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Do Dogs Understand Human Perspective? An Analysis of Construct Validity in the Guesser-Knower Paradigm

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Declaration of Authenticity

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Vienna, 21.03.2026 Nina Dygryn

Zusammenfassung

Die Frage, ob Tiere anderen Individuen Wissen zuschreiben können oder ob diese Fähigkeit ausschließlich dem Menschen vorbehalten ist, bleibt eine zentrale, aber kontroverse Frage in der Forschung der Theory of Mind. Frühere Studien nutzten das Guesser-Knower-Paradigma, um die visuelle Perspektivenübernahme bei Hunden zu untersuchen. Dennoch bestehen weiterhin Bedenken hinsichtlich der Konstruktvalidität dieser Methode und der Existenz alternativer Erklärungen für frühere Ergebnisse, wie beispielsweise Verhaltenslesen oder kontextabhängiges Lernen. Ziel der vorliegenden Studie war es daher nicht nur vorhergehende Befunde zu replizieren, sondern auch die Konstruktvalidität des Guesser-Knower-Paradigmas kritisch zu evaluieren.

Insgesamt nahmen 93 Hunde an drei Sitzungen teil. Im Rahmen des Experiments wurden die Hunde mit zwei Versuchsleitern konfrontiert, von welchen einer den Ort des versteckten Futters kannte (Knower), und der andere nicht (Guesser). Die Hunde konnten beobachten, welche Person den Vorgang des Futterversteckens visuell verfolgen konnte, allerdings nicht den Versteckort des Futters selbst. Der Test umfasste vier Bedingungen, in welchen der Informationszugang des Ratenden (Guesser) manipuliert wurde: „Guesser Present“ (Kontrollbedingung), „Guesser Absent“, „Guesser Back Turned“ und „Guesser Looking Away“.

Die zusammengefassten Ergebnisse aller Sitzungen und Bedingungen, zeigen eine signifikante Präferenz für den Knower, die informierte Person. Auf Bedingungsebene wählten die Hunde den Knower in den Bedingungen „Present“, „Absent“ und „Back Turned“ häufiger als zufällig zu erwarten, nicht jedoch in der „Looking Away“ Bedingung. Auf individueller Ebene wurden keine konsistenten Korrelationen zwischen den Bedingungen gefunden, und die Ergebnisse zeigen eine große interindividuelle Variabilität, welche über die Bedingungen hinweg nicht stabil ist.

Daher stützen die Ergebnisse die Annahme nur teilweise, dass das Guesser-Knower-Paradigma in seiner derzeitigen Anwendung bei Hunden eine geeignete Methode für die valide Messung visueller Perspektivenübernahme ist. Während Hunde zwischen Bedingungen mit klaren Wissens-, aber auch Verhaltensunterschieden zu differenzieren scheinen, lassen das Fehlen einer signifikanten Präferenz für den Knower in der „Guesser Looking Away“ Bedingung, sowie die signifikante Knower-Präferenz in der Kontrollbedingung darauf deuten,

dass sie die Aufgabe möglicherweise hauptsächlich durch Verhaltensbeobachtung lösen. Die mangelnde Stabilität und die fehlenden Korrelationen der individuellen Unterschiede zwischen den Bedingungen sind kritische Punkte, die berücksichtigt werden müssen. Insgesamt legen die Ergebnisse nahe, dass die beobachteten Leistungen in diesem Experiment eher kontextabhängige Strategien als eine stabile Perspektivenübernahme wiederspiegeln. Dies stellt die Konstruktvalidität der Aufgabe in Frage und unterstreicht die Notwendigkeit, Tests zur Perspektivenübernahme mit stärkeren psychometrischen Eigenschaften und strengeren Kontrollen für Verhaltensbeobachtung zu entwickeln.

Abstract

Understanding whether animals are capable of attributing knowledge to others or whether this ability is uniquely human, remains a central but controversial question in research on Theory of Mind. Earlier studies used the Guesser-Knower paradigm to examine visual perspective taking in dogs. Nonetheless, concerns regarding the construct validity of this method and the presence of alternative explanations for previous findings, such as behaviour reading or context dependent learning, remain. Therefore, the goal of the present study was not only to replicate earlier findings but also to critically evaluate the construct validity of the Guesser-Knower paradigm as a method to measure visual perspective taking in dogs.

Overall, 93 dogs participated in three sessions. Dogs were presented with two experimenters, one of whom knew the location of hidden food (Knower), and the other did not (Guesser). The dogs could observe that one experimenter had visual access to the food hiding process while the other did not, but they could not see themselves where the food was hidden. The test consisted of four conditions in which the Guesser's visual access was manipulated: "Guesser Present" (control condition), "Guesser Absent", "Guesser Back Turned" and "Guesser Looking Away".

Pooling together the results across all sessions and conditions, the results show a significant preference for the Knower, the informed person. At the group level, dogs chose the Knower significantly above chance in the "Present", "Absent" and "Back Turned" conditions, but not in the "Looking Away" condition. At the individual level, no consistent correlations were found between conditions, and results show a large inter-individual variability, that is not stable across conditions.

The results thus only partially support the claim that the Guesser-Knower paradigm as currently implemented with dogs is an appropriate test for the valid measurement of visual perspective-taking in dogs. While dogs seem to differentiate between conditions with clear knowledge (but also behavioural) differences, the absence of a significant preference for the Knower in the "Guesser Looking Away" condition and the significance preference for the Knower in the control condition suggests that they might pass the task relying mainly on behaviour-reading. The lack of consistency in individual differences across conditions, and the lack of correlations between individual performances across conditions are critical points that must be considered. Overall, results suggest that the observed performance in this task may reflect context-dependent strategies rather than stable perspective-taking, which calls into

question the construct validity of the task and highlights the need for developing tests of perspective-taking with stronger psychometric properties and more stringent controls for behaviour-reading.

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1 Introduction

1.1 Background and Relevance

Even in the absence of explicit verbal communication, humans are often able to infer what others think, know, or intend [1]. For example, when someone is watching another individual putting an object away, we assume that the observer knows where the object is located. Similarly, when a person avoids eye contact during a conversation, this may be interpreted as uncertainty or a lack of interest. The ability to adopt another person's perspective constitutes a central component of what is referred to in psychology as "Theory of Mind" (ToM) [1], a pillar of communication and cooperation [2]. There are several reasons why studying ToM is of central interest. Attributing mental states to others plays a critical role in social interaction, as it enables not only observation, but also the interpretation, prediction, and even manipulation of others´ behaviour [1,3–5].

The concept of ToM was initially discussed in philosophy (e.g., [6]) and was later elaborated within developmental psychology [2,7]. While research on human ToM has progressed steadily, and mainly focuses on developmental stages, i.e., the "when" of this ability [2], interest has grown in whether this ability is uniquely human or whether other species may also be capable of recognizing mental states [8]. Although previous studies in primates, corvids, and dogs provide initial evidence [9–11], findings remain inconsistent and often contradictory [8]. More precisely, for every positive result, there are numerous corresponding negative findings, sometimes even when the same paradigm is applied [12].

Investigating ToM in animals is particularly challenging because it must be tested nonverbally, making it difficult to determine whether they truly understand the mental states of others or are merely responding to learned behavioural cues [13,14]. For example, an animal might learn that a person who approaches it with open and unrestricted eyes is more likely to react to its behaviour, than a person who has their eyes shut [15]. However, it is important to note that this does not necessarily require attribution of mental state (e.g., being able to "see"), but could result from observing regularities in the behaviour of others. Although several nonverbal paradigms have been developed in recent years, such as the Guesser-Knower task, it remains uncertain whether they measure mental state attribution or merely detect learned

behaviour [8,16,17]. This makes the field of research a methodologically challenging, controversial and widely discussed area of cognitive psychology.

Dogs represent a particularly interesting model system in this context. They have coexisted with humans for thousands of years, which resulted in socio-cognitive skills functionally similar to those of human children [18,19] and a sensitivity to social cues such as gestures, gaze direction, and attention [15]. Previous studies show that dogs may exhibit certain aspects of ToM [13,14,20]. The Guesser-Knower task is an established experimental paradigm for assessing visual perspective-taking in dogs . The present study addresses the question of whether dogs can distinguish between knowledgeable and ignorant humans by attempting to replicate Catala et al.'s [17] findings, using parts of the methodology used in her study. Furthermore, the present study aims to investigate if the Guesser-Knower paradigm is an adequate method to demonstrate perspective-taking in dogs, thus evaluating the methodological problems, more precisely construct validity, which has been debated in the past.

1.2 Theory of Mind in Animals

As originally defined by Premack and Woodruff [1], Theory of Mind refers to the ability of an individual to "impute mental states to himself and others" ([1], p.515). This definition forms the conceptual foundation for following empirical research in whether nonhuman animals are capable of attributing mental states. ToM includes a variety of mental states, such as intention, belief, doubt, deception, desire, guessing, and knowledge [1]. Studies in developmental psychology describe a so-called "developmental model" [2,7]. This concept describes ToM as a capacity that gradually and continuously develops over time and is not an all-or-nothing ability. Early competencies, such as sensitivity to others' wishes and perceptions, develop earlier than more complex abilities like the understanding of false beliefs [2]. Modern studies further emphasize that mental state understanding consists of multiple representational levels and may manifest in partially differentiated forms [7,14]. This perspective implies that animals do not need to possess a fully human-like ToM to demonstrate subcomponents of mental state attribution [4]. Although previous studies (e.g., [17]) provide evidence consistent with visual perspective-taking in dogs, it remains unclear whether such performance reflects a fully-fledged

ToM or more limited subcomponents. Consequently, the question of whether ToM is uniquely human or varies in graded forms across species remains open.

As mentioned before, the question of whether nonhuman species can attribute mental states to others was first investigated by Premack and Woodruff [1]. In an empirical study, an adult chimpanzee was shown videos of a human struggling with various problems: reaching inaccessible food, being locked in a cage, freezing from a broken heater, or being unable to play music due to an unplugged phonograph. After viewing the tapes, the chimpanzee was presented with pictures showing potential solutions (e.g., a stick, a key, a lit wick). The aim of the study was to assess if chimpanzees could recognize another's problem and identify the appropriate solution. The chimpanzee chose the correct picture in 21 out of 24 trials. Premack and Woodruff [1] proposed three possible interpretations: associationism, empathy, and ToM, favouring the latter while acknowledging the provisional nature of their conclusion. Although they [1] presented their findings cautiously, their study sparked intense debate. Heyes [8] criticized both their methodology and interpretation and argued that the results could be explained by associative learning rather than genuine mental state attribution. She further questioned whether the experimental design allowed a clear distinction between mind reading and behaviour reading. Because the correct choice also matched the actor´s goal behaviour, it is unclear whether the chimpanzee truly understood the human´s intention or simply associated specific behaviours with certain outcomes [8].

Building on these early findings, Povinelli et al. [10] introduced a more controlled experimental paradigm to investigate knowledge attribution in nonhuman primates. In this so-called Guesser-Knower design, four chimpanzees were presented with two human experimenters, only one of whom had witnessed a food-baiting process. The animals were then required to choose between the informed and uniformed individuals' pointing gestures to find the hidden food. While the authors initially interpreted the positive findings of their study as evidence for visual perspective-taking in chimpanzees, the results sparked further debate [10]. Heyes [8] criticized this paradigm, arguing that the observed performance could still be explained by behavioural cue learning rather than indicating ToM. She emphasized that even in controlled designs, it remains difficult to exclude simpler associative explanations. Later, further publications followed in which Povinelli [21] himself questioned and criticised the methodology and results of his earlier study [10].

Call and Tomasello [4] later conducted a comprehensive reassessment of the evidence and concluded that chimpanzees likely possess a "perception-goal psychology" ([4], p.187). This would mean that they may recognize what others see and want, but not as refined as the human mind. While this interpretation offers the possibility of a more differentiated view of ToM in nonhuman animals, criticism of the methodology needs to be considered as the question of whether the animals behaviour reflects ToM or simpler processes remains a key issue [4,8]. Heyes [8] explicitly calls for more precise methods to differentiate true mindreading from alternative explanatory models.

1.3 Why Dogs? Cognitive and Evolutionary Considerations

While primates have long been at the centre of discussions on Theory of Mind in animals, dogs (*Canis familiaris*) have increasingly gained attention as promising experimental subjects. Their evolutionary history and domestication are thought to have contributed to dogs' enhanced sensitivity to human communicative cues [18,22] which makes them particularly well-suited for the study of social cognition [16,17]. Domesticated dogs are descended from wolves. Thousands of years of selection and domestication have led to a unique willingness to cooperate with humans, which greatly simplifies research on dogs. Additionally, because of their evolutionary history as social canids, dogs have also undergone selection processes that enhanced their sensitivity to human communicative cues [18,22]. Consequently, it is important to consider that dogs' socio-cognitive performance may reflect both domestication-related adaptions to a specific socio-ecological niche or learning through human interaction [23].

Previous studies show that not only can domesticated dogs follow pointing [24,25], but they also perform particularly well in gaze following [26] and in recognizing human attentional states [15]. While gaze following refers to the ability to recognize and follow the direction of another's gaze [4], attentional state refers to the cognitive condition of focusing one's attention on a specific stimulus. Importantly, dogs have even performed more successful than great apes in some of these tasks, further supporting their suitability for research on ToM in animals [4,25,27].

Despite their advantages, dog-based studies are not without limitations. As already mentioned in the previous chapter, it is uncertain whether certain behaviours in dogs truly reflect ToM. The

debate between behaviour reading and mind reading, already initiated by Heyes [8], can also be applied to research with dogs as test subjects. Moreover, it remains difficult to determine whether dogs can infer human mental states or whether they simply predict behaviour based on routines and prior experience [3].

1.4 The Guesser-Knower Task in Animal Cognition Research

To investigate whether animals can attribute knowledge to others, researchers rely on specific experimental paradigms. The Guesser-Knower paradigm has become one of the most widely used nonverbal approaches [28]. In the original Guesser-Knower task [10], food is hidden while one experimenter (the Knower) observes the baiting process and another individual (the Guesser) does not. In some conditions a third experimenter (the Hider) performs the baiting, while only the Knower watches the process. The animal subject does not witness the hiding itself but can observe who had visual access to the event and receives two simultaneous suggestions from the Guesser and Knower. The subject must then decide which experimenter to approach in order to obtain the reward. The central question is whether the subject can distinguish between knowledgeable and ignorant individuals based on their visual access [10,16,17].

As already mentioned, the paradigm was first systematically implemented by Povinelli and Eddy [10,21] in chimpanzees and young human children. In these studies, chimpanzees preferentially approached the experimenter who had visual access to the hiding event. While the authors initially reported that the chimpanzees did not take long to gain the understanding to react to the Knower [10], they corrected themselves in later studies, adding that the animals needed weeks of repetition [21]. The number of repeated trials necessary before observing a Knower-preference, supports the criticism that the animals' behaviour could be explained by learning and perceptual cues, rather than genuine mental state attribution [8]. These debates shaped subsequent refinements of the paradigm.

Early adaptions for dogs yielded mixed results. Cooper et al. [3] used a classic Guesser-Knower design and found that 14 out of 15 dogs chose the Knower in the first trial. However, performance declined to chance level across subsequent trials, raising questions about the stability and interpretation of the effect.

Maginnity and Grace [16] extended the paradigm by introducing multiple test conditions. Their study included conditions manipulating visual access (e.g., Knower being in the room vs. Guesser being absent; Knower covering their cheeks vs. Guesser covering their eyes; Knower watching intently vs. Guesser starring at the ceiling) while controlling for overt behavioural differences between informants. Despite the absence of prior training, dogs consistently preferred the Knower across trials and showed no learning effect, which the authors interpreted as evidence for stable sensitivity to visual access rather than associative learning [16].

In addition to standard knowledge-asymmetry conditions (e.g., the Guesser leaving the room during the baiting process) Catala et al. [17] further refined the design by introducing a geometrically controlled "Looking Away" condition. In this new condition, both individuals looked in the same direction but, because of their position (one to the left and one to the right of the experimenter performing the baiting), from the dog's perspective the Guesser seemed to look away from the scene, while the Knower looked towards it. Dogs significantly preferred the Knower in both cases. Importantly, in the control condition where both individuals witnessed the baiting, no preference emerged. This pattern was interpreted as support for visual perspective-taking rather than simple behaviour reading [17].

Despite these refinements, methodological concerns remain. Numerous studies suggest that experimental outcomes in canine cognition research depend heavily on contextual factors such as the familiarity of the setting, the relationship between the dog and the experimenter, and prior experience with humans [14,29]. Udell and colleagues [29] demonstrated that dogs' performance in perspective-taking tasks can vary substantially depending on whether they are tested in familiar versus unfamiliar environments and with known versus unknown humans. These findings suggest that apparent higher-level cognitive abilities may be mimicked by learning and context effects and the familiarity of the situation.

Furthermore, as Horowitz [14] emphasizes, interpreting animal behaviour in terms of mental state attribution carries the risk of over-attribution, particularly when alternative explanations based on behaviour reading remain plausible. According to the author, subtle differences in posture, attentional orientation, or previous reinforcement history may guide dogs' responses without requiring them to represent others' knowledge states. Such concerns further highlight the difficulty of disentangling genuine perspective-taking from behaviour-reading strategies.

These challenges provide a central justification for the present study. By introducing multiple conditions that systematically vary informational access (Guesser Present, Absent, Back Turned, and Looking Away), the design of the present study aims to differentiate between responses driven by visual access to information and those guided by simpler associative or contextual cues. In contrast to paradigms using physical barriers (e.g., [29]), the present study focused on manipulating visual perspective through bodily orientation and presence, thereby reducing the potential confounds of barrier salience and previous experience with barriers. By adding the Back Turned condition, the study aims to conceptually replicate previous findings that showed dogs' sensitivity to human facing or turning their back to them [15,29,30]. The inclusion of several conditions measuring the same underlying cognitive ability was intended to allow for an evaluation of the construct validity of the Guesser-Knower paradigm. Construct validity refers to the extent to which a task accurately measures the theoretical construct it is intended to assess [31,32]. In the present context, this concerns whether performance in the Guesser-Knower task genuinely reflects visual perspective-taking, rather than alternative explanations. If dogs truly attribute knowledge based on visual access, their performance should systematically follow the degree of informational asymmetry across conditions rather than fluctuate randomly or depend solely on familiarity with the situation.

1.4.1 Hypotheses

Based on previous Guesser-Knower research (e.g., [16,17]), we hypothesize that dogs are able to attribute knowledge to other individuals. We predict that dogs will show a significant preference for the informed person across experimental conditions. We further hypothesize that dogs are sensitive to visual access. Therefore, we predict performance to vary as a function of the clarity of visual access. Specifically, we expect the strongest effects in the Guesser Absent and Guesser Back Turned conditions, where the difference in knowledge between the two experimenters is more salient. A weaker effect is anticipated in the Guesser Looking Away condition, and no significate difference is expected in the control condition Guesser Present, where both experimenters are present in the room and looking at the baiting event.

1.4.2 Construct Validity

The construct validity of the Guesser-Knower paradigm depends on whether performance systematically reflects the intended ability (to differentiate between knowledgeable and ignorant others) rather than the ability to differentiate between superficial behavioural cues. High construct validity would be supported if dogs differentiate between the informants in all test conditions in which informants' knowledge access differs, irrespective of superficial differences in the experimenters' behaviour and shows stable results across conditions. Subjects not differentiating between experimenters in the control condition (in which knowledge access is identical between the experimenters) would further suggest that the method truly measures mental state attribution in dogs. On the contrary, if the dogs do not show a preference for the Knower in conditions with an existing knowledge asymmetry, performance in the control condition shows a differentiation between the experimenters, or performances vary unsystematically across conditions and individually, construct validity would be controversial.

2 Materials and Methods

2.1 Subjects

The study was conducted with pet dogs (Canis familiaris), recruited through the Clever Dog Lab at the University of Veterinary Medicine, Vienna. The animals participated in three sessions, each approx. three months apart with an average inter-session interval of 89.03 days between S1 and S2 (SD: 11.35 days) and 139.59 days between S2 and S3 (SD: 22.77 days).

The target sample size of 85 dogs in each session was determined by an a priori power analysis. This calculation was based on a significance level of $\alpha = 0,05$, a power of 80 %, and a minimum effect size of interest of $r = 0.3$, to ensure sufficient power for calculating test-retest reliability. A total of 108 dogs were initially tested in Session 1. Of these, 15 dogs were excluded because they did not pass the pretraining phase (n = 11) or failed the test phase (n = 4). This resulted in 93 dogs continuing for further testing. In session 2, all 93 eligible dogs were invited to participate. Five dogs did not continue in the second session either due to health-related or behavioural changes in the dogs (n = 2), personal or health-related reasons of the owners (n = 2), or because owners did not respond to follow-up contact (n = 1). One additional dog was temporarily unavailable in Session 2 but returned for Session 3. No dogs were excluded in Session 2 due to pretraining or test failure. In Session 3, three dogs were excluded because they no longer passed the pretraining phase. One additional dog was lost due to owner-related health reasons. As a result, 93 dogs participated in Session 1, 87 dogs in Session 2, and 84 dogs in Session 3. The final sample consisted of 52 female and 41 male dogs of various breeds. The mean age was 69.35 months (5.78 years).

The study focused on pet dogs, i.e., animals from a domestic environment familiar with human gaze and pointing behaviour. To obtain the broadest and most realistic sample possible, with good generalizability, the group included different breeds, ages, and sexes. Participation was conditional on the dogs' acceptance of food as a reward and successful completion of the pre-training process.

2.2 Study Design

The experimental setup was based on the Guesser-Knower paradigm described by Catala et al. [17]. A within-subject design with four experimental conditions was chosen, in which each dog

participated in all conditions. One advantage of this design is that individual differences between the dogs can be controlled, thereby reducing potential confounding variables [17].

To assess whether the dogs' decisions were stable over time and that the results had the highest possible validity (i.e., they were not affected by random variation in task-irrelevant features associated to any specific session), each dog was tested at three different time points. A three-month interval was scheduled between sessions to avoid learning effects. Each session consisted of between 14 and 32 pretraining trials followed by 24 test trials, with six trials per condition. Each dog was scheduled to complete 72 test trials. However, trials in which dogs did not make a valid choice, were excluded from analysis, resulting in a reduced number of valid trials for some individuals. After excluding invalid or no-choice trials, this resulted in 2,224 valid trials in Session 1, 2,087 valid trials in Session 2, and 2,015 valid trials in Session 3.

Three conditions from the original study by Catala et al. [17] ("Guesser Present", "Guesser Absent" and "Guesser Looking Away") were retained, and an additional condition ("Guesser Back Turned") was added. The four conditions differed in terms of the guesser's visual access to the baiting scene. A detailed description of these conditions is provided in Chapter 4.4.

To avoid systematic patterns, bias, or order effects, the order of presentation of the conditions, the experimenter role assignments (Knower, Guesser, Hider), the position of the cups, and the (left-right) side of placement of the two informants next to the Hider were pseudorandomized. Specific rules were applied – for example, no more than two trials with identical parameters (e.g., condition or baited cup) were allowed to occur consecutively. Each dog was assigned the same counterbalancing table throughout all three sessions.

The study was reviewed and approved by the Ethics and Animal Welfare Committee of the University of Veterinary Medicine, Vienna (approval number: ETK-097/09/2024). The approval was granted for 36 months. If any signs of stress or distress had been observed in the dogs, the experiment would have been terminated immediately. Participation was voluntary for dog owners after prior registration via email. All owners signed consent forms in advance and were present throughout the entire testing procedure.

2.3 Experimental Procedure

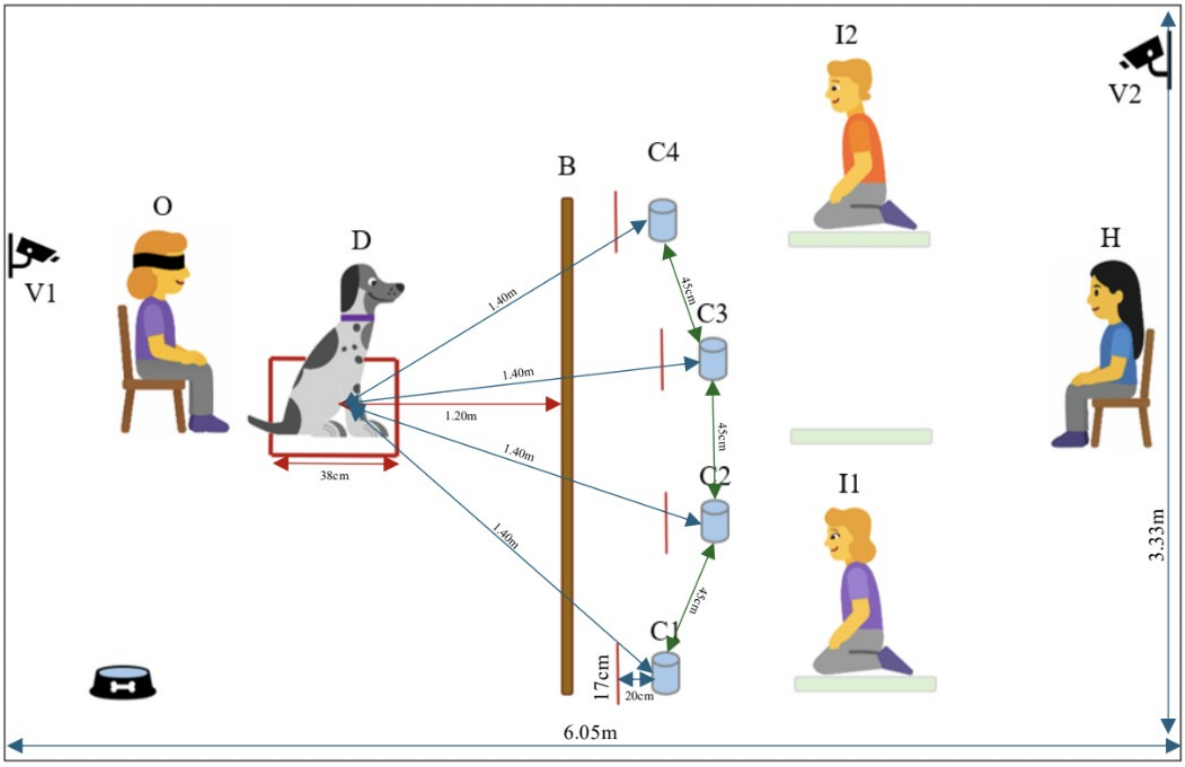


Figure 1: Schematic overview of the experimental setup. The blindfolded owner (O) was seated behind the tested dog (D), facing the barrier (B) and the two informants (I1, I2), who alternated between the roles of Guesser and Knower. Four cups (C1-C4) were positioned equidistantly from the dog's starting position and numbered from left to right from the experimenters' perspective. The Hider (H) faced the dog, gave the acoustic signal for the informants, and performed the baiting in the "Looking Away" condition. The session was recorded by two wall-mounted cameras (V1, V2) and one ceiling mounted camera (V3, not shown). Illustration created by Sarah Verrart.

2.3.1 Preparation of the testing room

Before each test, the testing room – the Green Room of the Clever Dog Lab Vienna – was prepared by an experimenter. A schematic overview of the spatial arrangement of the experiment setup is presented in Fig. 1. The room was equipped with three video cameras (V1-V3), each recording a different angle of the procedure. On the wall opposite the entry door, a chair was provided for the Hider (H). In front of that chair, three seating cushions marked the positions for the Knower (I1/I2), the Guesser (I1/I2), and, if applicable, the Hider. Four opaque cups (C1-C4), filled with paper towels to minimize noise and sealed with lids, were positioned in front of the cushions. A movable barrier (B), later used to shield the baiting process, was

placed in front of the cups and secured with two wooden fixing blocks. Behind the barrier, another chair was placed for the dog owner (O), with tape markings in front indicating the dog's (D) starting position. All object positions were measured and marked with tape in advance, ensuring exact replication in subsequent sessions.

Additionally, a bowl of water was placed in the corner of the room, and a blindfold was laid on the chair reserved for the owner. Commercially available sausages served as rewards and were cut into smaller or larger pieces, depending on the size of the dog. After cutting, the food was placed in a treat bag containing a plastic liner. In case of intolerances or special food preferences, cheese or owner-provided treats were used alternatively. Before the dogs' arrival, it was ensured that the window was closed and, on hot days, the room temperature was regulated by air conditioning. Cups were rubbed with a piece of the reward used during the trials, to ensure they all equally smelled of food.

2.3.2 Familiarization phase

After arriving at the Clever Dog Lab, the owners were asked to lead their dogs into the testing room. After that the dog owners were introduced to the procedure and the study by the Hider. Before the experiment began, video recording was started with the software OBS, using a computer outside of the room. This was followed by a familiarization phase in which the dogs could explore the room. A movable barrier positioned between the dog and the experimenters was part of the experimental setup and was used to control the dog's visual access during the trials. To familiarise the dog with the barrier, the dog was fed by the Hider while he and the experimenter positioned on the left side of the Hider gradually lifted the barrier. Once it was ensured that the dogs showed no signs of fear toward the moving barrier and had fully explored the environment, the next phase was initiated.

2.3.3 Pre-Training Phase

Before the actual test phase began, each dog completed a standardized pre-training phase aimed at introducing dogs to the logic of finding hidden food in one of the cups and at only including dogs in the subsequent test that could spontaneously follow an experimenter's pointing gesture to locate the food, when they no longer had visual access to the baiting. This

phase consisted of five stages of increasing complexity. From this stage onward, the owners were asked to wear a blindfold to avoid influencing the dog. The Hider remained seated during this phase and had the sole task of giving the release signal ("Okay") for the owners to let go of their dogs.

In the first stage, a single cup was placed at one of four marked positions. An experimenter held up a treat in clear view, waited for eye contact with the dog, and then hid the treat in the cup. After renewed eye contact, the experimenter pointed to the cup, and the dog was released by the owner to make a choice upon the Hider's signal. A second experimenter then repeated the same process. In stages two through four, the number of cups was gradually increased until all four were present but still only one cup per trial was baited and subsequently pointed at. Each experimenter performed each stage once, provided that the dog completed the stage without errors. In the fifth and final stage, alongside setting up the barrier, so-called "sham baiting" was introduced. After lifting the barrier, the treat was held up for the dog to see. Then each cup was opened from left to right, the paper insert was tapped with a finger (to simulate the sound of a falling treat), and closed again – while only one of the cups was baited. The barrier was then lowered, and the experimenter pointed to the cup containing the treat, thus during pre-training the dog never had to choose between the experimenters, and the Hider was never the one baiting the cups.

A dog could move on to the next phase as soon as it had made six correct choices in a row in stage 5. However, if a dog chose the wrong cup three consecutive times or four times in total across the whole pretraining phase, it was excluded from further testing. The positions of the cups and the placement of the treats varied pseudorandomly. Care was taken to ensure that the left-hand experimenter never had to point to the last right-hand cup and vice versa, to avoid difficult body movements.

2.3.4 Test trials

In the actual test phase, the dog stood again in the marked starting position and was held by the owner. The barrier was then set up, the Knower performed the baiting – as in the pre-training phase – and the barrier was subsequently lowered. In contrast to the training phase, an acoustic signal ("3, 2, 1, point") from the Hider was given, after which both experimenters pointed

simultaneously at one of the cups (see Fig. 2e). Following the signal for the experimenters, the release signal was given to the owner, who then released the dog to make a choice. The informants performed their roles in a strictly standardized manner. While the Knower was responsible for baiting in most conditions, the Guesser – depending on the condition – had no visual access to it, except in the control condition (Guesser Present). During pointing, attention was paid to synchrony between experimenters, consistency of gestures, gaze directions, and body posture to avoid unintentional cues. In trials where the cup positions required crossing arms (e.g., when the left experimenter pointed to a right-sided cup), the left informant was instructed to keep their arm above the right informant's arm. This was intended to prevent differences in arm visibility or movement from inadvertently influencing the dog's choice behaviour.

2.3.5 Choice Behaviour and Evaluation

A response was rated as a choice if the dog's nose crossed a line 20 cm in front of the cups and fixated on or touched it for at least two seconds. If the dog chose the cup indicated by the Knower, the trial was counted as correct; a decision for the Guesser was recorded as incorrect. If the dog did not choose any of the cups within 60 seconds, the trial was rated as "no choice" and was repeated up to three times. If the dog made an irrelevant choice, defined as selecting a cup not indicated at by either experimenter, or if the experimenters made a mistake, the trial was also repeated.

Dogs were excluded if they failed to complete the pre-training phase (three mistakes in a row or four in total) or if they made four consecutive "no choices" during the testing phase. Subjects that showed excessive fear or distress, or could not complete the testing protocol, were also excluded from the analysis. All exclusions were documented in Chapter 4.1.

2.4 Test Conditions

For this study, four testing conditions were carried out, which are explained in detail in the following subsections. A photographic illustration of the four experimental conditions is provided in Fig. 2.



Figure 2: Photographic illustration of the four experimental conditions. (a) Guesser Present, (b) Guesser Absent, (c) Guesser Back Turned, (d) Guesser Looking Away, and (e) test phase after baiting. The images illustrate the relative positions and attentional states of the informants during the baiting phase. The dog is positioned in front of the barrier and chooses between the indicated cups during the test phase.

2.4.1 Guesser Present

The “Guesser Present“ condition (see Fig. 2a) was used as a control to rule out the possibility of the dog having a general preference for one of the experimenters. In this condition, the Knower baited two cups, while the Guesser was visibly present and followed the Knower’s movements with their gaze. In this condition, both informants pointed to a baited cup. This meant that the dog could choose either the Knower or the Guesser, and in both cases, received a treat.

2.4.2 Guesser Absent

In the “Guesser Absent“ condition (see Fig. 2b), the Guesser left the testing room. Subsequently, the Knower baited the cups. The Guesser then returned, and the barrier was lowered. While the Knower pointed to the previously baited cup, the Guesser indicated an empty cup. During this condition, the Hider and Knower attempted to keep the dog’s focus on the task rather than on the Guesser leaving or entering the room.

2.4.3 Guesser Back Turned

The “Guesser Back Turned” condition (see Fig. 2c) was newly introduced in the present study to examine whether dogs differentiate between an informant who is physically present but visibly not attending to the baiting process and one who has full visual access. During the baiting phase, the Guesser was present in the room but turned their back toward the baiting event. The Knower hid the treat in one of the cups while the Guesser remained facing away. Then the barrier was lowered. As in other conditions, the Knower subsequently indicated the baited cup, whereas the Guesser pointed to one of the empty cups. Efforts were made to ensure that the dog’s attention was directed toward informational access rather than salient movement cues.

2.4.4 Guesser Looking Away

This condition, first introduced by Catala et al. [17], served as a geometrical control. In the “Guesser Looking Away” condition (see Fig. 2d), both experimenters looked in the same direction. Due to markings on the barrier and wall, their lines of sight were parallel. However, only the Knower could observe the baiting process, since the Guesser`s field of view was blocked by their perspective. At the start of this condition, both informants moved their cushions closer to the wall. The Hider sat on a cushion between them and alternately looked left and right to clarify the situation for the dog. Afterwards, they showed the treat to the dog, hid it in one of the cups, and returned to their chair. The informants then lowered the barrier, whereupon the Knower pointed to the baited cup, while the Guesser indicated an empty one.

2.5 Data Collection and Recording

During the experiment the Hider noted in real time the results on a table printed beforehand, including the dogs’ choice (Knower vs. Guesser), the side it went to (left vs. right) and the number of the cup it chose (C1-C4). Then the Hider marked the trial either as a correct choice, no choice, or an incorrect choice, by the criteria introduced in Chapter 4.3.5. In addition, all sessions were video-recorded using two wall-mounted cameras and one ceiling-mounted

camera to ensure complete coverage of the experimental area. Video recording was used to verify live coding and resolve ambiguous cases where necessary.

To assess coding reliability, a subset of trials (approx. 36% of the whole dataset) was independently coded by a second observer who was blind to the experimental condition. Inter-rater agreement was calculated using Cohen's Kappa on the number of trials in which the dogs chose the pointing of the experimenter on the left or on the right. The percentage agreement was 99.56 % (Cohen's $k = 0.99$, $z = 47.3$, $p < .001$), indicating high reliability.

2.6 Statistical Analysis

All statistical analyses were conducted in R using RStudio (version 4.2.2) [33]. Trials in which the dog made no choice or an irrelevant choice were excluded from the analysis. To assess whether dogs showed a preference for the Knower above chance level (0.5), intercept-only binomial generalized linear mixed models (GLMMs) with a logit link function were fitted using the function *glmer* from the package *lme4* [34]. In these models, the binary response variable (choice of Knower = 1, choice of Guesser = 0) was analysed. Subject ID was included as a random intercept to account for repeated measures within dogs.

Five intercept-only binomial models were calculated:

(1) one model pooling the test conditions (condition 2-4; excluding the control condition "Guesser Present"), and

(2-5) separate models for each condition.

To examine differences between conditions, a binomial GLMM with logit link function was fitted including condition as a fixed effect (four-level factor; reference level: Guesser Present). Age (z-transformed), trial number (z-transformed), and session (z-transformed) were included as additional fixed effects. Additionally, random slopes for condition (manually dummy-coded and centred), trial number and session (z-transformed) were included within the subject ID to account for individual variation in performance across conditions and trials and sessions. To evaluate the stability of the estimates, a leave-one-out procedure was conducted in which models were re-run while excluding one dog at a time to assess the stability of the estimates (min/max range).

The overall effect of condition was evaluated using a likelihood ratio test (χ^2 test), implemented with the R function drop1. Pairwise comparisons between conditions were conducted using the function *emmeans* from the package *emmeans*, which computes estimated marginal means adjusted for random effects and other model terms. P-values were corrected for multiple comparisons using Tukey's method. To assess individual-level performance, binomial tests were conducted on aggregated data across sessions and conditions. To examine construct validity across conditions, aggregated performance scores were correlated using pairwise-complete Pearson correlation tests across each pair of conditions. The significance level for all analyses was set to $\alpha = 0.05$.

3 Results

3.1 Overall Knower Preference Above Chance

Across all test conditions (i.e., excluding the control condition) and all sessions, dogs showed a significant overall preference for the Knower (estimated probability = 0.54, 95 % CI [0.53, 0.56], p < .001). Fig. 3 illustrates the average Knower preference across the four experimental conditions relative to chance level (50 %).

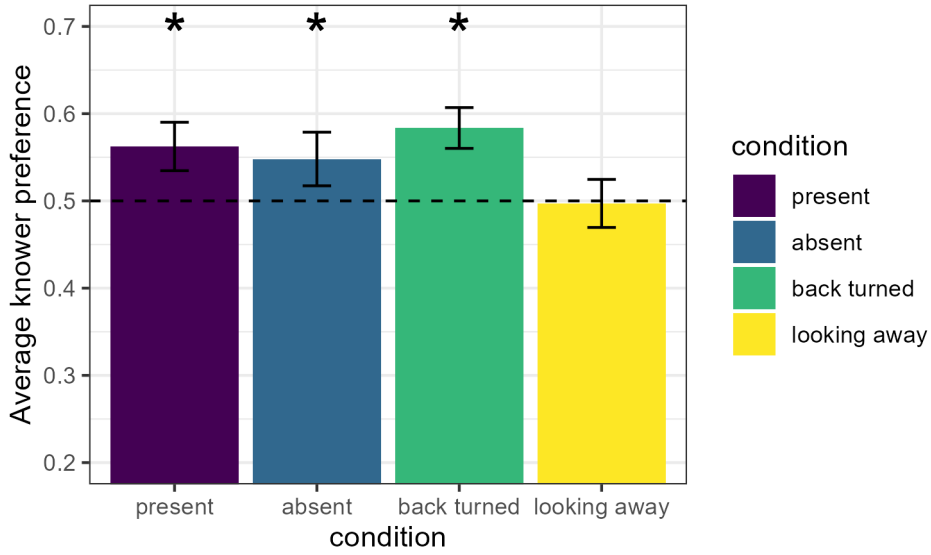


Figure 3: Estimated probability of choosing the Knower across all dogs, conditions and sessions. The x-axis displays the four experimental conditions, and the y-axis shows the proportion of choices directed toward the Knower. The dashed horizontal line indicates chance level (0.5). Error bars represent 95 % confidence intervals. Asterisks indicate performance significantly above chance (intercept-only binomial models).

3.2 Differences Between Conditions

Dogs chose the Knower significantly above chance in the Present condition (estimated probability = 0.56, 95 % CI [0.54, 0.59], p < .001), the Absent condition (estimated probability = 0.55, 95 % CI [0.52, 0.58], p = .001), and the Back Turned condition (estimated probability = 0.59, 95 % CI [0.50, 0.70], p < .001). In contrast, performance in the Looking Away condition did not differ significantly from chance level (estimated probability = 0.49, 95 % CI [0.47, 0.52], p = .619).

A generalized linear mixed model with binomial distribution revealed a significant overall effect of condition ($\chi^2(3) = 11.30$, $p = .01$), indicating that performance differed between at least one test condition and the reference (Guesser Present): relative to the reference condition (Guesser Present), performance in the Looking Away condition was significantly lower (estimate = -0.29, SE = 0.08, p= .01).

Post-hoc comparisons (Tukey-adjusted) confirmed that performance in the Looking Away condition was significantly lower than in the Present condition ($p = .003$), the Absent condition ($p = .045$), and the Back Turned condition ($p < .001$). No significant differences were found between the Present, Absent, and Back Turned conditions (all $p > .31$). Age, trial number, and session did not significantly influence performance (all $p > .05$). Fig. 3 illustrates the estimated probabilities and confidence intervals for each condition relative to chance level.

3.3 Individual Performance

Out of 93 dogs, 9 preferred the Knower significantly above chance level (93 binomial tests, uncorrected for multiple comparisons), when pooling together their data across the three test conditions. However, when correcting the p-values for multiple comparisons using the Benjamini-Hochberg method, none of the individual performances in the test conditions remained significantly above chance level.

None of the dogs showed a significant preference for the Knower in each of test conditions. None of the dogs significantly preferred the Knower in the Guesser Present condition; two dogs significantly preferred the Knower in the Guesser Absent condition; none in the Guesser Back Turned and none in the Guesser Looking Away (all binomial tests corrected for multiple comparisons).

One dog (a Bedlington terrier) showed a significant preference for the Guesser when pooling together the three test conditions. Fig. 4 shows individual performance across conditions. Substantial inter-individual variability was observed.

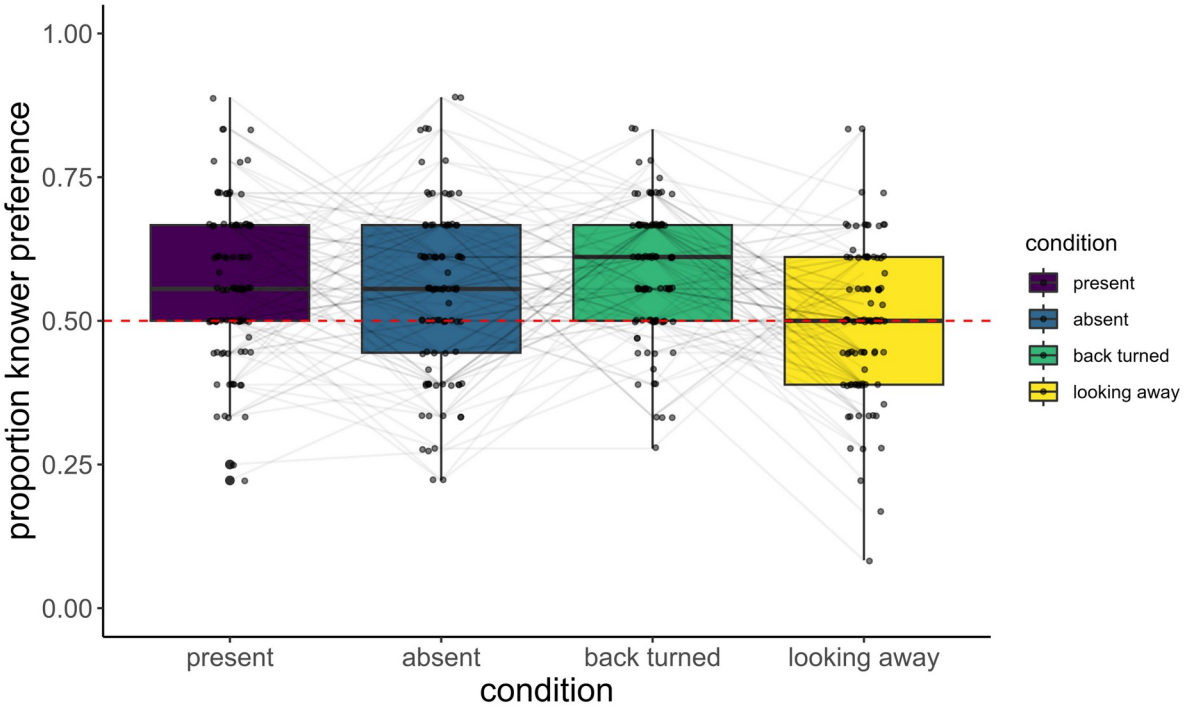


Figure 4: Distribution of individual Knower preference across all conditions and sessions. The x-axis displays the four experimental conditions, and the y-axis shows the proportion of choices directed toward the Knower. Each boxplot summarizes the distribution within one condition. The black horizontal line inside each box represent the median, and the box reflects the interquartile range (25^{th} - 75^{th} percentile). Whiskers indicate the range of the data excluding outliers. The red dashed horizontal line represents chance level (0.5). Each dot corresponds to one dog`s average Knower preference in the respective condition. Grey lines connect performance of the same individual across conditions.

3.4 Correlations Across Conditions

To assess whether performance generalized across conditions, Pearson's pairwise complete correlations between individual performances was calculated pooling together the data of all three sessions. Pearson correlations between conditions revealed no significant associations. Performance in one condition did not significantly correlate with the performance in any other condition (all $p > .05$). The corresponding scatterplots, r- and p-values are displayed in Fig. 5.

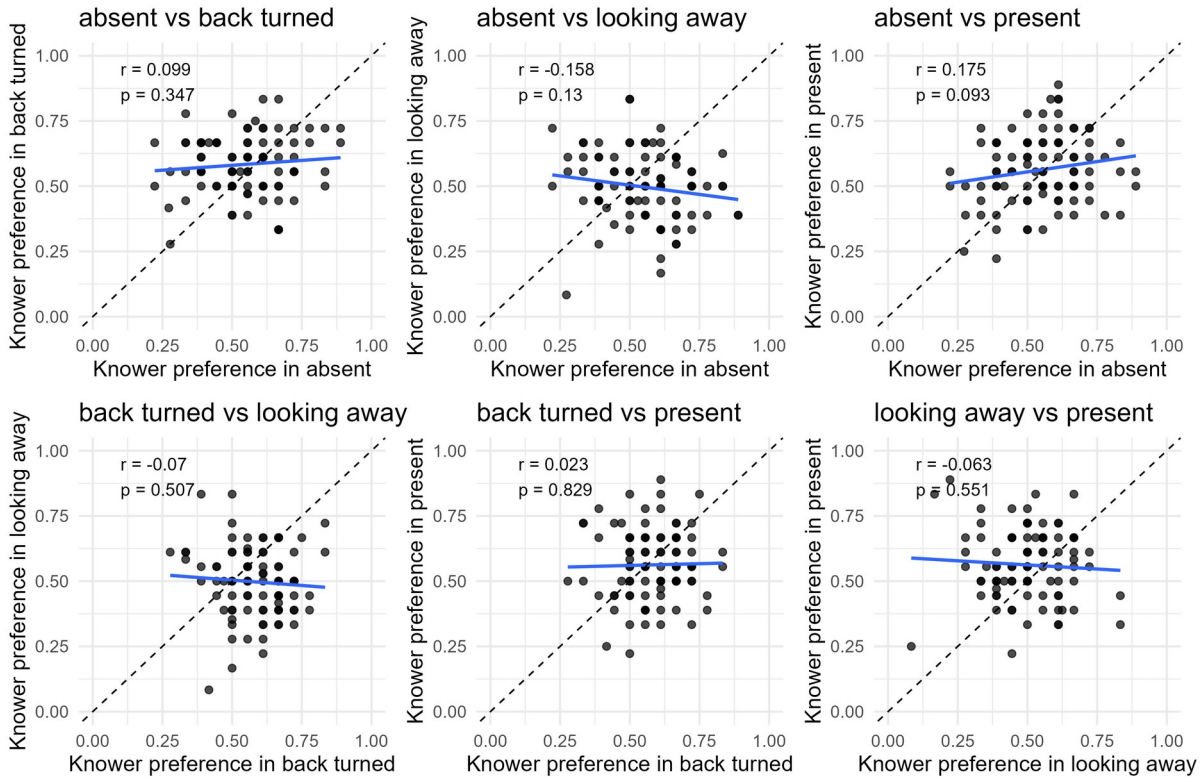


Figure 5: Pairwise correlations of individual Knower preference across conditions (data of the three sessions pooled together). Each scatterplot compares performance between two conditions. Each dot represents one dog (dots are darker when multiple dogs overlap at the same performance level). The black dashed line indicates perfect agreement between conditions, and the blue line represents the linear regression fit. Pearson´s correlation coefficient (r) and corresponding p-values are displayed within each panel.

3.5 Comparison with Catala et al.

To facilitate comparison with previous findings, Fig. 6 displays the mean Knower preference across conditions (data pooled together across the three sessions) in the present study alongside the results reported by Catala et al. (2017). While both studies show above-chance performance in conditions with clear knowledge asymmetry, performance in the geometrically controlled "Looking Away" condition differed between studies.

Catala et al. (2017) reported mean Knower preferences of M = 0.56, 95 % CI [0.495, 0.629] in the Present condition, M = 0.72, 95 % CI [0.659, 0.787], in the Absent condition, and M = 0.62, 95 % CI [0.565, 0.669] in the Looking Away condition. In comparison, the present study showed lower (although still above-chance) performance in the Absent condition and no above-chance preference in the Looking Away condition.

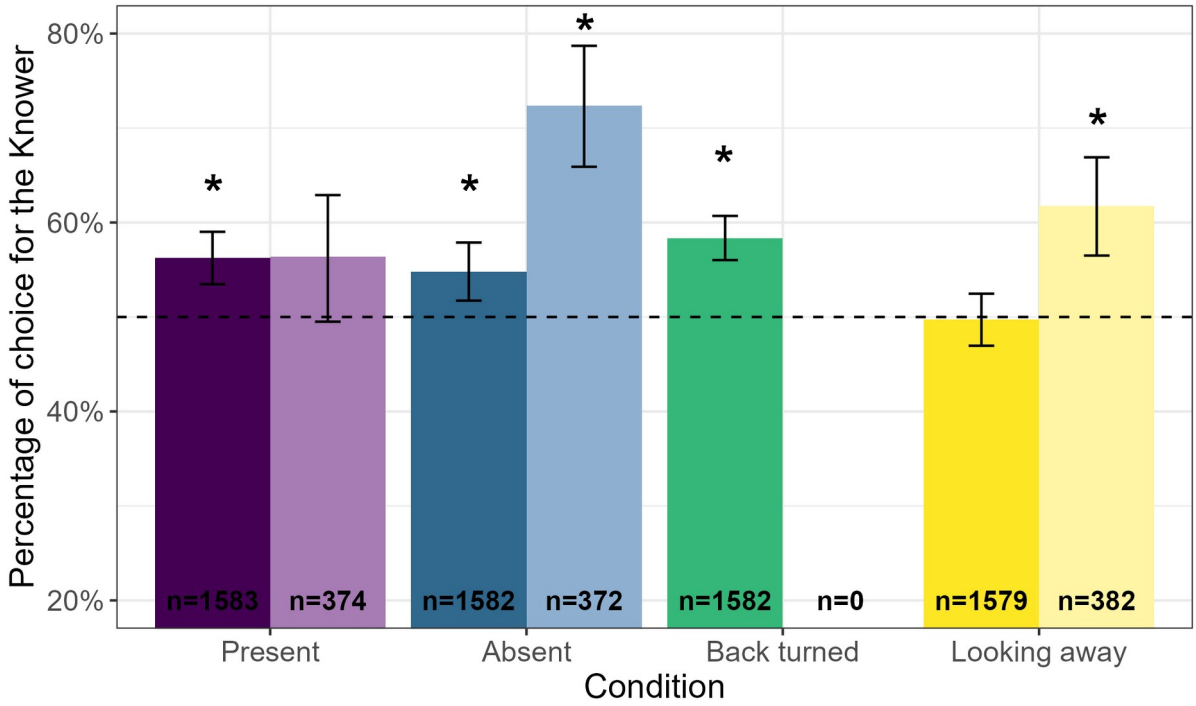


Figure 6: Comparison of average Knower preference across conditions between the present study and Catala et al. (2017). Bars represent the mean proportion of choices directed toward the Knower in each condition. Error bars represent 95% confidence intervals. The dashed horizontal line indicates chance level and asterisks indicate that performance was significantly above chance. Darker colored bars represent the present study and their lighter versions represent Catala et al. (2017)'s corresponding findings for the same condition. The study by Catala et al. (2017) lacks the Guesser Bak Turned condition, which was introduced by the present study. At the base of each bar the number of observations (trials) collected in each study and condition is shown.

4 Discussion

4.1 Summary of Main Findings

Combining data across all dogs, test conditions (excluding the Guesser Present), and sessions, the results revealed a marginal but significant preference for the Knower (54%). A significant Knower preference was observed in the Present, Absent, and Back Turned conditions, whereas no significant preference emerged in the Looking Away condition. Performance varied across conditions within individual dogs, and only a small number of dogs demonstrated consistently high performance across all test conditions. Furthermore, no significant correlations were found between conditions, indicating that performance in one condition did not reliably predict performance in another. Our results partly replicated the ones of Catala et al. (2017), with the exception of a generally lower performance in test conditions and no knower preference in the Looking Away condition.

4.2 Evaluation of Hypothesis 1: Overall Knowledge Attribution

The first research aim was to examine whether dogs are capable of attributing knowledge to others. We hypothesized that dogs would show a significant preference for the informed person across experimental conditions. This hypothesis was only partially supported. In the Guesser Present, Guesser Absent, and Guesser Back Turned conditions, dogs chose the Knower significantly above chance level, suggesting that they could differentiate between informed and uninformed individuals under certain circumstances. However, in the Looking away condition, performance remained around chance level. These findings indicate that dogs may distinguish between informed and uninformed individuals, but only when the informational difference is sufficiently salient, e.g., the knowledgeable informant also handles the food.

4.3 Evaluation of Hypothesis 2: Sensitivity to Visual Access

In addition, we hypothesized that performance would vary depending on the clarity of the behavioural differences between experimenters used to operationalise visual access. We expected the strongest effects in the Guesser Absent and Guesser Back Turned conditions, as these conditions provide the clearest contrast in visual access between Guesser and Knower.

The results partially align with this prediction. The Back Turned condition showed the strongest Knower preference. Although the effect in the Absent condition was less pronounced than anticipated, dogs still demonstrated a significant preference for the Knower. However, two conditions deviated from our expectations.

First, we anticipated a weaker but still significant preference for the Knower in the Guesser Looking Away condition, as directly observable cues to the difference in visual access between Guesser and Knower were only subtle (both informants looking in the same direction but due to their position in the room, one looked toward the food hiding, the other away from it). Contrary to this prediction, dogs did not show a significant preference for the Knower in this condition, suggesting that the cues may have been too subtle. In this condition, dogs were not only required to recognize presence, attention, and knowledge states, but also to infer geometric perspective and identify another individual's field of view. Further, the Looking Away condition was the only condition in which the Knower did not perform the baiting. This procedural difference may have confused some dogs or suggests that they relied on cues other than visual access, such as food handling.

Second, we hypothesized that no significant preference would occur in the Present condition, since both experimenters had identical informational access. In contrast to this expectation, dogs showed a significant preference for the Knower in this control condition, suggesting that they may have relied on subtle, uncontrolled behavioural or contextual cues, or developed a preference for a specific experimenter. One possible explanation is that dogs may have generalized the baiting pattern from earlier trials and associated the baiter with the correct choice. This finding raises concerns about whether the paradigm adequately isolates knowledge attribution.

4.4 Construct Validity

Beyond the evaluation of the hypotheses about dogs' Knower preference in the task, the central aim of the present study was to assess the construct validity of the Guesser-Knower paradigm as a measure of visual perspective-taking in dogs. Construct validity in this context refers to the extent to which task performance reflects sensitivity to informational access rather than reliance on superficial behavioural cues or associative strategies [31]. The following

section evaluates the degree to which the observed performance pattern meets the previously defined criteria for high construct validity.

First, performance differed significantly across conditions, indicating that dogs were sensitive to contextual differences in how visual access was manipulated. Stronger effects were observed in conditions in which the behavioural asymmetry between informants was most salient, suggesting that dogs' performance was not random, but was at least partly guided by behavioural cues present in the task. Second, the overall preference for the informed individual further suggests that, under certain circumstances, dogs could distinguish between knowledgeable and ignorant persons or between the experimenter handling the food and the one not doing so. At first glance, these findings may appear to provide partial support for the assumption that the paradigm captures sensitivity to informational access.

However, several aspects of the results raise questions regarding the strength of the paradigm's construct validity. First, performance in the geometrically controlled "Guesser Looking Away" condition did not significantly differ from chance. If dogs were reliably attributing visual perspective, systematic differentiation would be expected even when overt behavioural differences between experimenters are minimized. This finding suggests that dogs may not be sensitive to the subtle knowledge differences in this condition.

Moreover, dogs showed a significant preference for the Knower in the control condition ("Guesser Present"), in which both individuals had equal informational access. From a construct validity perspective, this finding is particularly critical, as a valid measure of knowledge attribution would predict no systematic preference in the absence of a knowledge asymmetry. The presence of such a bias suggests that factors other than informational access may have influenced dogs' choices.

Further, no significant correlations were observed between performances across test conditions. If the task captured a stable perspective-taking ability, individual dogs performing well in one condition would be expected to show comparable performance in other conditions. The absence of such consistency between conditions may be explained by differences in cognitive demands across the four experimental conditions. The Absent condition provided the clearest behavioural asymmetry between experimenters, as the Guesser was not present during baiting. The Back Turned condition also involved a relatively clear visual obstruction. In contrast, the Looking Away condition required a more complex interpretation of field of view. It

is therefore possible that each condition engaged different underlying processes and did not measure a single unified construct. Another explanation for the limited correlations may be that dogs altered their strategies throughout each session. For example, they may have initially relied on behaviour reading, later switched to selecting the more active person (e.g., the experimenter who moved more, handled the food, or provided more salient cues), and eventually chosen between options without consistent strategy. Under such circumstances, trials in which dogs may have used visual perspective-taking would be obscured by strategy shifts, resulting in inconsistent performance across conditions.

In addition, substantial inter-individual variability was observed, with none of the dogs consistently performing above chance across test conditions. This pattern may be explained by several factors. Individual characteristics, such as breed, hunger level at the moment of test, attentional capacity, or independence in decision-making, were not systematically controlled but rather heterogeneity was purposefully sought after, to increase the generalizability of our findings [35]. Additionally, differences in prior experience with humans, levels of training, and general orientation toward people may have influenced performance. It is also possible that some dogs consistently applied an incorrect strategy (e.g., side preference or selecting the individual who previously rewarded them), or that the task approached the dogs' performance limits, such that even small differences in concentration or motivation resulted in pronounced variability. These findings further challenge the interpretation of the task as measuring a consistent underlying ability. While the stability of performance over time was examined in a separate but related study using the same experimental paradigm, the present findings already indicate that performance may be strongly influenced by situational factors rather than reflecting a coherent cognitive construct.

An additional observation concerns the only dog showing a significant preference for the Guesser across conditions, which was a Bedlington Terrier. Previous research has suggested that certain terrier breeds may exhibit more independent behavioural tendencies and reduced reliance on human communicative cues compared to other breeds [36,37]. Although breed differences were not systematically examined in the present study and this observation is based on a single individual, this finding, in combination with the other results, may illustrate how individual predispositions could contribute to variability in performance. It also highlights

important limitations in interpreting performance in the Guesser-Knower paradigm as evidence for visual perspective taking.

4.5 Comparison with Catala et al.

The present findings can be meaningfully interpreted in relation to the study by Catala et al. [17], whose refined Guesser-Knower design served as the conceptual foundation for the current investigation. Similar to Catala et al., dogs in the present study showed an overall preference for the informed individual, particularly in conditions with a clear behavioural asymmetry between experimenters. This convergence supports the notion that dogs are sensitive to differences in informational access under certain circumstances or that they are sensitive to behavioural cues to human visual attention.

However, important deviations from Catala et al.'s [17] findings emerged. While Catala et al. reported a significant Knower preference in the geometrically controlled "Looking Away" condition, performance in this condition did not significantly differ from chance in the present study. This discrepancy may reflect differences in sample size, sample characteristics, or procedural nuances influencing dogs' interpretation of visual access. Alternatively, it may suggest that sensitivity to geometric perspective cues is less stable or more context-dependent than previously assumed.

Furthermore, dogs in the present study showed a significant preference for the Knower even in the control condition ("Guesser Present"), in which both individuals had equal informational access. Such a bias was not central in Catala et al.'s [17] interpretation (despite the very similar preference value) and raises questions regarding the specificity of the paradigm. The presence of a preference in the absence of a knowledge asymmetry suggests that factors beyond informational access – such as subtle behavioural cues or learned task heuristics – may have influenced choice behaviour.

Finally, dogs in the present study showed lower performance in the Absent condition than reported by Catala et al. [17]. It should be noted that a procedural difference existed between the two studies: whereas Catala et al. used a door positioned in front of the dog, the present study required the use of a door located behind the dog for the Guesser to leave the room. This modification may have influenced the dogs' attentional state and thereby affected performance.

This discrepancy further highlights the potential impact of procedural and contextual factors on task outcomes. A direct comparison of performance patterns across studies is presented in Fig. 6.

4.6 Limitations and Future Directions

Although every effort was made to ensure that the experiment was as replicable and as error-free as possible, several limitations must be taken into consideration. First, ethological validity should be considered, as the laboratory environment does not reflect an everyday situation for most of the sampled dogs. This may have influenced their behaviour. Furthermore, the dogs' mood may have varied across the three sessions, potentially contributing to differences in performance. Additionally, dropouts across sessions may have affected the power of the statistical analyses. Another limitation concerns the number of trials per condition. While a higher number of trials would increase the stability and reliability of results, it would also prolong the experiment and potentially lead to fatigue and a lower attentional state of the dogs. However, we did not find evidence for a systematic effect of trial number on performance (e.g., a decrease in Knower choices over time), suggesting that fatigue did not strongly influence behaviour in the present study. As no objective measurement of motivational, attentional, or stress levels was implemented, it is nevertheless difficult to determine whether variations in performance reflect differences in the ability to attribute knowledge or simply fluctuations in attention. Although the aspects mentioned before may be difficult to fully control in future research, their potential influence on performance should be acknowledged when interpreting the results.

An additional limitation concerns experimenter consistency. Due to practical circumstances, different experimenters were involved both within and across sessions. Although all experimenters followed a standardized protocol, subtle differences in posture, timing, tone of voice, or interaction style cannot be fully excluded. Given that socio-cognitive tasks are particularly sensitive to human behavioural cues, such variation may have introduced additional variability in dogs' responses. However, experimenter identity was largely balanced across roles, making it unlikely that such effects systematically biased the results.

Another important consideration is that the sample included various breeds, mixes, sexes, and levels of training, yet these factors were not systematically analysed. Furthermore, the study relied on a single experimental paradigm. However, an important strength of the present design is the inclusion of multiple test conditions intended to measure the same underlying construct of visual perspective-taking. This approach allows for a more fine-grained assessment of construct validity within a single paradigm. Future studies could extend this approach by including additional conditions to further disentangle the mechanisms underlying performance.

4.7 Conclusion

The present study aimed to evaluate the construct validity of the Guesser-Knower paradigm as a measure of visual perspective-taking in dogs. While dogs showed an overall preference for the knowledgeable experimenter, individual differences were not stable across conditions, dogs performed at chance level in a condition in which behavioural differences between informants were minimised, and instead preferred the experimenter handling the food above chance level even when both informants had the same knowledge state. These findings challenge the interpretation of the task as capturing the construct of perspective-taking. Future research should therefore aim to refine the paradigm to control for behaviour-reading and add complementary conditions to more robustly assess knowledge attribution in dogs.

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Figure 1: Schematic overview of the experimental setup. The blindfolded owner (O) was seated behind the tested dog (D), facing the barrier (B) and the two informants (I1, I2), who alternated between the roles of Guesser and Knower. Four cups (C1-C4) were positioned equidistantly from the dog's starting position and numbered from left to right from the experimenters' perspective. The Hider (H) faced the dog, gave the acoustic signal for the informants, and performed the baiting in the "Looking Away" condition. The session was recorded by two wall-mounted cameras (V1, V2) and one ceiling mounted camera (V3, not shown).....9

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