dog, only to move left or right to one of the cups when being just before the barricade. The owner released the dog as soon as the chooser started walking and could anticipate in choosing a side. When the dog met the chooser at the correct cup, within a predetermined amount of time, the dog was rewarded with a treat. The chooser would then grab the ball from under the cup, regardless of whether the dog was there, and act happy to have found his ball, underlining he/she had been looking for the ball. It was important that dogs anticipated the chooser's choice and went to a cup before the chooser arrived, as this showed where dogs expected the chooser to go based on what he/she believed. Therefore, the predetermined timeframe slowly decreased during the training. After successfully meeting the chooser within five seconds, the timeframe shrank to three seconds and after succeeding twice again it went down to one second. Dogs who did not show up in time went back one step in the training protocol. Dogs that had to go back three times in a row failed the training and their test was discontinued. Dogs that were quick in anticipating the chooser's choice were fast tracked. If the dog arrived at the cup within one second immediately at the start of the baited training runs thrice in a row, the test continued immediately into the test trials. If a dog needed all six baited training runs, but did pass the training after that, there was a small break of two minutes before the test trials started. After a break, the dog had to first perform two successful baited training runs again to ensure their attention. A small break was held also when the experimenter deemed the dog to be unfocused,

when for example the dog did well but after one mistake or an external stimulus underperformed in regard to its previous performance.

2.4.2 Testing phase

The test phase included three different scenarios, with a false belief situation, where the ball was moved while the chooser had left the room, a true belief scenario where the chooser left the room, but the ball was not moved, and a true belief scenario where the chooser stayed in the room and observed the ball being moved. Each dog performed four trials as the false belief scenario was done twice. The order of the scenarios was randomised beforehand, and the ball always started in a different cup during the two false belief scenarios. During the test trials, the chooser did not show a treat before walking anymore and the detailed protocols were as follows.

False belief trials started the same as the training trials, but now the chooser walked out of the room after the baiter was back in his/her spot after the baiting. Once the chooser was outside, the baiter moved the ball from the one cup to the other while the dog was watching. When the baiter was back on his/her spot again, the chooser returned to their starting position and then started walking straight towards the dog, before showing whether they would go left or right. The chooser would always go to where they saw the ball be initially placed. The rewarding was as in the baited training runs. The chooser would then lift the cup, act surprised upon not finding the ball and walk to the other cup to get the ball and act happy again. It was expected that the dogs would attribute a false belief to the chooser, and thus walk towards the initially baited cup.

True belief no switch trial had a similar protocol as the false belief scenario, except the ball was not moved to another cup, but was presented again to the dog while the chooser was outside. This true belief scenario acted as a control scenario in which the ball was manipulated, but not moved out of view of the chooser, and it was expected that the dogs would walk towards the baited cup.

True belief switch trial again had a similar protocol as false belief, but in this scenario the chooser stayed in the room and observed the baiter moving the ball. Once the baiter was back on his/her spot and the chooser started walking, they would thus move towards the latest location of the ball. This true belief scenario acted as a control in which the ball was moved, but not outside the view of the chooser. It was expected that the dogs would walk towards the baited cup.

2.4.3 Data recording and scoring

Data recording was done after the behavioural test from the Go Pro videos, using BORIS v8.25.4 software. The data was then collected in an Excel document. A correct meetup of the dog with the chooser was determined from spatial and temporal measures. Spatially there was a line drawn on the floor which the dog had to cross with at least both front paws. Also, the dog had to be over this line within a certain time frame. This time frame started as soon as the chooser was at the cup and ended after the predetermined amount of time elapsed. If the dog did not show up in time, the chooser took the ball, acted happy and positions were reset. We measured a time frame (window time) that counted when the experimenter was at the spot where they would meet the dog relative to the arrival of the dog. If the dog arrived before the chooser, this time would be negative and it would start ticking positively when the experimenter was at the meeting point before the dog.

2.5 Data analysis

Data analysis was done in Excel using statistical tests like binomial tests to find significant differences within groups and Chi-square tests to find differences across groups. Data was filtered in such a way that the tested population only exist out of dogs who performed their last baiting trials in <1 second, performed all four test trials given (with two false belief tasks) and showed no significant side preference.

3. results

A total of 59 dogs participated in this false belief task in which the dogs were tested for understanding false beliefs in humans. The dog subjects were expected to anticipate where an experimenter (chooser) would go to collect an object of interest (ball) on the basis of what he/she (falsely) believed about the object's location. The object was (not) replaced by another experimenter (baiter) as (not) seen by chooser, which was all witnessed by

the subject. The subjects partook in two same false belief scenarios and two slightly differing true belief scenarios. Dogs that went towards the cup where the experimenter last saw the hidden object, were expected to understand the belief that the chooser held. The study population consisted out of 27 different pure-bred breeds and 19 different mixed breeds, of which 23 were male and 35 females (Appendix I). Age ranged from 6 months to 12 years, with a mean age of 3.7 ± 2.6 years old (Appendix I). The study population was filtered before data analysis, because not every dog performed in accordance with the protocol. Sixteen dogs did not perform all test trials due to a shift in methods, leaving 42 dogs. Two dogs showed a statistical side preference (Binomial, $p = 0.018$, $p = 0.020$) reducing the number to 40 (Appendix II). Dogs should only be tested when having latencies to go to a cup in ≤ 1 second (s) during the final baited training trials. This removed nine more dogs from the population, which led to 31 dogs who performed two false belief (FB) trials and two true belief (TB) trials, all having a final training baiting time of ≤ 1 s and no side preference. The results of the two FB trials were grouped together (Figure 3.1). The FB trials resulted in significantly fewer successes than chance (24 successes out of 62, Binomial, $p = 0.049$, chance probability 0.5). The opposite was true for the TB trials with significantly more dogs being successful (22 out of 31 for the TB switch, $p = 0.015$, and 9 out of 31 for the no switch TB, $p = 0.005$) but the two control trials did not differ significantly (Chi-square = 2,4, $df = 1$, $p = 0.0.78$). FB switch against TB switch + TB no switch (TB trials combined = 45 successful, 17 unsuccessful) did show a significant difference (Chi-square = 2,4, $df = 1$, $p < 0.01$) There were four dogs who succeeded in all four test trials and, including those four, 11 dogs who succeeded in both false belief test trials.

It was expected that dogs would learn and become faster in going to the cup where they expected the chooser to go, this is reflected in the data. The walking phase had the highest average window time (s) at $1.74 \pm 4,26$ s, followed by the baiting phase with an average time of -0.15 ± 2.76 s (meaning that the dog was on average 0.15 s sooner at the meeting point then the experimenter). Lastly the testing phase had an average window time of -0.37 ± 2.20 s (Appendix III).

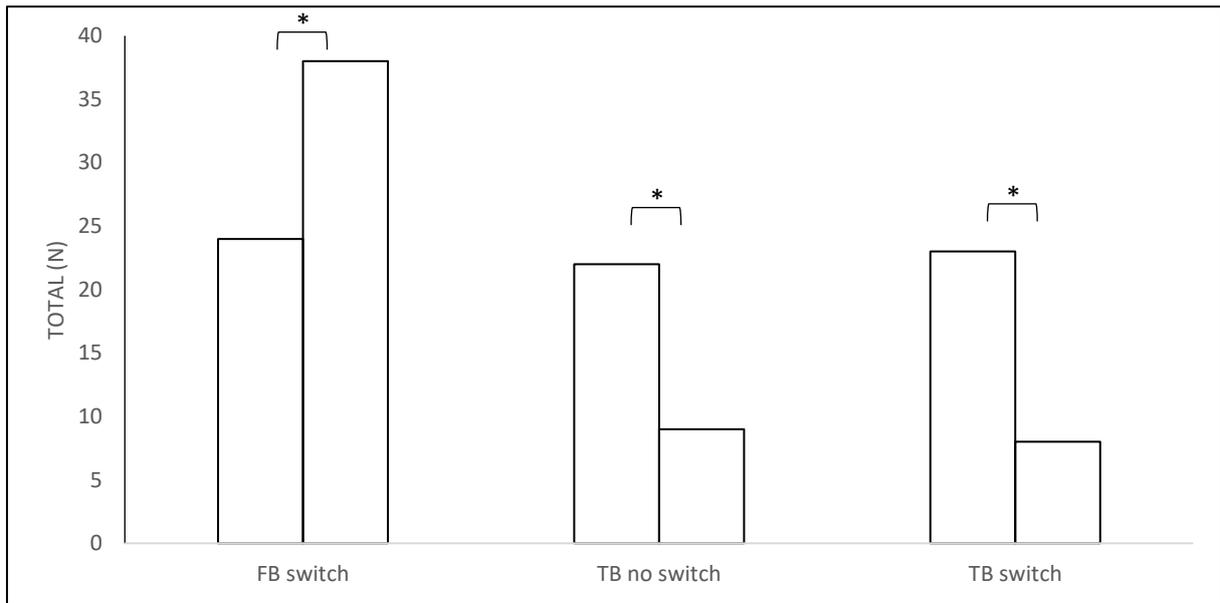


Figure 3.1: Dogs were tested for understanding (false) beliefs in an experimenter and had to anticipate where he/she would go to retrieve an object of interest. Presented are all test trial outcomes of the filtered 31 dogs. Y-axis has the number of (un)successful runs of a specific test trial. X-axis shows which test trial it is, false belief (FB) or true belief (TB) and with or without a switch of the object between cups. Every test trail has on the left the number of successful runs, and on the right the unsuccessful runs. Test trial FB switch has double the total runs due to being the two FB switch test trials being pooled together (N=62). *: a significant difference within the group, $p < 0.05$.

In more detail, the first time that dogs perform a FB test trial, they were significantly unsuccessful with 9 successes against 22 unsuccessful (binomial $p = 0.015$) (Figure 3.2). The number of successful runs the second time the dog performs a FB test trial was slightly higher, with 15 successes and 16 unsuccessful, but the two trials did not differ significantly (Chi-square = 2,4, $df = 1$, $p = 0.12$).

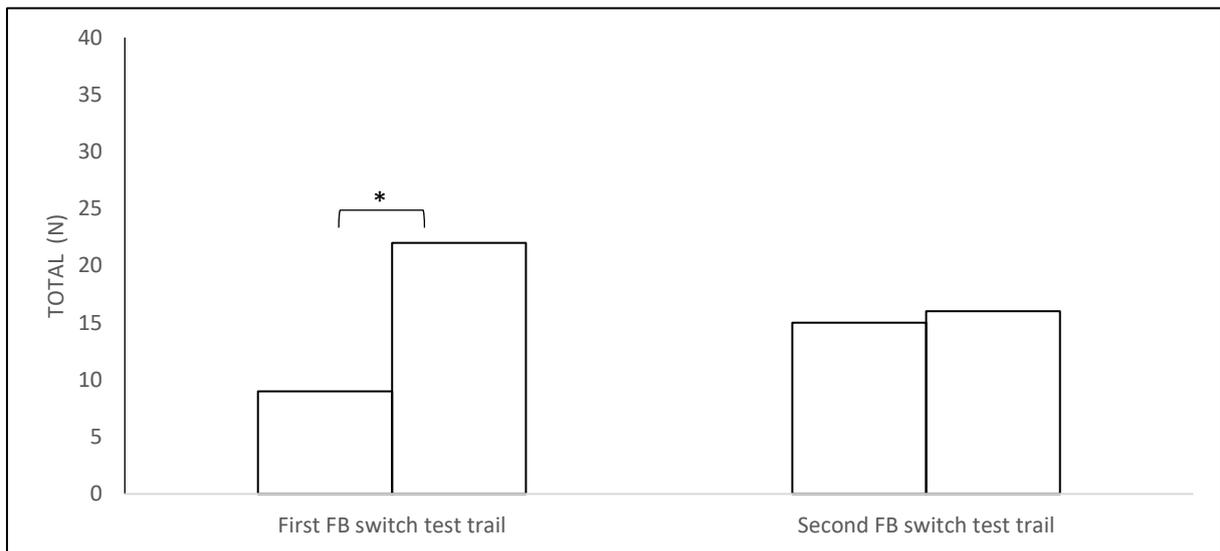


Figure 3.2: Dogs were tested for understanding (false) beliefs in an experimenter and had to anticipate where he/she would go to retrieve an object of interest. Presented are all false belief switch test trial outcomes of the filtered 31 dogs. Y-axis has the amount of (un)successful runs of a specific test trial. X-axis shows if it is the first or second false belief (FB) test trial. Both test trails have on the left the number of successful runs, and on the right the unsuccessful runs. *: a significant difference within the group, $p < 0.05$.

The experimental setup was flexible in that some dogs got a small break of two minutes to try to refresh their attention, after six training phases or when the dog's showed signs of losing attention. Twenty-four dogs out of the 31 dogs received such a break (Figure 3.3). Dogs that received a break succeeded significantly more when

performing TB no switch (18 successful, 6 unsuccessful with break against 4 successful, 3 unsuccessful without break) and switch test trials (18 successful, 6 unsuccessful with break against 5 successful, 2 unsuccessful without break) (binomial, both $p=0.011$). but the break against no break within any of the trials did not differ significantly (Chi-square = 2,4, df = 1, FB switch $p = 0.38$; TB no switch $p = 0.36$; TB switch $p = 0.85$).

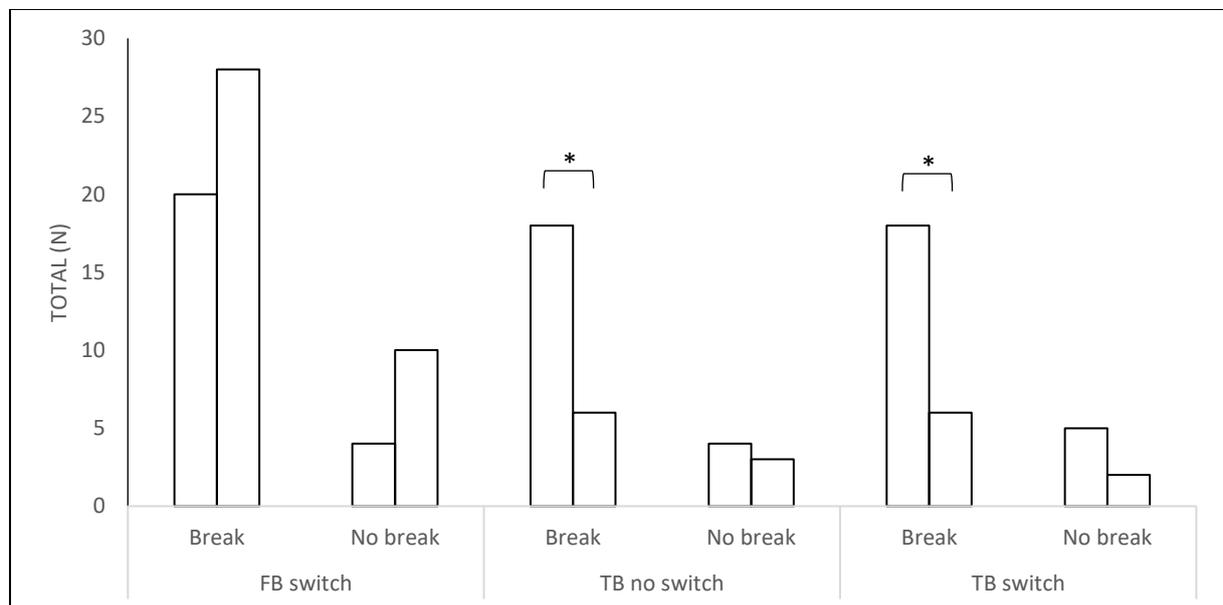


Figure 3.3: Dogs were tested for understanding (false) beliefs in an experimenter and had to anticipate where he/she would go to retrieve an object of interest. Presented are all test trial outcomes of the filtered 31 dogs. Y-axis has the amount of (un)successful runs of a specific test trial. X-axis shows which test trial it is, false belief (FB) or true belief (TB) and with or without a switch of the object between cups. There is also a division between dogs that got a break before the test phase and that did not. Every group on the x-axis has on the left the number of successful runs, and on the right the unsuccessful runs. Test trial FB switch has double the total runs due to being two FB switch test trials being pooled together. *: a significant difference within the group, $p < 0.05$.

4. Discussion

Dogs are likely to have at least a rudimentary Theory of Mind (ToM) and their social cognitive abilities towards humans might even reach up to the third level of ToM, being able to attribute knowledge to persons in the Guesser-Knower paradigm (Catala et al. 2017). Here, we studied dogs' higher level of ToM and tested for the ability to recognize and understand a person's false belief. A new test was set up based on the classical Sally-Anne false belief test that was previously used on human children (Wimmer & Perner, 1983). Our dogs had to anticipate where a person (chooser) would look for their item, after this had or had not been moved by a second person (baiter), in view or out of view of the chooser and as all witnessed by the dog. Whereas human children can simply be asked where the person would look for the item upon his/her return, for animals this requires a more delicate approach. The dogs' expectations about the chooser's beliefs were deduced from its anticipatory response in going to where the chooser was likely to go. The dogs were trained by rewarding them when meeting the chooser at the correct cup within the correct timing. To meet the time constraint, the dog had to anticipate where the chooser would go. We predicted that dogs would go to the cup of which they thought the chooser believed the item was, making it possible to see if they would also take possible false beliefs of the chooser into account. Thirty-one out of 59 tested dogs performed the task according to protocol and these 31 dogs each performed two false belief tasks and two true belief control tasks. Dogs did not seem to take the false beliefs of the chooser into account and mostly anticipated the chooser to go to the cup the dogs knew held the object of interest (38 out of 62 false belief trials, $p < 0.005$, Binomial). During the true belief control trials, where the chooser knew the correct location of the item, dogs successfully anticipated the choice of the chooser (true belief no switch: 22 out of 31 trials; true belief switch 23 out of 31, $p < 0.05$). Our findings suggest that dogs do not have an understanding of false beliefs. The dogs were not able to predict the experimenter's movement based on their beliefs but may have understood the experimenter's intentions of getting the object of interest. The successes in the true belief control conditions indicate that the training of this new setup worked. The dogs

successfully learned to meet up with the chooser at the correct cup withing the correct amount of time in true belief situations. Further analysis on the false belief trials showed that the first time the dogs perform the trial they were successful only 9 out of the 31 time. The second time, this was 15 out of 31 indicating that dogs may quickly learns from its past failure and learns to perform the second (false belief) trial successfully through simple associate learning (Kirsch et al., 2004). True insight should show as successes in the first trials.

Although the majority of the dogs did not seem to understand false belief in this test set-up, there were a select few that seemed to do. Eleven dogs performed both false belief trials successfully in line with understanding false belief in humans. Four of these dogs performed the set-up perfectly, succeeding in all four test trials. This might indicate that there is strong individual variation in ToM. Things like a dog's breed, age but also training background or amount of socialising might be of influence. In future research, the background data of each dog should be analysed in regard to how successful dogs of certain categories are. Fugazza et al. (2021) also saw performance differences between individuals in her study on word learning in dogs. They tried to learn 40 dogs two novel toy-names in three months. All but seven failed the test at the end, but these remaining seven did show remarkable results (Fugazza et al. 2021), pointing towards a qualitative rather than quantitative effect of individual variation. Similarly, there is the special talent of perfect pitch in humans, which is rare and hardly trainable, but for perhaps during a sensitive period. A dog's understanding of false belief could fall in the same category as this phenomenon, when regarding the results of the present study, providing some evidence of exceptional performance in in a select few dogs. Analysing those talented few further can give insight to what is necessary for a dog to possess the ability to understand false beliefs in humans.

The true belief control trials revealed significant successes by the dogs and this indicates that the set-up worked in training dogs to meet up with a person at a specific location within a specific time frame. However, it might still be that the way of training affected the results of some dogs during the test phase. Dogs were taught to meet with the chooser, and that the chooser would go to the object of interest, creating a potential strong connection between the hidden object and the treat. Since this step was repeated multiple times within the training phase, it is possible that some dogs simply learned an association between going to the object and receiving a treat, rather than taking the beliefs of the person into account. To avoid this from happening, we attempted to make it a bit more of a story with the experimenter acting happy once collecting the ball from under the cup and acting sad if they encountered an empty cup. However, encountering an empty cup only happened during the testing phase, which might have been too late. Though this could have been an extra stimulus for the dog to learn, and thus perform better at the second false belief trial as somewhat evident in the results. This means that the dogs must have used simple associative learning to solve the current task rather than insight into the person's mental states. It cannot be ruled out that dogs have an understanding of false beliefs, but we could not demonstrate it with this set-up in part due to the possibility of using simple learning. Enhancing the story by encountering empty cups during the training phase could be beneficial. However, it is risky to create a more elaborate, more detailed training, which may be too complex or prone to problem solving in unexpected ways. It should be in such a way that the dogs learn the set-up in the training phase and needs to use insight during the test phase to be successful.

Contradictory results were found when dogs were presented with staged scenarios to test their understanding of beliefs (Lonardo et al., 2021). In the false belief scenario, an experimenter watched as food was placed in a container (A) and then left the room. While they were away, the food was moved to a different container (B). Upon returning, the experimenter, unaware of the switch, guided the dog to container A. In the true belief scenario, the experimenter witnessed the food being transferred after re-entering the room, yet still directed the dog to container A. Although most dogs correctly went to container B, they were more likely to follow the misleading cue in the false belief scenario than in the true belief scenario (Lonardo et al. 2021). This indicates that dogs might indeed be taking the beliefs of humans into account, but alternative interpretations are possible. Dogs may rely only on cues available at the moment of decision-making, without considering past events to infer what others might have seen previously (Huber & Lonardo, 2023). Additionally, during a fetching task dogs have shown that they can consider the human perspective rather than relying solely on their own (Kaminski et al., 2009). The dogs were asked to fetch a toy by an experimenter who could see only one of two toys, one visible behind a transparent barrier and the other hidden behind an opaque one, while the dogs themselves could see both toys. The dogs showed a preference for retrieving the toy that was visible to the experimenter. However, in

a second experiment were the experimenter left the room after the hiding of one toy behind an opaque barrier, dogs did not demonstrate an awareness of what the experimenter had previously observed. When asked to fetch a toy, they did not show a preference for bringing the toy that the experimenter had seen being hidden over one of which the experimenter had not witnessed the hiding and was therefore unaware of (Kaminski et al., 2009).

The attention span of the dogs might have been a limiting factor during this study. Dogs that participated in the false belief task also performed a Guesser-Knower task beforehand, causing dogs to possibly be less focused during the false belief task. Fatigue may have caused them to lose interest or get frustrated, leading to them not completing the task according to protocol or choosing randomly. Dogs that chose randomly might have chosen wrong multiple times in a row, after which they might have lost motivation to walk towards any cup, since choosing wrongly led to not receiving a food reward at all. To try and counteract the dogs losing interest we implemented the possibility of a two-minute pause after six baited training phase trials or if the experimenter saw the dog building up frustration or losing interest/ focus. During the pause, the dogs would walk freely in the room while getting some food enrichment. This seemed to help, as the dogs who received a break were significantly more successful at the true belief test trials than the dogs who did not get a break in between. However, it did not impact the results of the false belief test trials. Another potentially limiting factor during the study was the stress caused by the new experience of being at our research facility when performing in these tasks (Foraita et al., 2021). We did use a habituation phase before the test, and when dogs seemed too stressed, we discontinued the test. Still, follow up studies could experiment with longer breaks to reduce the mental fatigue, which in turn could improve performances during the test trials. A design that could be performed at a person's home would also be of interest to exclude the new and possibly 'scary' environment of our facilities all together. Having two experimenters for the dogs to focus on might also be making the task more tiresome to begin with. Dogs already seem to have shorter attention spans than humans and having to focus on two persons while making decisions could tire out a dog quickly (Wallis et al., 2017). Age counterintuitively was said to have limited effect on the attention span (Wallis et al., 2017). However, older dogs showed a decrease in overall looking time towards novel stimuli compared to young dogs, which could be explained by a life-long learning process to reduce reaction to novel external stimuli (Lindsay, 2001). Our testing facility was at times quite noisy because of the placement right next to the cat facilities, which could have affected the attention of our relatively young population of dogs with a mean age of ~4 years old. Future research could thus best be done with a slightly more aged population of dogs to reduce the effect of external stimuli. Also, complicated tasks such as this one should be performed without other challenging tasks on the same day to ensure sufficient focus of the subjects.

Besides a large variety of ages our population also was very diverse in breeds, as the 59 tested dogs were of 46 different breeds (pure and mixed breeds). Due to the small sample size per breed, finding a breed effect would be hard. However, in the study by Lonardo et al. (2021) they ran a follow up experiment with a larger sample of terriers and border collies, to test if their false belief task was influenced by breed characteristics like cooperativeness or independence. This showed that border collies were significantly more likely to follow a misleading suggestion in a false belief situation than terriers, suggesting the presence of a breed effect within false belief. For follow up studies on false belief, it would thus be of interest to find larger samples sizes per breed to investigate this potential breed effect further.

Lastly, we cannot forget that false belief is an inherently difficult task, and Bloom & German (2000) took a critical look at false belief and if it is fit for theory of mind research in animals. The factoring of multiple things at a same time, including where someone should look versus where will they look, is challenging. Since, we are dealing with non-human animals who cannot simply talk to us, extra steps are needed that complicate tasks. This makes the interpretation of the results at times difficult, as in our current task. Bloom and German (2000) highlight that "while failure in the false belief task is not necessarily informative about a child or animal's conceptual abilities, success is". Our study did not show that dogs are capable of understanding false beliefs in humans, but we did see a few high performing individuals. The complex nature of this task might cause failure while there might be understanding in the dogs. Knowledge about what dogs do and do not understand about mental states in humans may strengthen the human-dog relationship, by leading us to better training methods, better communication and correct interpretations of dogs' behaviour. Gaining knowledge on the complexity of the animal mind helps to improve animal welfare and strengthen human-animal relationships further.

References

- Beer, J. S., & Ochsner, K. N. (2006). Social cognition: A multi level analysis. *Brain Research*, 1079(1), 98–105. <https://doi.org/10.1016/j.brainres.2006.01.002>
- Bellerose, J. S., Beauchamp, M. H., & Lassonde, M. (2011). New insights into neurocognition provided by brain mapping: Social cognition and theory of mind. In D. Hugues (Ed.), *Brainmapping: From neural basis of cognition to surgical applications* (pp. 181–190). Springer Vienna.
- Benecke, N. (1987). Studies on early dog remains from Northern Europe. *Journal of Archaeological Science*, 14(1), 31-49
- Bensky, M. K., Gosling, S. D., & Sinn, D. L. (2013). The world from a dog's point of view: a review and synthesis of dog cognition research. *Advances in the Study of Behavior*, 45, 209-406
- Bhattacharjee, D., Mandal, S., Shit, P., Varghese, M. G., Vishnoi, A., & Bhadra, A. (2020). Free-ranging dogs are capable of utilizing complex human pointing cues. *Frontiers in Psychology*, 10, 507348.
- Bloom, P., & German, T. P. (2000). Two reasons to abandon the false belief task as a test of theory of mind. *Cognition*, 77(1). [https://doi.org/10.1016/S0010-0277\(00\)00096-2](https://doi.org/10.1016/S0010-0277(00)00096-2)
- Bradford, E. E. F., Hukker, V., Smith, L., & Ferguson, H. J. (2018). Belief-attribution in adults with and without autistic spectrum dis-orders. *Autism Research*, 11, 1542–1553.
- Brothers, L., & Ring, B. (1992). A neuroethological framework for the representation of minds. *Journal of Cognitive Neuroscience*, 4(2), 107–118. <https://doi.org/10.1162/jocn.1992.4.2.107>
- Brubaker, L., & Udell, M. A. (2018). The effects of past training, experience, and human behaviour on a dog's persistence at an independent task. *Applied Animal Behaviour Science*, 204, 101-107.
- Brüne, M., & Brüne-Cohrs, U. (2006). Theory of mind—Evolution, ontogeny, brain mechanisms and psychopathology. *Neuroscience and Biobehavioral Reviews*, 30(4), 437–455. <https://doi.org/10.1016/j.neubiorev.2005.08.001>
- Brunsdon, V., Bradford, E., & Ferguson, H. J. (2019). Sensorimotor rhythm during action observation changes across the lifespan independently from social cognitive processes. *Developmental Cognitive Neuroscience*, 38, 100659.
- Bugnyar, T., & Kotrschal, K. (2002). Observational learning and the raiding of food caches in ravens, *Corvus corax*: Is it “tactical” deception? *Animal Behaviour*, 64(2), 185–195. <https://doi.org/10.1006/anbe.2002.3056>
- Call J, Santos L (2011) Understanding other minds. In: Mitani J et al (eds) *The Evolution of Primate Societies*. University of Chicago Press, Chicago
- Cane, J. E., Ferguson, H. J., & Apperly, I. (2017). Using perspective to resolve reference: The impact of cognitive load and motivation. *Journal of Experimental Psychology: Language, Memory & Cognition*, 43, 591–610.
- Catala, A., Mang, B., Wallis, L., & Huber, L. (2017). Dogs demonstrate perspective taking based on geometrical gaze following in a Guesser–Knower task. *Animal Cognition*, 20(4), 581–589. <https://doi.org/10.1007/s10071-017-1082-x>
- Charlton, R. A., Barrick, T. R., Markus, H. S., & Morris, R. G. (2009). Theory of mind associations with other cognitive functions and brain imaging in normal aging. *Psychology and Aging*, 24(2), 338–348. <https://doi.org/10.1037/a0015225>
- D'Aniello, B., Scandurra, A., Prato-Previde, E., & Valsecchi, P. (2015). Gazing toward humans: a study on water rescue dogs using the impossible task paradigm. *Behavioural processes*, 110, 68-73.

- Duval, C., Piolino, P., Bejanin, A., Eustache, F., & Desgranges, B. (2011). Age effects on different components of theory of mind. *Consciousness and Cognition: An International Journal*, 20(3), 627–642. <https://doi.org/10.1016/j.concog.2010.10.025>
- Foraita, M., Howell, T., & Bennett, P. (2021, July 1). Environmental influences on development of executive functions in dogs. *Animal Cognition*. Springer Science and Business Media Deutschland GmbH. <https://doi.org/10.1007/s10071-021-01489-1>
- Frith, C. D. (1992). *The cognitive neuropsychology of schizophrenia*. Lawrence Erlbaum Associates.
- Fugazza, C., Dror, S., Sommesse, A., Temesi, A., & Miklósi, Á. (2021). Word learning dogs (*Canis familiaris*) provide an animal model for studying exceptional performance. *Scientific Reports*, 11(1). <https://doi.org/10.1038/s41598-021-93581-2>
- Gácsi M, Maros K, Sernkvist S, Faragó T, Miklósi Á (2013) Human analogue safe haven effect of the owner: behavioural and heartrate response to stressful social stimuli in dogs. *PLoS ONE* 8(3): e58475. <https://doi.org/10.1371/journal.pone.0058475>
- Hare B, Call J, Agnetta B, Tomasello M (2000) Chimpanzees know what conspecifics do and do not see. *Anim Behav* 59(4):771–785
- Hare B, Call J, Tomasello M (2006) Chimpanzees deceive a human competitor by hiding. *Cognition* 101(3):495–514
- Hayashi T, Akikawa R, Kawasaki K, Egawa J, Minamimoto T, Kobayashi K, Kato S, Hori Y, Nagai Y, Iijima A, Someya T, Hasegawa I (2020) Macaques exhibit implicit gaze bias anticipating others' false-belief-driven actions via medial prefrontal cortex. *Cell Rep* 30(13): 4433–4444. <https://doi.org/10.1016/j.celrep.2020.03.013>
- Heyes CM (1998) Theory of mind in nonhuman primates. *Behav Brain Sci* 21(1):101–148
- Horowitz A (2011) Theory of mind in dogs? Examining method and concept. *Learn Behav* 39(4):314–317. <https://doi.org/10.3758/s13420-011-0041-7>
- Huber, L. (2016). How dogs perceive and understand us. *Current Directions in Psychological Science*, 25(5), 339–344.
- Huber, L., & Lonardo, L. (2023). Canine perspective-taking. *Animal Cognition*, 26(1), 275–298.
- Huber, L., & Lonardo, L. (2023). Canine perspective-taking. *Animal Cognition*, 26(1), 275–298.
- Kaminski J, Tomasello M, Call J, Bräuer J (2009) Domestic dogs are sensitive to a human's perspective. *Behaviour* 146(7):979–998. <https://doi.org/10.1163/156853908X395530>
- Kaminski, J., & Marshall-Pescini, S. (2014). *The social dog: behavior and cognition*. Elsevier.
- Kano F, Krupenye C, Hirata S, Call J (2017) Eye tracking uncovered great apes' ability to anticipate that other individuals will act according to false beliefs. *Commun Integr Biol* 10(2): e1299836. <https://doi.org/10.1080/19420889.2017.1299836>
- Kano F, Krupenye C, Hirata S, Tomonaga M, Call J (2019) Great apes use self-experience to anticipate an agent's action in a false-belief test. *Proc Natl Acad Sci USA* 116(42):20904–20909. <https://doi.org/10.1073/pnas.1910095116>
- Karg K, Schmelz M, Call J, Tomasello M (2016) Difering views: Can chimpanzees do Level 2 perspective-taking? *Anim Cogn* 19(3):555–564. <https://doi.org/10.1007/s10071-016-0956-7>
- Karl S, Boch M, Zamansky A, van der Linden D, Wagner IC, Völter CJ, Lamm C, Huber L (2020) Exploring the dog–human relationship by combining fMRI, eye-tracking and behavioural measures. *Sci Reports*. <https://doi.org/10.1038/s41598-020-79247-5>

- Kirsch, I., Lynn, S. J., Vigorito, M., & Miller, R. R. (2004, April). The Role of Cognition in Classical and Operant Conditioning. *Journal of Clinical Psychology*. <https://doi.org/10.1002/jclp.10251>
- Kovács, A. M., Tegf as, E., & Endress, A. D. (2010). The social sense: Susceptibility to others' beliefs in human infants and adults. *Science*, 330(6012), 1830–1834
- Krupenye C, Kano F, Hirata S, Call J, Tomasello M (2016) Great apes anticipate that other individuals will act according to false beliefs. *Science* 354(6308):110–114. <https://doi.org/10.1126/science.aaf8110>
- Lazzaroni, M., Marshall-Pescini, S., Manzenreiter, H., Gosch, S., Přibilová, L., Darc, L., ... & Range, F. (2020). Why do dogs look back at the human in an impossible task? Looking back behaviour may be over-interpreted. *Animal Cognition*, 23(3), 427–441.
- Li, X., Wang, K., Wang, F., Tao, Q., Xie, Y., & Cheng, Q. (2013). Aging of theory of mind: The influence of educational level and cognitive processing. *International Journal of Psychology*, 48(4), 715–727. <https://doi.org/10.1080/00207594.2012.673724>
- Lindsay, S. R., (2001). "Handbook of applied dog behavior and training," in *Etiology and Assessment of Behavior Problems*, Vol. 2, ed. S. R. Lindsay (Ames: Iowa State University Press), 304. doi: 10.1002/9780470376997
- Lonardo, L., Völter, C. J., Lamm, C., & Huber, L. (2021). Dogs follow human misleading suggestions more often when the informant has a false belief. *Proceedings of the Royal Society B*, 288(1955), 20210906.
- Marshall-Pescini, S., Colombo, E., Passalacqua, C., Merola, I., & Prato-Previde, E. (2013). Gaze alternation in dogs and toddlers in an unsolvable task: evidence of an audience effect. *Animal cognition*, 16, 933–943.
- McNulty, K. P. (2010). Apes and Tricksters: The Evolution and Diversification of Humans' Closest Relatives. *Evolution: Education and Outreach*, 3(3), 322–332. <https://doi.org/10.1007/s12052-010-0251-z>
- Meder, A. (2015). Great ape social systems. In *Handbook of Paleoanthropology, Second Edition* (pp. 1593–1629). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-39979-4_46
- Melis A, Call J, Tomasello M (2006) Chimpanzees conceal visual and auditory information from others. *J Comp Psychol* 120:154–162
- Miklósi, Á., Kubinyi, E., Topál, J., Gácsi, M., Virányi, Z., & Csányi, V. (2003). A simple reason for a big difference: Wolves do not look back at humans, but dogs do. *Current Biology*, 13(9), 763–766. [https://doi.org/10.1016/S0960-9822\(03\)00263-X](https://doi.org/10.1016/S0960-9822(03)00263-X)
- Povinelli, D. J., Nelson, K. E., & Boysen, S. T. (1990). Inferences about guessing and knowing by chimpanzees (*Pan troglodytes*). *Journal of Comparative Psychology* (Washington, D.C.: 1983), 104(3), 203–210. <https://doi.org/10.1037/0735-7036.104.3.203>
- Rowley, S. (2020). False Beliefs in Dogs.
- Rubio-Fernández, P., & Geurts, B. (2013). How to pass the false-belieftask before your fourth birthday. *Psychological Science*, 24(1), 27–33. <https://doi.org/10.1177/0956797612447819>
- Shamay-Tsoory, S. G., Harari, H., Aharon-Peretz, J., & Levkovitz, Y. (2010). The role of the orbitofrontal cortex in affective theory of mind deficits in criminal offenders with psychopathic tendencies. *Cortex: A Journal Devoted to the Study of the Nervous System and Behavior*, 46(5), 668–677. <https://doi.org/10.1016/j.cortex.2009.04.008>
- Shamay-Tsoory, S. G., Tomer, R., Berger, B. D., Goldsher, D., & Aharon-Peretz, J. (2005). Impaired "affective theory of mind" is associated with right ventromedial prefrontal damage. *Cognitive and Behavioral Neurology*, 18(1), 55–67. <https://doi.org/10.1097/01.wnn.0000152228.90129.99>
- Shaw, R. C. & Clayton, N. S. Careful cachers and prying pilferers: Eurasian jays (*Garrulus glandarius*) limit auditory information available to competitors. *Proc. R. Soc. Lond. B Biol. Sci.* 280, 20122238 (2013).

- Shaw, R. C. & Clayton, N. S. Pilfering Eurasian jays use visual and acoustic information to locate caches. *Anim. Cogn.* 17, 1281–1288 (2014).
- Smith, A. N., & Woodfill, D. M. (2023). *Monkey See, Monkey Do: Assessing Learning Abilities of Three Primate Species Using Communication Buttons*. SSRN. <https://doi.org/10.2139/ssrn.4613154>
- Topál J, Gácsi M (2012) Lessons we should learn from our unique relationship with dogs: an ethological approach. In: Birke L, Hockenhull J (eds) *Crossing boundaries*. Brill Academic Press, Leiden, pp 163–187
- Udell, M. A. (2015). When dogs look back: inhibition of independent problem-solving behaviour in domestic dogs (*Canis lupus familiaris*) compared with wolves (*Canis lupus*). *Biology letters*, 11(9), 20150489.
- Wellman, H. M., & Liu, D. (2004). Scaling of theory-of-mind tasks. *Child development*, 75(2), 523-541.
- Wellman, H. M., Cross, D., & Watson, J. (2001). Meta-analysis of theory of-mind development: The truth about false belief. *Child Development*, 72(3), 655–684
- Wellman, H. M., Fang, F., & Peterson, C. C. (2011). Sequential progressions in a theory-of-mind scale: Longitudinal perspectives. *Child development*, 82(3), 780-792.
- Wimmer H, Perner J. 1983 Beliefs about beliefs: representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition* 13, 103–128. (doi:10.1016/0010-0277(83)90004-5)
- Wimmer, H., & Perner, J. (1983). Beliefs about beliefs: Representation and constraining function of wrong beliefs in young children's understanding of deception. *Cognition*, 13(1), 103–128. [https://doi.org/10.1016/0010-0277\(83\)90004-5](https://doi.org/10.1016/0010-0277(83)90004-5)
- Wynne, C. D. (2016). What is special about dog cognition? *Current Directions in Psychological Science*, 25(5), 345-350

Appendix I, Dog breed/age/sex test population

Table I.1: List of the dogs that participated in the false belief test based on alphabetical order of the breed. Age is in years with 0,5 being 6 months and sex is male (m) or female (f). Information of five dogs was lost (-). The green highlighted dog numbers on the left are the 31 dogs on which data analysis has been performed.

Dog	Breed	Age [years]	Sex [m/f]
1	Akita	0,5	f
2	American Pitbull/Rednose	7	m
3	Appenzeller sennen	2	F
4	Australian Shepherd	1	m
5	Australian Shepherd	6	m
6	Beauceron	4	f
7	Boomer	4	f
8	Border Collie	5	f
9	Border Collie	3	m
10	Border Collie	1	m
11	Bouvier mix	6	f
12	Boxer	1	f
13	English Springer Spaniël	2	f
14	French Bulldog	8	f
15	Frisian Stabyhoun	4	f
16	Frisian Stabyhoun	3	m
17	German shepherd	2	m
18	German shepherd	10	m
19	German shepherd	1	m
20	German Wirehaired Pointer	2	f
21	Golden Retriever	4	m
22	Golden retriever	4	f
23	Jack Russel Terrier	7	f
24	Kuvasz	2	f
25	Labradoodle	2	f
26	Labradoodle	0,5	m
27	Labrador	3	f
28	Labrador mix	0	m
29	Mix Poodle-mix & Poodle-mix (Labradoodle)	5	f
30	Mix 3/4 Border Collie & 1/4 American Stafford	2	f
31	Mix Bernese Mountain dog & Labrador	6	f
32	Mix Border Collie & Famer's Fox & Scottish Collie	7	f
33	Mix Border Collie & Frisian Stabyhoun	3	f
34	Mix Frisian Stabyhoun & Heidewachtel (German Spaniel)	4	f
35	Mix Golden Retriever & Labrador & Shaperd & Frisian Stabyhoun	2	f
36	Mix Husky & pomeranian	6	f

37	Mix Kelpie & Peruvian hairless dog	4	m
38	Mix Kooiker & Cavalier King Charles Spaniel	2	m
39	Mix Labrador & Sheperd	3	m
40	Mix Maltese & Shih Tzu	3	m
41	Mix Pitbull & American Stafford	0,5	f
42	Mix Saint Bernard & Bernese Mountain dog	3	m
43	Mix Spanish Tibetan	6	f
44	Mix unknown	0,5	f
45	Mix unknown	10	f
46	Rhodesian Ridgeback	1	f
47	Rottweiler	4	f
48	Rough-haired Jack Rusell Terrier	5	m
49	Schipperke	12	m
50	Shih Tzu	1	f
51	Spanish Greyhound	6	f
52	Standart Rough-haired Dachshund	1	m
53	Weimaraner	3	f
54	White Sheperd	3	m
55	-	-	-
56	-	-	-
57	-	-	-
58	-	-	-
59	-	-	-

Appendix II, side preference

Table II.1: the two dogs that showed significant side preference and thus excluded in the data analysis. Dog number matches that of table I.1, left and right shows the amount of time the dog choice for that direction and the p-value of the performed binomial test. All other dogs were $p > 0.05$.

Dog	Left	Right	Total	P-value
4	12	3	15	0.018
20	1	8	9	0.020

Appendix III, average time per phase

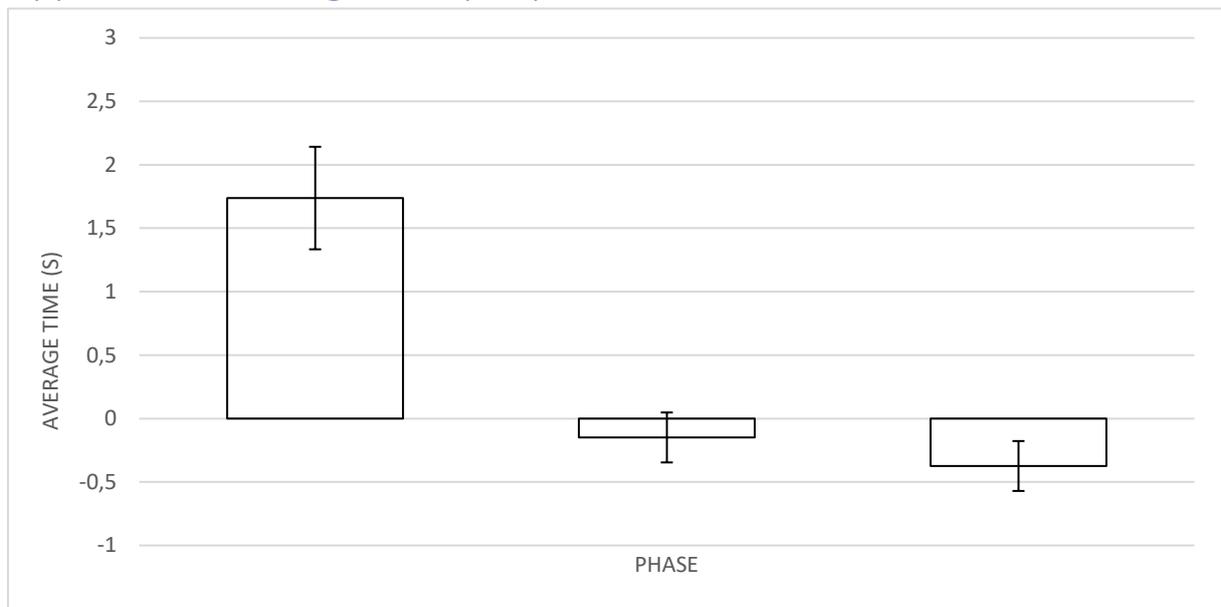


Figure III.1: Dogs were tested for understanding (false) beliefs in an experimenter and had to anticipate where he/she would go to retrieve an object of interest. Presented is the average window time per phase of the false belief task. Y-axis has the average amount of window time spend on that phase. Window time start counting when the experimenter is at the designated spot of that phase (like at a cup). Negative values thus mean the dog arrived between the experimenter starting to walk and arriving at the designated spot. X-axis shows which phase it is. Left to right, is the walking phase (n=110), then the baiting phase (n=196), and lastly is the testing phase (n=124). The black lines on the bars indicate the standard error.