universität wien

MASTERARBEIT / MASTER'S THESIS

Titel der Masterarbeit / Title of the Master's Thesis

„Are ravens mislead by human cues in a change of location false belief task?“

verfasst von / submitted by

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angestrebter akademischer Grad / in partial fulfilment of the requirements for the degree of

Master of Science (MSc)

Wien, 2022 / Vienna, 2022

Studienkennzahl lt. Studienblatt / degree programme code as it appears on the student record sheet:	UA 066 878
Studienrichtung lt. Studienblatt / degree programme as it appears on the student record sheet:	Masterstudium, Verhaltens, Neuro-, und Kognitionsbiologie
Betreut von / Supervisor:	Univ. Prof. Mag. Dr. Thomas Bugnyar

Table of content

Acknowledgments

I would like to thank the entire Bugnyar Lab for their support, especially to K. Wenig and D. Nagel, who taught me how to handle the ravens and helped with running the experiments. Many thanks go to C. Blum, L. Horn and K. Wenig for their helpful comments. I am also grateful to the keepers at Haidlhof who always took care of the ravens with great dedication. Finally, I would like to thank Prof. Bugnyar for his trust, knowledge and time, which made this work possible.

Abstract

The Theory of Mind helps to decode what and how others perceive their environment. In its most comprehensive form, it includes the understanding of false beliefs, which means having two conflicting stages of reality in one own's mind. So far, this understanding is limited to apes and macaques. The aim of this research was to test whether common ravens (*Corvus corax*) are capable to attribute false beliefs to others. I used a change of location task with two experimenters, a hider and a communicator, similar to Lonardo et al. (2021). The final experiments had two conditions: A false belief condition with an ignorant communicator, who was not aware of the bait transfer, and a true belief condition where the communicator was aware of the transfer. In both conditions, the communicator made after the transfer a misleading cue and suggested to the raven the initial position of the bait. Ravens chose in both conditions the suggested cover more often even though they have witnessed the transfer and knew the true location of the bait. This study could not find evidence that ravens have a false belief understanding. This finding could be also explained due to a potential recency bias, which was not investigated further in this study.

Key words: Theory of Mind, ravens, false belief, corvids

Zusammenfassung

Die „Theory of Mind“ (Theorie des Mentalen) hilft zu entschlüsseln, wie und was andere über ihre Umwelt wahrnehmen. In ihrer umfassendsten Form beinhaltet die „Theory of Mind“ das Verständnis von „false beliefs“ (falscher Überzeugungen). Das heißt, dass zwei widersprüchlicher Realitäts-Zustände im eigenen Kopf vorhanden sein und unterschieden werden können. Bisher wurde dieses Verständnis bei Menschenaffen und Makaken nachgewiesen. Ziel dieser Studie war es, zu untersuchen, ob Kolkraben (*Corvus corax*) fähig sind, anderen „false beliefs“ zuzuschreiben. Das Versuchsdesgin war an die Methodik von Lonardo et al. (2021) angelehnt. Es beinhaltete einen Objekttransfer und wurde von zwei Experimentator*innen, einer versteckenden und einer kommunizierenden Person, durchgeführt. In den finalen Experimenten gab es zwei Bedingungen: Eine "false belief"-Bedingung mit einer*m unwissenden Kommunikator*in, die oder der sich des Futtertransfers nicht bewusst war, und eine "true belief"-Bedingung, in der sich der oder die Kommunikator*in des Transfers bewusst war. In beiden Konditionen gab der oder die Kommunikator*in nach dem Transfer einen irreführenden Hinweis, indem die kommunizierende Person dem Raben die ursprüngliche Position des Futters anzeigte. Die Raben wählten in beiden Konditionen häufiger das vorgeschlagene Versteck aus, obwohl sie den Transfer beobachtet hatten und den aktuellen, neuen Ort des Futters kannten. In dieser Studie konnten keine Hinweise gefunden werden, dass Raben ein Verständnis für „false beliefs“ haben. Dieses Ergebnis könnte auch durch einen möglichen „Recency Bias“ (Rezenzeffekt) erklärt werden, der in dieser Studie nicht weiter untersucht wurde.

Schlagwörter: Theorie des Mentalen, falsche Überzeugungen, Raben, Corviden

Introduction

One of the proposed reasons why various higher cognitive abilities have evolved in humans and some non-human animal species is a more complex social life (Krupenye and Call, 2019). The ability to decode major parts of this complex social life is depicted by the Theory of Mind. This theory describes that one individual can attribute mental states to others or read the mind of another individual, more precisely, individuals being able to attribute perception, desires and beliefs to others (Krupenye and Call, 2019). The awareness of an individual to know *what* others can perceive is called level I perspective-taking, the ability that one understands *how* others perceive something in their environment is called level II perspective-taking (Krupenye and Call, 2019).

The understanding of others' false beliefs is described in the literature as a "key marker" for advanced social cognition (Buttelmann et al., 2017) or a "signature of a full-blown" Theory of Mind (Krupenye and Call, 2019). Krupenye and Call (2019) state that a false belief is an epistemic state that conflicts with reality. Understanding a false belief would mean to have two views about a situation in mind (one's own and one from another individual) and to be aware of the difference (Krupenye and Call, 2019). Implicit and explicit methods were designed to test the false belief understanding. In implicit experimental designs, which are less cognitive demanding, the gaze of the test subject was analysed (infants: (e. g. Oniski and Baillargeon, 2005; Southgate et al., 2007), non-human apes: (Kano et al., 2019; Krupenye et al., 2016), macaques: (Hayashi et al., 2020)), whereas in explicit experiments a behavioural response was used to assess the ability of a false belief understanding (helping behaviour: (infants: Buttelmann et al., 2009; non-human apes: Buttelmann et al., 2017)).

Attributing false beliefs to others is cognitively demanding and believed to undergo ontogenetic trajectories. In 1983, Wimmer and Penner introduced an experimental design to test the false belief understanding in children, which is nowadays called Sally-Anne task. In this task, a child observes a scene where two persons, Sally and Anne, are in a room equipped with a basket and box. Sally places her marble in the basket and leaves the room. While she is outside, Anne takes the marble and transfers it into the box. After Sally comes back in, the child is asked where Sally will look for her marble. Only children with an age of four years and higher could solve the task (Wimmer et al., 1983). In follow up studies it was shown that the Sally-Anne task is comparatively cognitive demanding. Lowering the demands led to younger children being able to show a false belief understanding (Carpenter et al., 2002). Buttelmann et al. (2009) reported that eighteen-month-old infants showed a false belief understanding in

an experiment which used an active helping behaviour as a behavioural response. The behaviour itself, to help someone, has been observed in fourteen-month-old infants (Warneken and Tomasello, 2007). In the study by Buttelmann and colleagues, an eighteen-month-old infant and an experimenter were watching how a second experimenter hid a toy in one of two boxes. In the false belief condition the experimenter, who hid the toy, left the room and the experimenter who was still in the room with the infant transferred the toy into a second box. In the true belief condition the second experimenter stayed in the room during the transfer and moved to the door afterwards. After returning, in both conditions the second experimenter tried to open the locked box where the toy was placed initially (Table 1). After this unsuccessful try, the infant, who was trained before how to open the boxes, was allowed to help. If children had the ability to attribute false beliefs to others, in the true belief condition they would more often select the box that the experimenter had tried to open while in the false belief condition they would more often select the other box. The results of the study go into the same direction, in the true belief condition 84% of the infants approached the box which the experimenter had tried to open and in the false belief condition 72% of the infants went for the box where the toy had been transferred to (Buttelmann et al., 2009).

For over 40 years it has been questioned in the literature whether animals like chimpanzees have a Theory of Mind (Premack and Woodruff, 1978). False belief attribution has long been seen as unique for humans as non-human apes failed to succeed in experiments, for instance in explicit experiments with food-choices tasks (Hare et al., 2001; Kaminski et al., 2008; Krachun et al., 2009).

With the ground-breaking study by Krupenye et al. in 2016, it was shown that three non-human ape species anticipate the action of another individual who had a false belief about the reality. Their new approach was to track the eye movement while the apes were watching a recorded play with a strong social stimulus on a screen. In one of the two scenarios a man, dressed as King Kong, had an aggressive interaction with a keeper. After the ape-like character hit the keeper, it hid itself in one of the two haystacks. In one condition the keeper went inside while the ape-like character changed its location, from one to the other haystack. In the other condition, the keeper was present during the location change and went then inside. In both conditions, the ape-like character left the scene while the keeper was inside. The keeper returned with a raised stick and took a central position between the two haystacks. Subsequently, the looks of the non-human apes were analysed. The non-human apes showed significantly more first looks at the place where an agent falsely believed that an object was hidden even when the non-human apes knew that the object had left this place (Krupenye et al., 2016). A

second anticipatory looking study by Kano et al. (2019) with non-human apes concluded that apes did not read behavioural cues of others to succeed in false belief paradigms.

Buttelmann et al. (2017) argued that the results of the Krupenye et al. (2016) study could also occur if the non-human apes had predicted that the actor always went to the last place. Therefore, Buttelmann et al. adapted their study with infants from 2009 and tested the same three ape species with the same helping paradigm. In the false belief condition non-human apes unlocked the second box, which was not suggested by the experimenter, more often and helped the experimenter to find the sought object, while in the true belief trials non-human apes were unlocking both boxes equally often. Thus, non-human apes acted differently between the conditions, and Buttelmann et al. (2017) argued that the non-human apes attributed a false belief to the experimenter. Their study contributed with a second method to the decade old question whether non-human apes can attribute false beliefs to others, which in contrast to the study by Krupenye et al. (2016) also included social interactions.

Until recently, studies on rhesus macaques (*Macaca mulatta*) failed to show that other primate species beside apes are sensitive to beliefs (Marticorena et al., 2011; Martin and Santos, 2014). A new study by Hayashi et al. (2020) demonstrated that Japanese monkeys (*Macaca fuscata*) passed an anticipatory-looking false belief test.

Lonardo et al. (2021) adapted the methods of the infants and non-human apes studies by Buttelmann et al. (2009, 2017), to test whether dogs (*Canis familiaris*) follow a misleading cue by an experimenter, the communicator. Dogs observed two conditions, the true belief condition, where the communicator was present, or the false belief condition with an absent communicator during a food transfer. In the following, the communicator suggested always the container where the food was initially hidden. Dogs preferred to choose the container which was suggested by the experimenter even though the experimenter had a false belief, while in the true belief condition dogs were choosing this container less often. This result led to the conclusion that dogs were at least sensitive to the study design. Terrier, unlike other breeds, seemed to behave like the infants and apes of the studies by Buttelmann et al., namely that they selected more often the suggested container when the communicator had a true belief, while they went for the unsuggested container more frequently in the false belief condition. Therefore, new cohorts of 40 border collies and 40 terriers were tested in a final third experiment. Border collies replicated the initial results of the first experiment with various group of breeds. Terriers instead chose in true belief condition the suggested container more often than the container that was not suggested, as if they expected the communicator would show something new. The terriers in the false belief group went more frequently to the unsuggested container,

which may indicate that the terriers attributed a false belief to the communicator because they went to the location where they had seen the bait being transferred to. Thus terriers showed the same results of the first experiment of the dog study and similar results as infants and non-human apes have shown in the helping paradigm (Buttelmann et al., 2009; Buttelmann et al., 2017; Lonardo et al., 2021; overview of the three studies see Table 1).

In summary, being sensitive to beliefs is so far limited to a very few mammals, more precisely to apes and macaques (Kano et al., 2020) and possibly terriers, given the results of Lonardo et al., (2021).

Table 1: Overview of the studies, which base on the methodology of Buttelmann et al. (2009). The notes refer to the false belief (FB) and true belief (TB) trials in the studies.

	This study	**Lornado et al. 2021**	**Buttelmann et al. 2017**	**Buttelmann et al. 2009**
Species	Ravens *Corvus corax* n=7	Dogs *Canis familiaris* Experiment 1: n=120 Exp. 2: n=60 Exp. 3: 40 border collies and 40 terriers	Chimpanzees n=23 *Pan troglodytes*, bonobos n=5 *Pan paniscus*, Orang-utans n=6 *Pongo abelii*	1.5-years-old Infants; n=50 note: 1.3- and 2.5-years-old infants were tested in separate experiments
Age (years)	2 ravens: 1 year 5 ravens: 3 years	μ = 5.3	*P.t.* range: 5.5 - 48 *P.p.* range: 9 - 31.2 *P.a.* range: 4.7-33.4	μ=1.5
Paradigm	Nonverbal, food hiding	Nonverbal, food hiding	Nonverbal, Helping	Nonverbal, Helping
Hidden object	Food (removed after transfer)	Food (removed after transfer)	Small orange box	Caterpillar toy
Item to hide the object	3 wooden covers	2 buckets	2 coloured boxes with a hinged lid and a handle, bolt to un-/lock the lid	2 coloured boxes with a hinged lid and a handle, pin to un-/lock the lid
Experimenters	2	2	2	2
Number of trials	FB: n=12 TB: n=12 non-FB-TB-trials, interspersed: n=36	Each dog had either 1 FB or 1 TB trial	6 FB or 6 TB trials, each test trial had prior 2 training trials, 1 test trial per day	1 FB or 1 TB trial; Before: training to open the box
Design	Within subject	Between subject	Between subject	Between subject
TB, FB Baited?	No, interspersed non-FB-TB trials: yes	No	Yes afterwards, independent which box was chosen	No
Role of the two experimenters:	**Familiarisation phases**: Communicator was helpful, suggested the baited cover, hider hid the bait. **Test**.: Communicator was deceitful, suggested empty cover, hider hid the bait and sneakily removed it.	**Familiarisation phases**: Communicator was helpful, suggested the baited container, Hider hid the bait. **Test**.: Communicator was deceitful, suggested empty container. Hider hid the bait and sneakily removed it.	**Training:** Assistant taught apes to open box. Experimenter not present. **Test:** E. presented object, hid it, left. Assistant and in TB E. returned, A. transferred object in presence or absence of E., both left. E. returned and unsuccessfully tried to open empty box, signalled for help	**Training**: E2 showed interest in the boxes while E1 and child were watching, E2 left, E1 taught the child to unlock boxes. **Test**.: E1 transferred toy from Box A to B, E2 left during FB, after returning E2 tried to open empty box in TB & FB and signalled to the child that E2 needed help
Results: TB condition	Ravens chose **the suggested cover more often**.	Dogs chose the **suggested bucket less often** than in the FB condition. Different results for terriers.	Apes unlocked **both boxes equally** often.	18 months-old infants opened the **suggested box more often** (which the experimenter had tried to open)
Results: FB condition	Ravens chose **the suggested cover more often.**	Dogs chose **the suggested bucket more often.** Only Terrier behaved like infants and apes from the other studies. TB terrier chose more often the suggested container than FB terrier.	Apes unlocked **the box containing the object**. **more frequently**. This box **was not suggested** by the experimenter.	Infants opened the box **more often** which **had the toy inside,** which was **not suggested** by the experimenter.

Besides mammals, birds demonstrate various remarkable cognitive abilities. The last common ancestor between mammals and birds lived approximately 300 million years ago (Güntürkün and Bugnyar, 2016). Recently, it was shown that a core common neuronal microcircuit may have already been present in the common ancestor of birds and mammals. In addition, the same study argues that the similar microcircuits in the bird's pallium and the neocortex of mammals use similar processing operations and therefore achieve corresponding cognitive abilities from different forebrains (Stacho et al., 2020). Research from the last decades has shown that corvids have extraordinary cognitive abilities: Common ravens (*Corvus corax*) plan flexibly for future events (Kabadayi and Osvath, 2017), scrub jays (*Aphelocoma coerulescens*) remember when and where they cached food (Clayton et al., 2001), New Caledonian crows (*Corvus moneduloides*) use and manufacture tools (Weir et al., 2002) and mentally represent goals of metatool problems (Gruber et al., 2019). Ravens are a large-brained songbird and a moderately social species compared to other corvids (Review: Bugnyar, 2013). Research on the social cognition of corvids, especially ravens revealed several interesting insights: Ravens observe the food caching of others before pilfering it, whereas the cachers try to deceive potential pilferers and thus show the ability to control their intentions (Bugnyar and Kotrschal, 2002). Additionally, ravens adjust their cache protection and pilfer tactics depending on whether the conspecific was present during the caching process and if an obstacle was blocking the view of the conspecific (Bugnyar and Heinrich, 2005). From the age of six months onwards, ravens are capable of following the gaze direction of a humans around a visual barrier (Bugnyar et al., 2004). Furthermore, ravens have knowledge about the dominance hierarchy of their own social group members but also of the neighbouring group (Massen et al., 2014). Playback experiments have shown that ravens remember not only former members of their social group for up to three years but also their relationship quality, and thus demonstrate a complex social knowledge (Boeckle and Bugnyar, 2012). However, evidence that birds understand that other agents are driven by beliefs about reality is still missing.

Attributing beliefs to others could be relevant for birds, especially for common ravens (*Corvus corax*), including juveniles as their group compositions show a high fission-fusion dynamic. Juvenile common ravens become part of non-breeder groups for foraging, roosting and socializing usually six months after hatching (Loretto et al., 2012). The group size varies for different activities: >1000 birds during roosting, <10 birds for socializing, <30 birds during foraging, but also >100 birds have been observed around large carcasses and dump sites (Boucherie et al., 2019). Dominance hierarchies in competition over resources are formed, in captive ravens as well as in wild ravens (Loretto et al., 2012). The social life of non-breeders

consists of cooperation and competition, depending on the daily situations and challenges (Boucherie et al., 2019). Loretto et al. (2017) analysed four large datasets of presence-absence observations and GPS-tracks of non-breeders and found that the observed ravens had a big fission-fusion dynamic although they had access to permanent and good food resources provided at the long-term study sites. At the Austrian study site 21% of the observed birds were "locals" meaning according to the study being present on more than two thirds of the 1091 observation days, while 44% of the observed birds belonged to the rare visitor group, meaning being present only one third of the days. Thus, from a social perspective it could be relevant for the "locals" to be able to attribute a false belief to others. For example, to birds which are only rarely present and therefore know that individuals of the rare visitor group might have missed some relevant social events. In an ecological context, attribution of false beliefs to others might be relevant when individuals recache food. For example, if the cacher was observed by a conspecific during the first hiding, the cacher could intentionally change the hiding place once the conspecific is no longer looking.

Bugnyar and his colleagues reported in 2016 that ravens can attribute mental states like "seeing" to others which is a building block of the Theory of Mind. In previous studies, behavioural cues such as the conspecific's (observer) line of gaze could not be ruled out as an associative cue (Bugnyar, 2011; Dally et al., 2006). In the study by Bugnyar et al. (2016), the conspecific was replaced by a loudspeaker located in a neighbouring apartment, which was connected to the experimental room via a small peephole. The ravens learned to look through the peephole in advance. In the experiment, the loudspeaker emitted calls from a conspecific while food was presented to the raven in the experimental room. The ravens attributed their prior perceptual experience of looking through a peephole to the putative conspecific and completed their cache just as quickly compared to the condition in which they were directly observed. On the other hand, when the peephole was closed, ravens needed significantly longer to finish the caches and made also more improvements (Bugnyar et al., 2016).

Eurasian jays (*Garrulus glandarius*), which also belong to the family Corvidae, exchange food during their courtship behaviour. Ostojić et al. (2013) used this behaviour to investigate whether male jays can ascribe desires to their partners and found that male jays feed their mates corresponding to their food preference. In a follow up study, male jays had an own desire which differed from the partner's desire. The experiments showed that males were not only acting upon their own desire but were also taking into account the desire of their partner (Ostojić et al., 2014).

Research on the Theory of Mind with different taxa and broader phylogenetic distance between the tested species is important to understand the evolution of the Theory of Mind, its mechanism and its necessary neural properties. Corvids attribute mental states like 'seeing' (Bugnyar et al., 2016) and ascribe desires to others (Ostojić et al., 2013; Ostojić et al., 2014), and also represent mentally the relationship of others (Massen et al., 2014). Hence, it could be likely that corvids are also sensitive to false beliefs.

Aims and Prediction

To date, ravens have never been tested in a false belief paradigm. Given the results of previous research in corvids on their social behaviour, their cognitive capabilities and the potential social relevance for them, corvids are good candidates for having a comprehensive Theory of Mind. Thus, my hypothesis of this master thesis was that ravens are likely to understand that the actions of others are driven not by reality but by beliefs about reality. To test this, I adapted the methods of Lonardo et al. (2021) to expose ravens to the test paradigm. In this paradigm a raven observed a bait transfer which took place in the absence (the false belief condition) or presence (the true belief condition) of an experimenter. Subsequently, the experimenter suggested in both conditions, with a pointing gesture, the initial location of the hidden bait. The H_0-Hypothesis was that the ravens act the same, in the true belief and in the false belief condition. The H_1-Hypothesis was that the ravens act differently in both conditions. I predicted that, in both conditions, ravens would prefer to choose the location where the bait has been transferred to over the original location where the bait had already left, and which is suggested by an experimenter. Secondly, I predicted that ravens choose the suggested location more often in the true belief condition than in the false belief condition.

Methods

Subjects and housing

The experiments were undertaken at the Haidlhof Research Station, Bad Vöslau, Austria between 6.4.2021 and 16.09.2021.

Nine subadult ravens (three males and six females) participated in the experiments. All of them, except one bird (Zazou), were individually marked with coloured leg bands. Since fledging, they have been part of behavioural experiments at the research station and were trained to commands and their names. The birds were fully habituated to the experimenters, the experimental objects and the test compartment, which means being in a visual isolation. Prior to this study, the ravens had no experience with any false belief task.

During the experiments, all nine birds were kept in a social group with 14 individuals in total. The nine birds were hand raised by humans. Seven hatched in April 2018 in the captive colony at the Haidlhof research station, Bad Vöslau, Austria. In mid-May, after fledging, the juvenile ravens were moved to an outdoor aviary (928 m^2) and were kept together for one year. Later, the juveniles joined another group of sub-adult and adult non-breeder ravens (Wenig et al., 2021). This procedure was undertaken to simulate natural social groupings of non-breeding ravens (Braun and Bugnyar, 2012; Marzluff et al., 1996). Zazou and Quito were born in 2020 and hand raised by two different private persons. Both were integrated in the social group at the Haidlhof Research Station in 2020. It is worth mentioning that Kofi, a male raven which was also the alpha bird of the group which hatched in 2018, got sick nine months after hatching and showed an untypical development. This resulted in it eating less, losing weight as a result, and also at one point Kofi could no longer fly. For some time, Kofi was kept alone, but after recovery he could be reintegrated into the group. At the end of my experiments, the feathers grew back and Kofi made his own attempts to fly again. The reason for this sickness and the behavioural changes are not known.

The outdoor aviary was five meters high and had multiple perches, four bathing ponds, trees and wooden walls with a two meters height. Additionally, it was equipped with different ground substrate (wooden chips, sand and gravel). The ground area of the outdoor aviary was 14.5 m x 15.3 m. The roof was a plastic net and had several sun and rain protection areas.

The ravens were fed two times a day with milk products, eggs, meat and different fruits. On the experimental days, the afternoon feeding with meat was always given after the experiments were finished. The raven group had always ad libitum access to water, also in the experimental compartment.

Four breeder groups were kept at least 10 meters away from this non-breeder group and were partly visible from certain perches. From time to time, wild ravens circled above the research station.

Set-up

The experiments took place in a wooden test compartment (7 m x 5 m) which was attached to the outdoor aviary. Within this compartment there were five sub compartments which were separated by doors, wooden walls or wire mesh. The caches were wooden pieces, 10 cm x 10 cm with a height of 2 cm. On one bottom, the pieces had a cavity with a diameter of 3.5 cm and a depth of 1.8 cm to cover the bait, a whole or a quarter frolic® (dog food). A one meter long wooden board was used to move the three or four caches around (Figure 1, Figure 2). Due to a regrouping of the social group, the false and true belief experiments with Zazou were undertaken in another aviary (Sup. Information Fig. 1), while the two familiarisation phases took place in the test compartment, where all the other birds were tested (Figure 1).

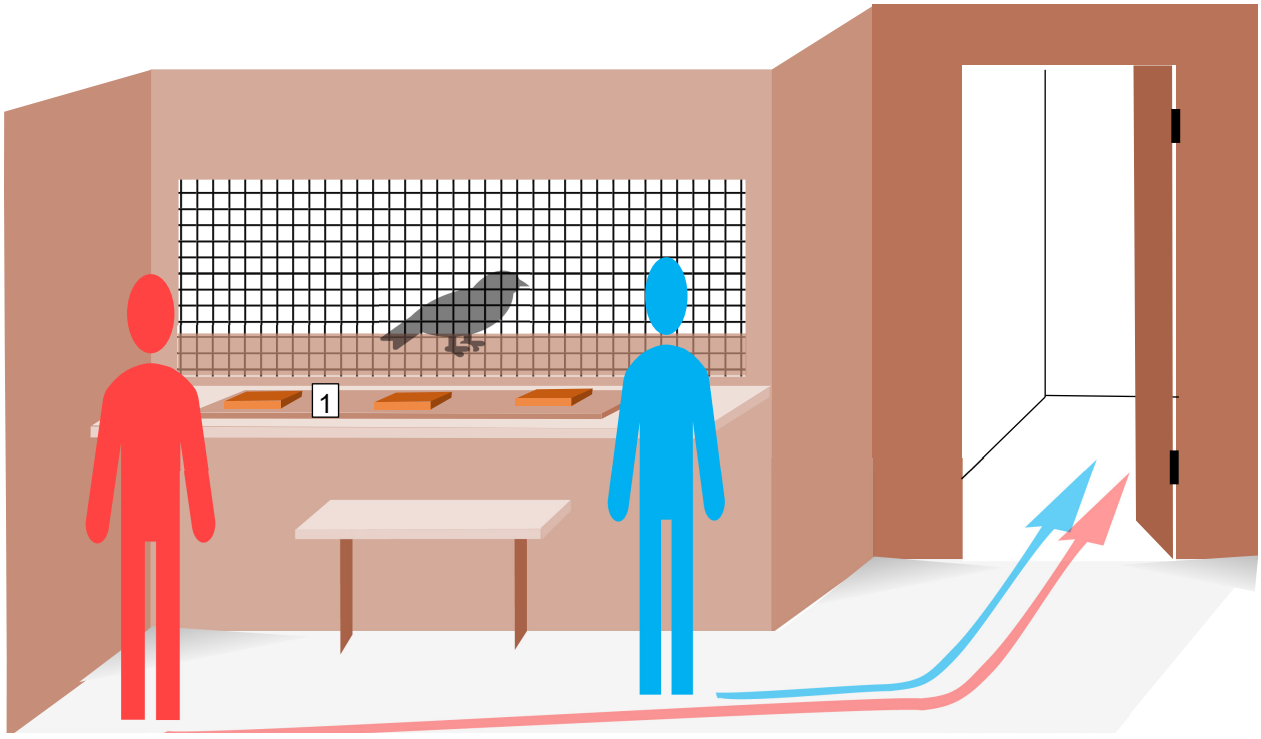

Figure 1: Setup overview of the experiment, false belief-, true belief condition. The Raven saw the experimental board (1) and the two experimenters, the hider in blue and the communicator in red, through the wire mesh. The hider hid a bait beneath one of the 3 covers which were on top of the experimental board, transferred the bait and left the room. In the true belief condition the communicator stayed during the bait transfer, left together with the hider and returned alone. While in the false belief condition the communicator left before the hider walked out of the room and did not witness the bait transfer. After the return of the communicator and the subsequent display of the initial position of the bait, the board was pushed to the fence and the raven was allowed to choose.

Figure 2: Photo of the experimental design. On top of the wooden experimental board were 4 covers. Each cover had a small cavity for the bait. In the final false- & true belief experiment only 3 covers were used. (Photo credit: Adrian Hiß)

Procedure

The methods of this study are based on the change of location task from Lonardo et al. (2021) and were adapted for ravens and the lower number of experimental animals in my study design.

Familiarisation Phase 1 – FP1

The goal of this phase was to familiarise the ravens with the hiding and displacement of the food. The experimenter placed the four covers on the board, which was put on the testing surface. Subsequently, the experimenter called the raven by its name and ensured the raven was standing in front of the board. Now, one out of four different conditions was applied, depending on whether the food caching was in- or visible for the raven and whether a displacement of the hidden food was included or not:

In the *visible-without-displacement* condition, the experimenter lifted one cover, hid a bait underneath and pushed the whole board gently towards the raven to the fence. The raven was allowed to choose one cover and was rewarded with the hidden food if it chose the right hiding place, if not, the chosen empty cover was shortly lifted to show that no bait was underneath. Afterwards the baited cover was lifted and the experimenter took the bait away.

In the *visible-with-displacement* condition, everything remained the same as described in the previous condition, except that, after the hiding procedure of the bait, the experimenter lifted with one hand the baited cover, took the bait with the other hand, put down the cover again, lifted one of the other covers and hid the bait beneath it.

In the *invisible-without-displacement* condition, before any hiding event took place the board was taken down so that the raven could not see the board and the hiding process. While

the board was out of sight the experimenter baited one cover, waited five seconds, replaced the board carefully on the testing surface and pushed it towards the fence.

In the *invisible-with-displacement* condition, everything remains the same as described in the previous condition except that, after the hiding procedure, the experimenter waited five seconds and then displaced the bait from one cover to one of the others and waited five seconds again. Subsequently the board is replaced on the testing surface and pushed towards the fence.

Familiarisation phase 2 – FP2

This phase had the goal to test if the raven had enough motivation and attention to select the baited cover and to make the raven familiar with the hiding and cueing procedure. Two experimenters were present, a hider who only baited the covers (only three in this phase) and a communicator who marked via a pointing gesture the baited cover to the raven. In the beginning of the conditions, both hider and communicator were standing next to each other in front of the raven and the experimental surface. There were four conditions divided again in in- or visible and with or without a displacement of the bait by the hider:

In the *visible-without-displacement* condition the hider showed the bait to the raven called its name made sure it was attentive and hid the bait under one of the covers while the communicator paid attention to all the movements. The hider stepped back and left the scene by going into another room. The communicator stepped forward behind the midpoint of the board, moved then behind the baited cover, tapped 5 times on the cover with the index finger while saying “Hier”. Subsequently, the board was pushed to fence and the raven could make its decision.

The procedure of the *visible-with-displacement* condition remained the same except that the hider transferred the bait to a second hiding place while both the communicator and the raven observed it. This happened as follows, the hider hid the bait for the first time, waited five seconds, lifted the cover with one hand, took the bait with the other, lowered the cover and lifted one of the other two covers, placed the bait beneath it, stepped back and left the scene.

The last two conditions of this phase checked whether the raven followed the communicator’s cue to select the baited cover even when they had not witnessed the hiding event. In the *invisible-without-displacement* condition, the hider removed the board from the test surface on a little table under the test surface, hid the bait under one of the covers. Thus the hiding process was not visible to the raven. Afterwards the hider left the scene. The communicator observed the hiding movements in a stooped posture, took the board after the hider has left, replaced it on the test surface and performed the pointing gesture.

The *invisible-with-displacement* condition had a displacement of the bait by the hider while the board was out of sight from the raven.

The persons (2 women, 1 man) who played the hider and the communicator changed their roles, although their characters remained the same for the same raven during this phase and the following true and false belief experiment (Sup. Information Tab. 1).

False belief & true belief experiment

Both conditions started the same as the previous conditions of the second familiarisation phase. After the hider hid the bait under cover e.g. A, the false belief, and the true belief conditions differed, summarised in Table 2 and Figure 4.

In the true belief condition, the communicator stayed in the room and observed the following bait displacement by the hider. The hider tilted the cover by 45° (Figure 3) so that the edge facing the raven still touched the experimental board and the raven could not see behind it. The bait is picked up by the hider and after replacing cover A the hider transferred the bait at eye level of the raven, tilts cover e. g. B by 45°, put the bait underneath but sneakily removed the bait while lowering the cover. None of the three covers were baited. The hider stepped a step back and both experimenters left the scene. After 5 seconds, only the communicator came back and took a position which was one step away from the centre of the experimental board. The communicator steps forward, always behind the cover where the hider first hid the bait (here: A) and pointed on the cover with the index finger like in the previous conditions. Thereafter, the board was pushed by the communicator to the fence.

The difference to the false belief condition was that the communicator left before the bait displacement took place and was thus ignorant. The hider transferred the bait in the presence of the raven and left after the sneaky removal of the bait. Five seconds later only the communicator returned and indicated as in the true belief condition only the place where the food was first hidden.

These two not baited conditions were combined with the baited FP2 conditions for motivational reasons.

Figure 3: The wooden cover was tilted by 45 degrees during the false and true belief trials to prevent that the raven observed the removing of the bait. (Photo credit: Adrian Hiß)

Table 2: Summary of the false belief & true belief experiment workflow, which is based on the study by Lonardo et al., (2021). Bold words indicate differences between the two conditions. For a visual description see Figure 4.

	False Belief	**True Belief**
1	• Communicator (C) and Hider (H) were in the experimental room • Raven separated in a neighbour room, but had visual access to the experimental room	
2	H hid the bait in the hiding place A in full visibility of C & the raven	
3	C **left** in the room.	C **stayed** the room.
4	• H made sure raven is watching • H transferred the bait from the hiding place A to B, but sneakily removed the bait after it was hidden in B	
5	H left the room	H & **C left** the room
6	C returned, went to neutral position, then to place A, and pointing on A, went back to neutral position	
7	Raven was allowed to decide	

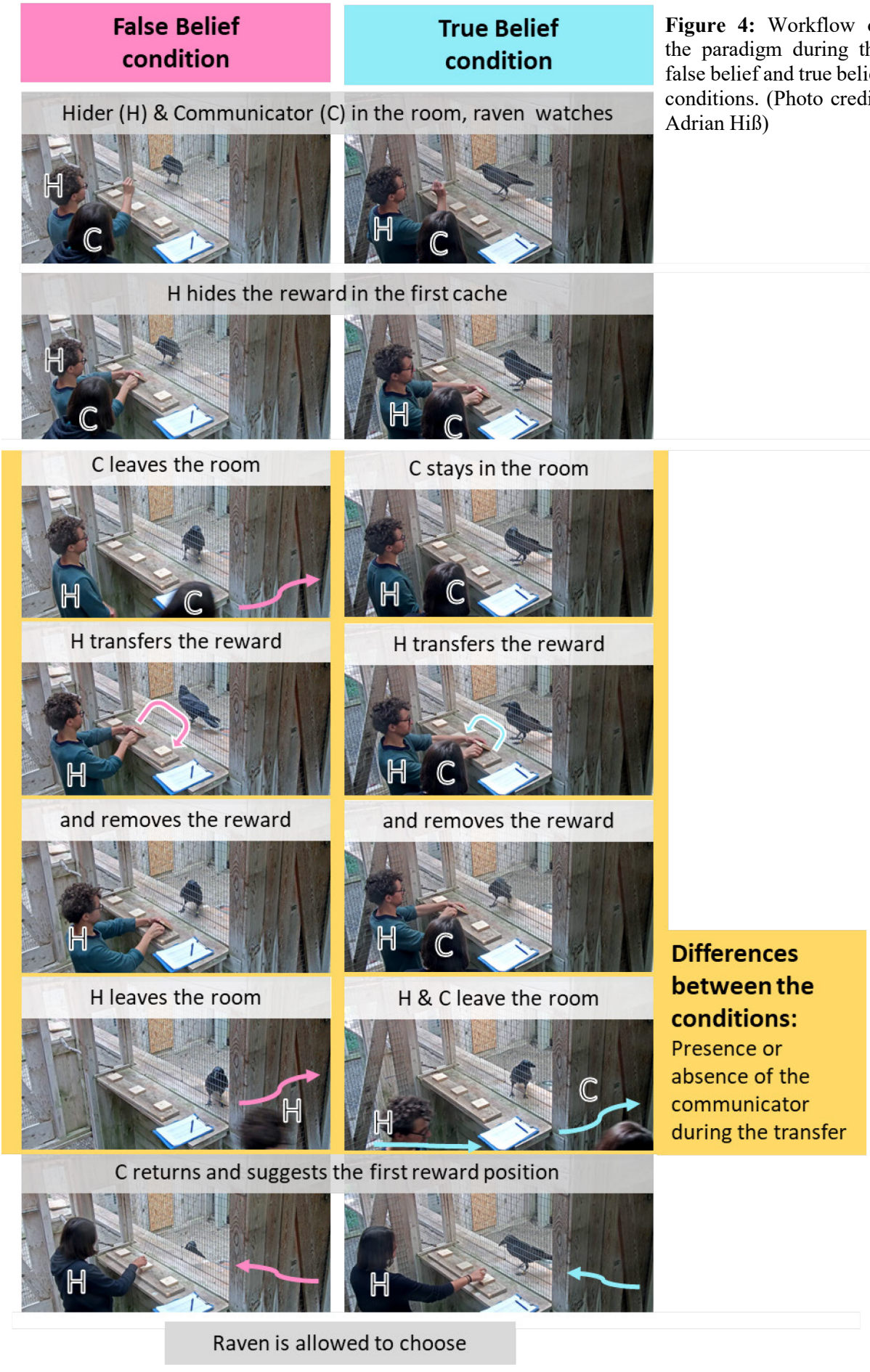

Figure 4: Workflow of the paradigm during the false belief and true belief conditions. (Photo credit: Adrian Hiß)

Analysis & Statistics

The experiments were video recorded with the camera system of the Haidlhof Research Station mounted on the ceiling of the test compartment.

In familiarisation phase 1, all nine ravens participated. Each raven had in total 12 trials of the each of the four conditions, which were organised in three sessions. One session consisted of 16 trials and was divided in two blocks with eight trials. Of these eight trails, two were from each condition and directly followed each other (4 x 2). The order of the conditions in one block of the session was pseudorandomised. Some ravens were more engaged in testing if another raven from the group with whom they had a good relationship was also in the testing compartment. The companion animal was in another separate area and had no direct contact with the test subject or the experimenters. This was the case for Janis, Harriet and Romi.

In familiarisation phase 2, all nine birds participated, but two had to be excluded from the analysis due to a side bias (Sup. Information Tab. 2). This phase had 18 trials for each condition and 3 sessions in total. One session consisted of two blocks which itself had 12 trials each. Three of the 12 trials were from the same condition and were consecutive. The order of the conditions during one session were pseudorandomised.

The true belief and false belief experiments consisted in total of 12 true belief and false belief trials respectively. Each of the six sessions, was organised into two blocks. Each block had one false and one true belief trial. Trials form the *invisible-without-displacement, visible-with-displacement* and *visible-without-displacement* conditions of the familiarisation phase 2 were interspersed. That means, each block had in total 11 trials, two belief trials plus three trials of each of the three conditions. The order was pseudorandomised.

As soon as the experimental board was pushed towards the mesh, the raven could make a decision. Once a cover was touched by the ravens' beak, I defined and coded it as a decision. When the tested raven did not make a decision for 4 minutes in the familiarisation phase 1, which happened only once with Janis during its first trial of the *invisible with displacement* condition, I went on with the next trial. During the familiarisation phase 2 and the experimental phase, trials were repeated, if during the procedure the tested raven was distracted by other members of the social group which made sounds in front of the test compartment or by the wild raven flock's calls.

A second coder, who was unfamiliar with the ravens, coded 10% of the true and false belief trials. The inter-observer reliability was excellent (Cohen's Kappa = 1.0).

The data, the statistics and graphics were computed and analysed with R (version 4.2.0; Core R Team, 2019) and R studio (version 2022.2.1.461; (RStudio Team, 2022)). The following package was used to calculate Cohens Kappa: DescTools (Version 0.99.45).

First, for all three experimental phases, the binomial test was used to check for a potential individual side bias of the ravens. The variables were: x, which was the frequency of choosing the cover, n, which was the number of trials of each condition (FP1: n=12 ; FP2: n=18; TB-FB: n=12; interspersed FP2 during TB-FB: n=36) and p, which was the probability of choosing one of the covers (FP1: p=0.25 ; FP2: p=0.333; TB-FB: p=0.333; interspersed FP2 during TB-FB: p=0.333). Birds were excluded from further analysis, when the binomial test resulted in two visible conditions of the same phase for one of the cover locations in a p-value smaller than 0.05 (results: Sup. Information Tab. 2). A side preference in the invisible condition was tolerable. Two ravens, Janis and Harriet, had to be excluded due to a side bias in the analysis of familiarisation phase 2 and the final true and false belief experiments.

A visual analysis of the quantile-quantile plots for each condition and phase revealed that the data of the conditions did not follow a normal distribution. Thus, non-parametric tests were used for the further analysis. The two-sided wilcoxon-one-sample-test was used to check if the raven's selection rate of each condition was different from the chance level (results: Sup. Information Tab. 3). The wilcoxon-two-sample-test, two-sided, was calculated to test for differences between the conditions (results: Sup. Information Tab. 4).

Results

Results FP1

The experiments of the first familiarisation phase showed that when the ravens (n=9) saw the hiding of the bait, the ravens chose in both conditions the baited cover significantly more often than at chance level, regardless of whether a bait displacement took place or not (Wilcoxon one sample, $p<0.05$, see Sup. Information Tab. 3 and Figure 5). The selection rate was 8 out of 12 in the *visible-without-displacement* condition versus 4 out of 12 in the *invisible-without-displacement* condition (Wilcoxon two sample, $p<0.05$) and 9 out of 12 in the *visible-with-displacement* condition versus 3 out of 12 in the *invisible-with-displacement* (Wilcoxon two sample, $p<0.05$). In both invisible conditions, the selection rate of the baited cover was close or at chance level of 25% indicating that there was no cue which helped them to solve the task (Wilcoxon one sample, $p>0.05$, see Sup. Information Tab. 3).

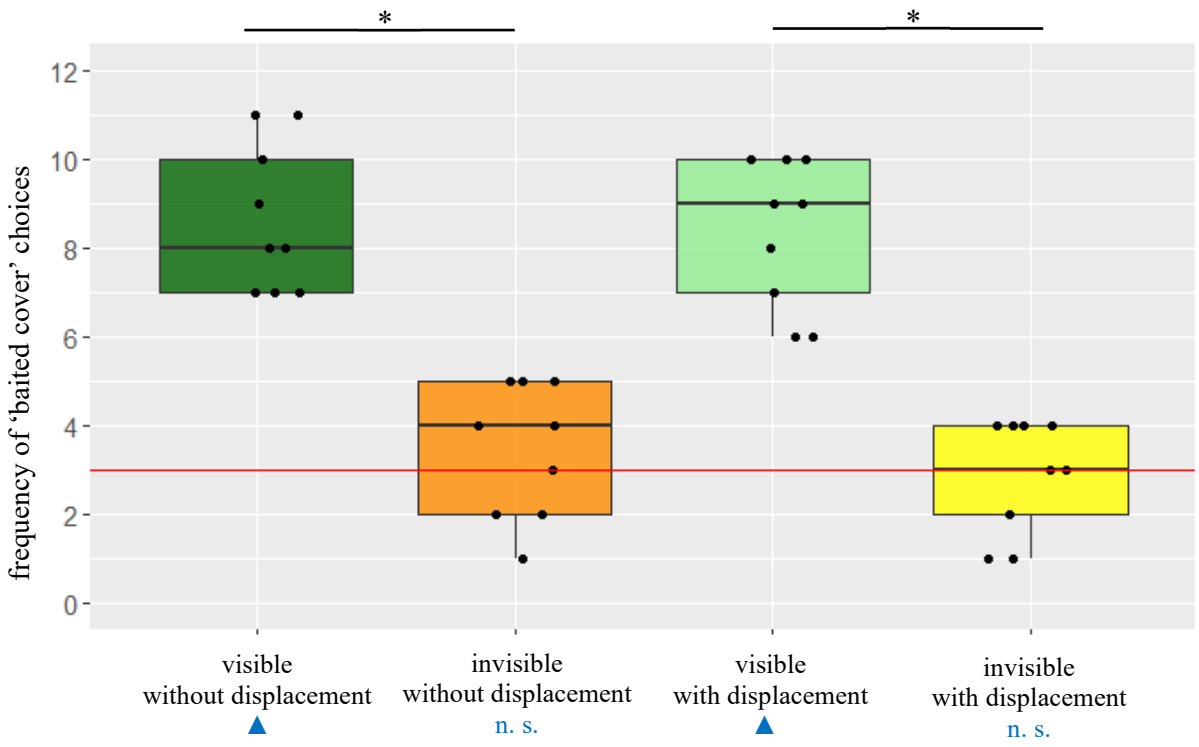

Figure 5: Familiarisation phase 1. A hider hid the bait beneath one of the four covers. Ravens (n=9) choose the cover where a bait was hidden on chance level when they could not see the hiding process, which is indicated by the red line. Four covers and 12 trials result in a chance level of 3 correct trials. Witnessing the hiding process let to an increase in choosing the baited cover, also when a displacement from one to another cover of the bait happened. Each condition had 12 trials. In the *invisible with displacement* condition, one bird which chose the baited cover only once in this condition, had only 11 trials instead of 12 as it did not choose a cover during one trial. The * indicate a significant difference between two conditions (Wilcoxon two sample $p<0.05$) and the blue ▲ for the difference between the chance level and each condition respectively (Wilcoxon one sample $p<0.05$).

Results FP2

Across three conditions of the second familiarisation phase, ravens (n=7) significantly selected the baited cover above the chance level, which was located at six trials (Wilcoxon one sample, $p<0.05$, see Sup. Information Tab. 3). In this phase I excluded two ravens from the analysis, Janis and Harriet, as they showed a side bias for both visible conditions (Binomial test (n=18, p=0.333, x); $p<0.05$, Sup. Information Tab. 2). Ravens took the additional communicator's pointing gesture as supportive as they solved the *invisible-without-displacement* condition in 11 out of 18 trials (Figure 6). The chance level and the selection rate of the *invisible-with-displacement* condition was close to a significant difference (Wilcoxon one sample, p=0.06). Compared to the other three conditions, all birds showed a drop in their performance in this condition except Kofi. The raven Kofi appeared as an outlier with a rate of 4 out of 18 trials in the *invisible-without-displacement* condition but showed an improvement when the invisible displacement took place (9 out of 18).

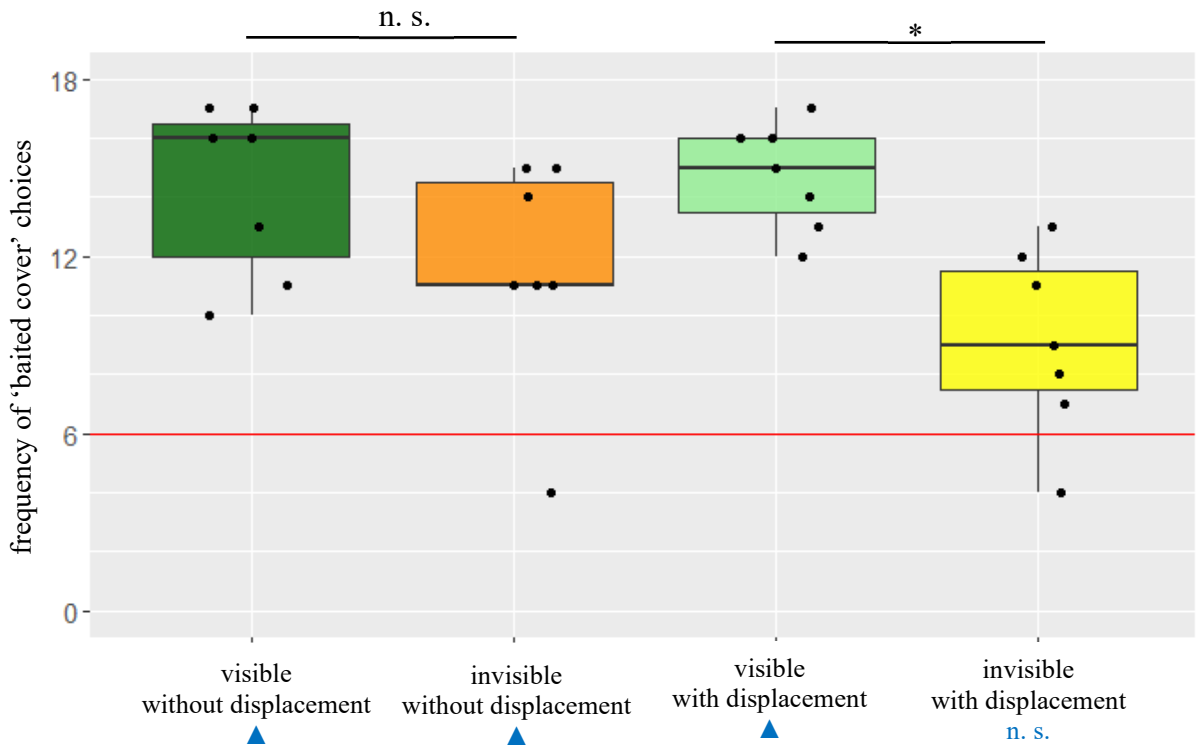

Figure 6: Familiarisation phase 2. A hider hid the bait beneath one out of three covers. The second experimenter, the communicator, indicated to the raven (n=7) the true location of the bait before the raven could make its decision. Each condition had 18 trials. In one invisible and in the two visible conditions ravens choose above chance level the baited cover. The chance level is indicated by the red line. Three covers and 18 trials result in a chance level of six correct trials. The * indicate a significant difference between two conditions (Wilcoxon two sample, $p<0.05$) and the blue ▲ for the difference between the chance level and each condition respectively (Wilcoxon one sample, $p<0.05$).

Results true belief & false belief experiment

In the false belief and in the true belief condition ravens (n=7) were, contrary to my prediction, less likely to choose the cover where the bait was transferred to (Figure 7). Only in 17% of the true belief trials and in 25% of the false belief trials the baited cover was chosen, which differed not significantly from the chance level of 33% respectively (Wilcoxon one sample, $p>0.05$, see Sup. Information Tab. 3). Instead, the cover which was suggested by the communicator was chosen by the seven birds in 66% of the trials in the true belief and in the false belief condition (not visualised).

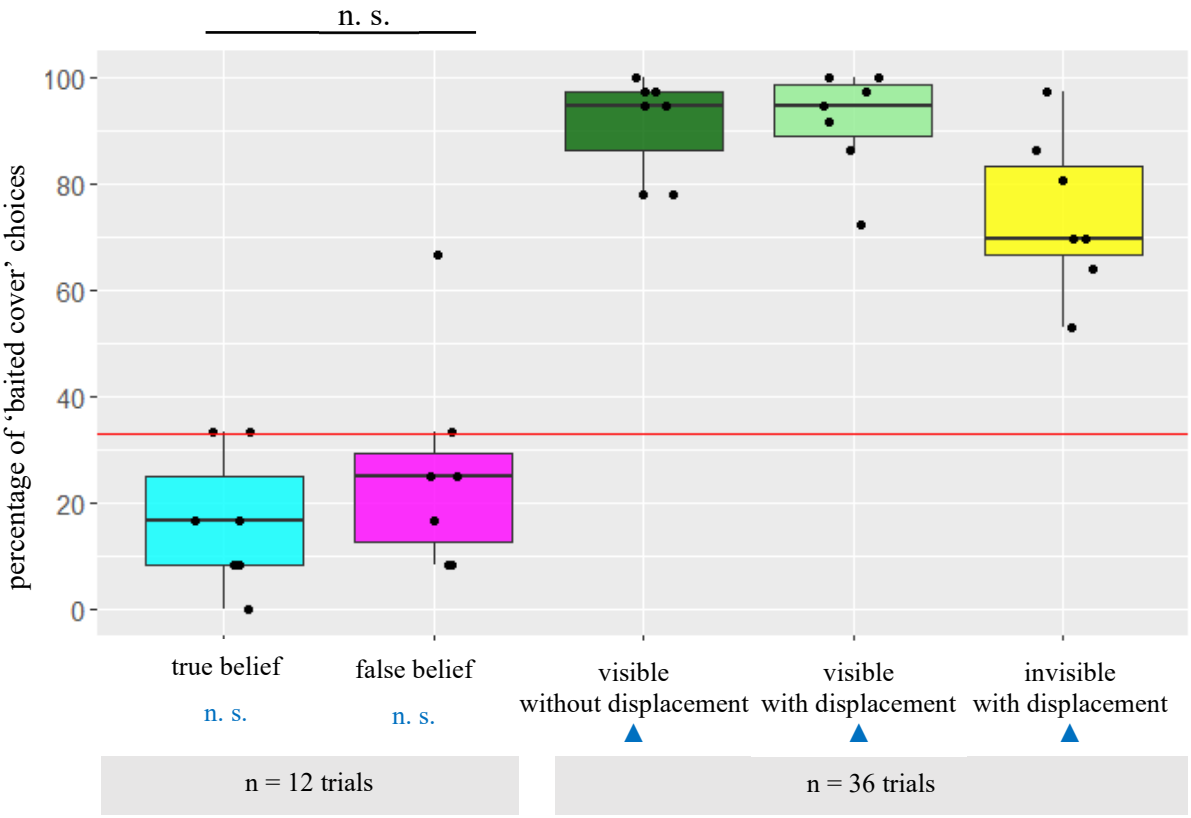

Figure 7: True belief and false belief experiment. A hider hid the bait beneath on of 3 covers while the raven watched. Either in the presence (true belief) or absence (false belief) of the communicator the bait was transferred to a second cover. The ravens (n=7) could choose one of the covers after the communicator showed interest in both conditions for the cover where the bait was hidden before the transfer (true belief & false belief: n=12 trails, unrewarded, as the bait was sneakily removed). To keep the motivation high, there were trials of three baited conditions (each n=36) from the second familiarisation phase interspersed between the false and true belief trials. The blue ▲ indicates a significant difference between the chance level and each condition respectively (Wilcoxon one sample, $p<0.05$). The chance level is indicated by the red line (three covers in all five conditions result in a chance level of 33%).

For the second prediction, namely that ravens select more often the baited cover in the false belief trials than in the true belief trials, it turned out that against the prediction ravens selected in the false belief trials and in the true belief trials equally often the baited cover

(Wilcoxon two sample $p>0.05$). Only one raven behaved according to the prediction: Kofi, selected more often in the false belief condition the baited cover (Table 3, Figure 7).

The selection rate of the baited cover in the other three baited conditions were clearly above the chance level respectively (Wilcoxon one sample, $p<0.05$, see Sup. Information Tab. 3). Two birds, Zazou and Pico, went in the visible displacement condition in all of the 36 trials for the baited cover, which was suggested by the communicator.

Table 3: Individual performance in the false and true belief experiment. For each condition and raven the proportion of choosing the cover where the bait has been transferred to is noted and highlighted by the colour. A blue cell with a "1" means that in all trials the cover was chosen where the bait has been transferred to. The * indicates that the bird was left out in the final analysis due to a side bias.

	Conditions				
	Visible & No Displacement	**Visible & Displacement**	**Invisible & Displacement**	**True Belief**	**False Belief**
number of trials:	36	36	36	12	12
Harriet*	0.78	0.56	0.47	0.33	0.42
Janis*	0.53	0.42	0.31	0.42	0.17
Kai	0.97	0.94	0.69	0.00	0.08
Kofi	0.78	0.72	0.53	0.33	0.67
Murphy	0.47	0.44	0.39	0.08	0.33
Pico	0.97	1.00	0.97	0.08	0.25
Quito	0.94	0.97	0.86	0.17	0.17
Romi	0.36	0.42	0.42	0.33	0.25
Zazou	1.00	1.00	0.69	0.17	0.08

Results Selection sequence in the true and false belief condition

A descriptive analysis of the selection sequence of the 12 true belief and the 12 false belief trails reveals no pattern, e. g. that the birds did not choose differently in the first encounters than at a later time (Figure 8). But interestingly, Kai never went for the 2nd cover in the true belief condition and only once in the false belief condition. Additionally, all birds went at least once for the third cover which was not part of the respective trial (Figure 8).

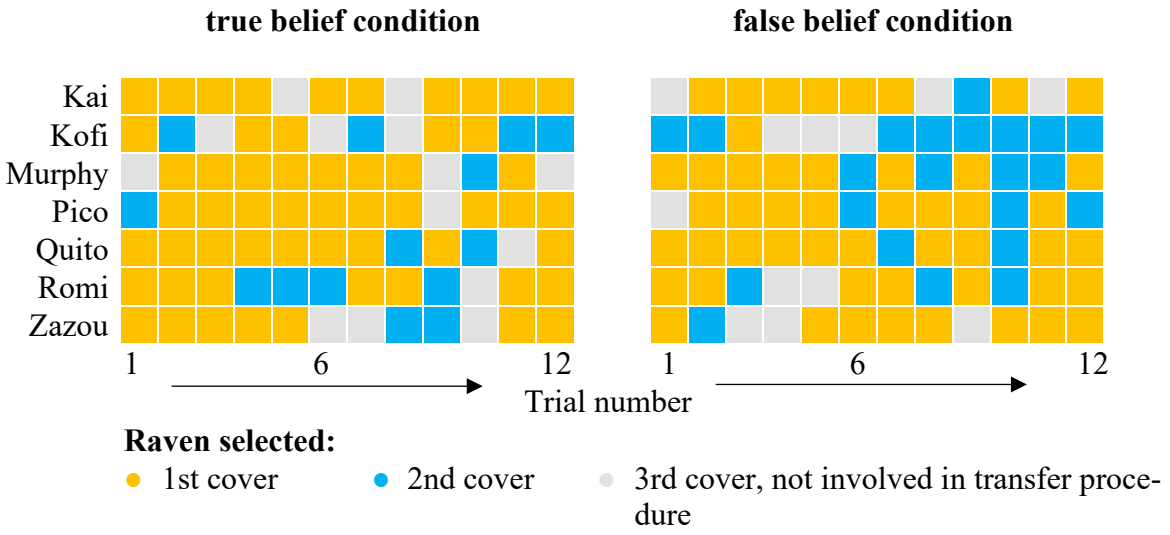

Figure 8: Selection sequence of 7 ravens. Each raven was exposed to two true belief trials and to two false belief trials during the same session, which had 22 trials in total. Each true or false belief trial was separated by trials of the other three conditions and pseudo randomised over the session. During a false belief and true belief trials ravens could choose between one of the 3 covers, one, where the hider hid the bait in the beginning, a second, where the hider transferred the bait to and sneakily removed it, or a third, which was not involved during the same trial.

Discussion

The goal of this study was to determine whether ravens are capable of attributing true and false beliefs to others and thus have a comprehensive Theory of Mind. Against my first prediction, ravens followed the misleading cue by a human actor in the true belief and in the false belief condition more frequently instead of selecting the cover where the bait was transferred to. Also, contrary to my second prediction, namely that ravens favour to choose the suggested location more often in the true belief condition, I found that the selection rate of the bait's true location did not differ between the two conditions. The misleading suggestion came from a human experimenter who had either a true belief or a false belief about the location of a bait. This difference was used to investigate if ravens follow this misleading cue even, they knew the true location of the bait.

The first familiarisation phase revealed that in absence of any cueing event the ravens chose the baited cover only when they saw the hiding process. If ravens did not witness the hiding of the bait, then they were only as good as the chance level, which indicates that ravens did not use olfactory cues. With the cuing of the communicator in the second familiarisation phase, ravens were able to find the baited cover, although they had not noticed the hiding process. Interestingly, the selection rate of the baited cover was not different from the chance level when hiding took seven seconds longer because of the hidden bait transfer in *the invisible-with-displacement*-condition. However, in the trials of the same condition which were interspersed between the false and true belief conditions of the final experiment, the performance of the ravens improved. The ravens showed that they chose the baited cover more frequently than the chance level. The ability to follow a pointing cue even though the hiding of the bait was invisible was also shown in Pika et al. (2020).

The true belief and false belief conditions differed only in the presence or absence of the communicator during the bait transfer. Apart from this difference, both conditions were structured the same. Both experimenters left and returned with equal rates and the communicator always suggested the bait's initial location. From the difference if the communicator was present during the bait transfer, it could be deduced that the communicator had a false belief and thought that the bait is still at the initial location.

The design of this thesis was based on the study by Lonardo et al. (2021), which itself is based on two studies by Buttelmann et al. (Infants: Buttelmann et al., 2009; Non-human apes: Buttelmann et al., 2017). Non-human apes unlocked the box containing the item desired by the experimenter more often in the false belief condition and equally often in the true belief

condition (Buttelmann et al., 2017). Similar to the study with 18-months-old infants, in which the infants approached the box containing the toy also more often in the false belief condition, but not in the true belief condition, here they preferred the box which was suggested by the experimenter (Buttelmann et al., 2009). Lonardo et al. (2021) showed in two experiments with 180 dogs (belonging to different breeds) that contrary to the experiments with non-human apes and infants more dogs chose in the false belief than in true belief condition the suggested bucket. In a third experiment, when only terrier and border collies were tested, the results were for the border collies similar to the first two experiments, but for terriers the same selection pattern from the ape and infant study appeared (Lonardo et al., 2021). Ravens in contrast chose the suggested cover more often but with an equal rate in the true belief and in the false belief condition and thus did not differentiate between false belief and true belief trials like infants, non-human apes and dogs did. Interestingly only one bird, Kofi, acted similar to my second prediction: Kofi chose in the false belief condition the second cover in 8 out of 12 trials, while in the true belief condition it preferred to choose the suggested cover in 5 out of 12 trials. It is also the raven, which got sick starting 8 months after hatching and needed special care by humans at that time. It remains unknown whether the described result and the particular treatment have common causes. Future cognitive studies should look more closely at Kofi.

Notable differences between the methodology used in this study and also in the study by Lonardo et al. (2021) compared to the two studies by Buttelmann et al. (2009, 2017) were the relation of the experimenter to the hidden object and the behavioural change of the communicator. In both studies by Buttelmann et al. the hidden objects (infants: toy, non-human apes: orange box) were neutral to the tested subject and desired by the experimenter. In this study and the study by Lonardo et al. (2021) the objects were food pieces and thus desired by the tested subject and not interesting for the experimenter. Theoretically, in the true belief conditions of the two studies by Buttelmann et al. the experimenter searching for the object had a higher motivation to find it. If the experimenter shows interest in the original hiding place the tested subject could think that the experimenter would like to show something as the experimenter was aware of the transfer. Contrary in this raven study and the dog-study the experimenter had less motivation to look for the right place as the experimenter was not interested in the food object. Hence the point that the experimenter would like to show something new to the tested subject might be comparable weaker. Likewise, the experimenter had no own interest to find the object in the false belief condition as the bait was for the raven. This results that the potential contrast between the true belief and the false belief condition is weaker compared to the ‘helper-design’ by Buttelmann et al. (2009, 2017).

Additionally, the cost of not receiving four rewards, each time a quarter of a frolic®, on one day was also not very high, since they were baited on the same day in 18 other trials, which had a reliable communicator. On the other hand, outside the experiment, ravens spared no effort to seek out even the smallest piece of frolic®-rewards, as I have been able to observe.

Another difference was that the ravens had three hiding places to choose from, of which only two were used during the same trail. I introduced the third option to have a better control for a potential guessing on chance level behaviour. Ravens went for the third option between one and three times in the true or false belief condition. Notable, my study design was a within-subject design and ravens had 12 exposures in both, true belief and false belief, conditions. All other three studies have been a between-subject design.

The hidden object (non-food) of the two Buttelmann studies were not sneakily removed, while in this study and in the dog study the bait was hidden and sneakily removed. The reason for the removing was that the experimenter should not reward one of the possible places where the food could be and thus influence indirectly the choosing rate as in my study ravens participated in 12 false belief and 12 true belief trials. A descriptive analysis of which cover was preferred in the beginning of the experiments and which in the end revealed that ravens choose from the beginning onwards the suggested cover.

The communicator was suddenly deceitful in the false belief and true belief trials after a helpful communicator role during the familiarisation phases. In the studies with non-human apes (Buttelmann et al., 2017) and infants (Buttelmann et al., 2009), the experimenter who matched the role of the communicator (interacting with the empty box in false belief & true belief trials) was either not present (non-human apes) or had a neutral role (infants) during the training trials and was looking for help while unsuccessfully trying to open the empty box. In this role the communicator could not be seen as not reliable. Interestingly, the ravens did not choose according to their knowledge in both conditions, as in both conditions they have seen the transfer of the bait and preferred to choose the location where the communicator was pointing on. The false belief and true belief trials were interspersed between trials which were the same as the trials of the second familiarisation phase to keep the motivation high and which had not a deceitful communicator.

In summary, I found no evidence that ravens could represent what others believe, but this finding could also have resulted from limitations of my study design. There is the possibility, which has not further been tested in my study, that the familiarisation phase 2 influenced the outcome of the final true and false belief experiments. Ravens might have connected the pointing gesture and thus the decision of the communicator as positive for them. Additionally,

ravens might be very focused on social cues. This could be especially the case for the hand-raised ravens from my study. Observations by C. Blum, who was part of the study Pika et al. (2020), seems to highlight this point. His observations showed that ravens often displayed a recency bias, i.e., subjects preferentially went to the place that was touched last by the experimenter (personal communication, July 8, 2022). His observations and my results emphasise the importance to control for this in the experimental design of future studies.

A possible next step could be to test birds for an implicit false belief understanding. Eye-tracking techniques have proven to be a powerful technique and have contributed to expand the understanding of social cognition in non-human primates (Lewis and Krupenye, 2022). Given that non-human apes and macaques passed anticipatory-looking false belief tests (Hayashi et al., 2020; Kano et al., 2019; Krupenye et al., 2016), potential future experiments where the gaze of the birds is tracked could reveal interesting insights. Eye-tracking techniques have already been successfully used in birds (invasive: (Schwarz et al., 2013), non-invasive: (Tyrrell et al., 2014; Tyrrell et al., 2015; Yorzinski et al., 2013; Yorzinski et al., 2015; Yorzinski et al., 2017)). Kano et al. (2020) outline that it is possible that in anticipatory looking paradigms only paradigms with stimulating content might uncover the comprehensive cognitive capacities of primates (Kano et al., 2020). In this context it could be important to develop a paradigm with a social stimuli like the play in Krupenye et al. (2016) to motivate birds to focus and track the actions of the representatives in the play. Horschler et al. 2020 argued to interpret the three recent anticipatory looking studies by Hayashi et al. (2020), Kano et al. (2019) and Krupenye et al. (2016) with caution as anticipatory looking paradigms have a replication problem in the human literature. Further, Horschler et al. (2020) state that the three studies face theoretical challenges too and used also different primary measures such as first look and the differential looking score (For a discussion to this critique see: (Horschler et al., 2020b; Kano et al., 2020) but also the review on eye-tracking in primate research: (Lewis and Krupenye, 2022)). Nevertheless, pioneering work in which birds are tested in a false belief anticipatory looking paradigm could bring interesting new insights and if it includes a control for ignorance and an analysis of all three measurements (first look, total looking time and the differential looking score) it would provide a good basis for comparison.

Conclusion

Ravens preferred to choose the location indicated by a human although they knew that the bait was already transferred to a second position, providing no evidence for the study subjects'

capacity to ascribe beliefs to others. The experience of the ravens in the second familiarisation phase and the interspersed trials of the familiarisation phase 2 between the false and true belief trials might have influenced the choosing behaviour in the final experiment. The knowledge of the ravens, about the current position of the bait, was no longer decisive for their actions. Future experiments should focus on finding a way to test birds in an implicit test design. The fascinating questions remain whether species outside the primate lineage are capable of attributing false beliefs and which neuronal structures and properties are required for a comprehensive Theory of Mind.

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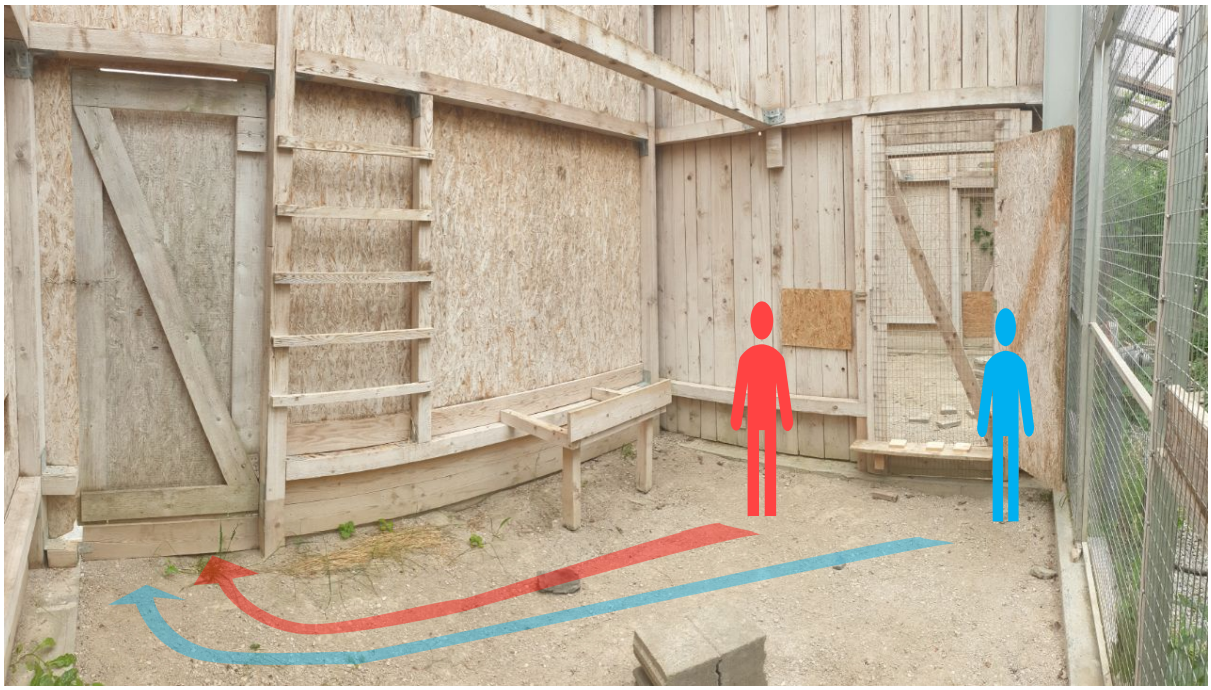
Supplementary Information:

Figures:



Sup. Information Fig. 1: The true and false belief experiments with the raven Zazou were conducted in another aviary. Zazou was located behind the wire mesh door. The person in red is the communicator, the person in blue the hider. The arrows indicate the paths of the two experimenters. Zazou was kept with her social partner in this aviary, which is attached to an outdoor compartment with trees and a mesh roof. (Photo credit: Adrian Hiß)

Tables:

Sup. Information Tab. 1: The roles of the two experimenters within the FP2 and the true belief and false belief experiments.

Raven	*Hider*	*Communicator*
Harriet	Man	Woman 1
Janis	Woman 1	Man
Kai	Man	Woman 2
Kofi	Man	Woman 1
Murphy	Woman 2	Man
Pico	Woman 1	Man
Quito	Man	Woman 2
Romi	Man	Woman 2
Zazou	Woman 2	Man

Sup. Information Tab. 2: A Binomial test was used to check for a potential side bias, with x= the frequency of choosing the cover, n= number of trials and p= the probability of choosing one of the covers. Birds with a resulting p-value < 0.05 are highlighted in red in the visible conditions. Having two visible conditions in the same phase with p-value<0.05 led to an exclusion for further analysis in the respective phase due to a potential side bias and is indicated by an *. A side preference in the invisible condition was tolerable. Colours of the condition column correspond to colours which were used in the result chapter for the different conditions. Input values of the binomial test: FP1: a) & b) n=12, p=0.25; FP2: c) & d) n=18, p= 0.333; true belief & false belief condition: e) n=12, p=0.333; other conditions: n=36, p=0.333.

a)	**FP1** - Hiding process *invisible* to the raven			
name	**choice**	**frequency**	**p-value**	**condition**
Harriet	A	10	0.00	No displacement, invisible to raven
Harriet	B	2	0.74	No displacement, invisible to raven
Harriet	C	0	0.05	No displacement, invisible to raven
Harriet	D	0	0.05	No displacement, invisible to raven
Janis	A	2	0.74	No displacement, invisible to raven
Janis	B	7	0.01	No displacement, invisible to raven
Janis	C	3	1.00	No displacement, invisible to raven
Janis	D	0	0.05	No displacement, invisible to raven
Kai	A	1	0.32	No displacement, invisible to raven
Kai	B	7	0.01	No displacement, invisible to raven
Kai	C	4	0.51	No displacement, invisible to raven
Kai	D	0	0.05	No displacement, invisible to raven
Kofi	A	3	1.00	No displacement, invisible to raven
Kofi	B	6	0.09	No displacement, invisible to raven
Kofi	C	2	0.74	No displacement, invisible to raven
Kofi	D	1	0.32	No displacement, invisible to raven
Murphy	A	3	1.00	No displacement, invisible to raven
Murphy	B	3	1.00	No displacement, invisible to raven
Murphy	C	3	1.00	No displacement, invisible to raven
Murphy	D	3	1.00	No displacement, invisible to raven
Pico	A	0	0.05	No displacement, invisible to raven
Pico	B	4	0.51	No displacement, invisible to raven
Pico	C	5	0.19	No displacement, invisible to raven
Pico	D	3	1.00	No displacement, invisible to raven
Quito	A	2	0.74	No displacement, invisible to raven
Quito	B	2	0.74	No displacement, invisible to raven
Quito	C	4	0.51	No displacement, invisible to raven
Quito	D	4	0.51	No displacement, invisible to raven
Romi	A	2	0.74	No displacement, invisible to raven
Romi	B	3	1.00	No displacement, invisible to raven
Romi	C	5	0.19	No displacement, invisible to raven
Romi	D	2	0.74	No displacement, invisible to raven
Zazou	A	0	0.05	No displacement, invisible to raven
Zazou	B	2	0.74	No displacement, invisible to raven
Zazou	C	5	0.19	No displacement, invisible to raven
Zazou	D	5	0.19	No displacement, invisible to raven
Harriet	A	9	0.00	displacement, invisible to raven

Harriet	B	3	1.00	displacement, invisible to raven
Harriet	C	0	0.05	displacement, invisible to raven
Harriet	D	0	0.05	displacement, invisible to raven
Janis	A	2	0.74	displacement, invisible to raven
Janis	B	6	0.09	displacement, invisible to raven
Janis	C	0	0.05	displacement, invisible to raven
Janis	D	3	1.00	displacement, invisible to raven
Kai	A	4	0.51	displacement, invisible to raven
Kai	B	5	0.19	displacement, invisible to raven
Kai	C	3	1.00	displacement, invisible to raven
Kai	D	0	0.05	displacement, invisible to raven
Kofi	A	4	0.51	displacement, invisible to raven
Kofi	B	5	0.19	displacement, invisible to raven
Kofi	C	2	0.74	displacement, invisible to raven
Kofi	D	1	0.32	displacement, invisible to raven
Murphy	A	3	1.00	displacement, invisible to raven
Murphy	B	4	0.51	displacement, invisible to raven
Murphy	C	3	1.00	displacement, invisible to raven
Murphy	D	2	0.74	displacement, invisible to raven
Pico	A	0	0.05	displacement, invisible to raven
Pico	B	3	1.00	displacement, invisible to raven
Pico	C	5	0.19	displacement, invisible to raven
Pico	D	4	0.51	displacement, invisible to raven
Quito	A	2	0.74	displacement, invisible to raven
Quito	B	5	0.19	displacement, invisible to raven
Quito	C	3	1.00	displacement, invisible to raven
Quito	D	2	0.74	displacement, invisible to raven
Romi	A	2	0.74	displacement, invisible to raven
Romi	B	5	0.19	displacement, invisible to raven
Romi	C	2	0.74	displacement, invisible to raven
Romi	D	3	1.00	displacement, invisible to raven
Zazou	A	1	0.32	displacement, invisible to raven
Zazou	B	2	0.74	displacement, invisible to raven
Zazou	C	2	0.74	displacement, invisible to raven
Zazou	D	7	0.01	displacement, invisible to raven

b) **FP1** - Hiding process *visible* to the raven

name	choice	frequency	p-value	condition
Harriet	A	3	1.00	displacement, visible to raven
Harriet	B	8	0.00	displacement, visible to raven
Harriet	C	0	0.05	displacement, visible to raven
Harriet	D	1	0.32	displacement, visible to raven
Janis	A	5	0.19	displacement, visible to raven
Janis	B	5	0.19	displacement, visible to raven
Janis	C	2	0.74	displacement, visible to raven
Janis	D	0	0.05	displacement, visible to raven

Kai	A	4	0.51	displacement, visible to raven
Kai	B	4	0.51	displacement, visible to raven
Kai	C	2	0.74	displacement, visible to raven
Kai	D	2	0.74	displacement, visible to raven
Kofi	A	3	1.00	displacement, visible to raven
Kofi	B	5	0.19	displacement, visible to raven
Kofi	C	4	0.51	displacement, visible to raven
Kofi	D	0	0.05	displacement, visible to raven
Murphy	A	3	1.00	displacement, visible to raven
Murphy	B	3	1.00	displacement, visible to raven
Murphy	C	5	0.19	displacement, visible to raven
Murphy	D	1	0.32	displacement, visible to raven
Pico	A	3	1.00	displacement, visible to raven
Pico	B	2	0.74	displacement, visible to raven
Pico	C	3	1.00	displacement, visible to raven
Pico	D	4	0.51	displacement, visible to raven
Quito	A	3	1.00	displacement, visible to raven
Quito	B	1	0.32	displacement, visible to raven
Quito	C	5	0.19	displacement, visible to raven
Quito	D	3	1.00	displacement, visible to raven
Romi	A	3	1.00	displacement, visible to raven
Romi	B	3	1.00	displacement, visible to raven
Romi	C	5	0.19	displacement, visible to raven
Romi	D	1	0.32	displacement, visible to raven
Zazou	A	3	1.00	displacement, visible to raven
Zazou	B	3	1.00	displacement, visible to raven
Zazou	C	2	0.74	displacement, visible to raven
Zazou	D	4	0.51	displacement, visible to raven
Harriet	A	5	0.19	No displacement, visible to raven
Harriet	B	5	0.19	No displacement, visible to raven
Harriet	C	2	0.74	No displacement, visible to raven
Harriet	D	0	0.05	No displacement, visible to raven
Janis	A	2	0.74	No displacement, visible to raven
Janis	B	5	0.19	No displacement, visible to raven
Janis	C	4	0.51	No displacement, visible to raven
Janis	D	1	0.32	No displacement, visible to raven
Kai	A	3	1.00	No displacement, visible to raven
Kai	B	5	0.19	No displacement, visible to raven
Kai	C	2	0.74	No displacement, visible to raven
Kai	D	2	0.74	No displacement, visible to raven
Kofi	A	5	0.19	No displacement, visible to raven
Kofi	B	6	0.09	No displacement, visible to raven
Kofi	C	1	0.32	No displacement, visible to raven
Kofi	D	0	0.05	No displacement, visible to raven
Murphy	A	5	0.19	No displacement, visible to raven
Murphy	B	2	0.74	No displacement, visible to raven
Murphy	C	3	1.00	No displacement, visible to raven
Murphy	D	2	0.74	No displacement, visible to raven

Pico	A	2	0.74	No displacement, visible to raven
Pico	B	3	1.00	No displacement, visible to raven
Pico	C	3	1.00	No displacement, visible to raven
Pico	D	4	0.51	No displacement, visible to raven
Quito	A	2	0.74	No displacement, visible to raven
Quito	B	5	0.19	No displacement, visible to raven
Quito	C	1	0.32	No displacement, visible to raven
Quito	D	4	0.51	No displacement, visible to raven
Romi	A	3	1.00	No displacement, visible to raven
Romi	B	4	0.51	No displacement, visible to raven
Romi	C	2	0.74	No displacement, visible to raven
Romi	D	3	1.00	No displacement, visible to raven
Zazou	A	3	1.00	No displacement, visible to raven
Zazou	B	1	0.32	No displacement, visible to raven
Zazou	C	3	1.00	No displacement, visible to raven
Zazou	D	5	0.19	No displacement, visible to raven

c) **FP2** - Hiding process *invisible* to the raven

name	choice	frequency	p-value	condition
Harriet	A	14	0.00	No displacement, invisible to raven
Harriet	B	4	0.45	No displacement, invisible to raven
Harriet	C	0	0.00	No displacement, invisible to raven
Janis	A	5	0.80	No displacement, invisible to raven
Janis	B	12	0.00	No displacement, invisible to raven
Janis	C	1	0.01	No displacement, invisible to raven
Kai	A	5	0.80	No displacement, invisible to raven
Kai	B	8	0.32	No displacement, invisible to raven
Kai	C	5	0.80	No displacement, invisible to raven
Kofi	A	9	0.14	No displacement, invisible to raven
Kofi	B	9	0.14	No displacement, invisible to raven
Kofi	C	0	0.00	No displacement, invisible to raven
Murphy	A	3	0.21	No displacement, invisible to raven
Murphy	B	12	0.00	No displacement, invisible to raven
Murphy	C	3	0.21	No displacement, invisible to raven
Pico	A	7	0.62	No displacement, invisible to raven
Pico	B	3	0.21	No displacement, invisible to raven
Pico	C	8	0.32	No displacement, invisible to raven
Quito	A	7	0.62	No displacement, invisible to raven
Quito	B	6	1.00	No displacement, invisible to raven
Quito	C	5	0.80	No displacement, invisible to raven
Romi	A	0	0.00	No displacement, invisible to raven
Romi	B	9	0.14	No displacement, invisible to raven
Romi	C	9	0.14	No displacement, invisible to raven
Zazou	A	5	0.80	No displacement, invisible to raven
Zazou	B	7	0.62	No displacement, invisible to raven
Zazou	C	6	1.00	No displacement, invisible to raven

Harriet	A	14	0.00	displacement, invisible to raven
Harriet	B	4	0.45	displacement, invisible to raven
Harriet	C	0	0.00	displacement, invisible to raven
Janis	A	2	0.05	displacement, invisible to raven
Janis	B	14	0.00	displacement, invisible to raven
Janis	C	2	0.05	displacement, invisible to raven
Kai	A	6	1.00	displacement, invisible to raven
Kai	B	5	0.80	displacement, invisible to raven
Kai	C	7	0.62	displacement, invisible to raven
Kofi	A	7	0.62	displacement, invisible to raven
Kofi	B	10	0.08	displacement, invisible to raven
Kofi	C	1	0.01	displacement, invisible to raven
Murphy	A	6	1.00	displacement, invisible to raven
Murphy	B	8	0.32	displacement, invisible to raven
Murphy	C	4	0.45	displacement, invisible to raven
Pico	A	6	1.00	displacement, invisible to raven
Pico	B	6	1.00	displacement, invisible to raven
Pico	C	6	1.00	displacement, invisible to raven
Quito	A	9	0.14	displacement, invisible to raven
Quito	B	3	0.21	displacement, invisible to raven
Quito	C	6	1.00	displacement, invisible to raven
Romi	A	1	0.01	displacement, invisible to raven
Romi	B	10	0.08	displacement, invisible to raven
Romi	C	7	0.62	displacement, invisible to raven
Zazou	A	7	0.62	displacement, invisible to raven
Zazou	B	6	1.00	displacement, invisible to raven
Zazou	C	5	0.80	displacement, invisible to raven

d) **FP2** - Hiding process *visible* to the raven

name	choice	frequency	p-value	condition
Harriet*	A	10	0.08	displacement, visible to raven
Harriet*	B	8	0.32	displacement, visible to raven
Harriet*	C	0	0.00	displacement, visible to raven
Janis*	A	4	0.45	displacement, visible to raven
Janis*	B	11	0.02	displacement, visible to raven
Janis*	C	3	0.21	displacement, visible to raven
Kai	A	6	1.00	displacement, visible to raven
Kai	B	7	0.62	displacement, visible to raven
Kai	C	5	0.80	displacement, visible to raven
Kofi	A	7	0.62	displacement, visible to raven
Kofi	B	7	0.62	displacement, visible to raven
Kofi	C	4	0.45	displacement, visible to raven
Murphy	A	6	1.00	displacement, visible to raven
Murphy	B	7	0.62	displacement, visible to raven
Murphy	C	5	0.80	displacement, visible to raven
Pico	A	6	1.00	displacement, visible to raven

Pico	B	7	0.62	displacement, visible to raven
Pico	C	5	0.80	displacement, visible to raven
Quito	A	7	0.62	displacement, visible to raven
Quito	B	6	1.00	displacement, visible to raven
Quito	C	5	0.80	displacement, visible to raven
Romi	A	3	0.21	displacement, visible to raven
Romi	B	9	0.14	displacement, visible to raven
Romi	C	6	1.00	displacement, visible to raven
Zazou	A	6	1.00	displacement, visible to raven
Zazou	B	8	0.32	displacement, visible to raven
Zazou	C	4	0.45	displacement, visible to raven
Harriet*	A	13	0.00	No displacement, visible to raven
Harriet*	B	4	0.45	No displacement, visible to raven
Harriet*	C	1	0.01	No displacement, visible to raven
Janis*	A	4	0.45	No displacement, visible to raven
Janis*	B	12	0.00	No displacement, visible to raven
Janis*	C	2	0.05	No displacement, visible to raven
Kai	A	7	0.62	No displacement, visible to raven
Kai	B	6	1.00	No displacement, visible to raven
Kai	C	5	0.80	No displacement, visible to raven
Kofi	A	5	0.80	No displacement, visible to raven
Kofi	B	12	0.00	No displacement, visible to raven
Kofi	C	1	0.01	No displacement, visible to raven
Murphy	A	6	1.00	No displacement, visible to raven
Murphy	B	6	1.00	No displacement, visible to raven
Murphy	C	6	1.00	No displacement, visible to raven
Pico	A	6	1.00	No displacement, visible to raven
Pico	B	5	0.80	No displacement, visible to raven
Pico	C	7	0.62	No displacement, visible to raven
Quito	A	8	0.32	No displacement, visible to raven
Quito	B	4	0.45	No displacement, visible to raven
Quito	C	6	1.00	No displacement, visible to raven
Romi	A	0	0.00	No displacement, visible to raven
Romi	B	12	0.00	No displacement, visible to raven
Romi	C	6	1.00	No displacement, visible to raven
Zazou	A	7	0.62	No displacement, visible to raven
Zazou	B	5	0.80	No displacement, visible to raven
Zazou	C	6	1.00	No displacement, visible to raven

e) **true belief & false belief** experiment

name	**choice**	**frequency**	**p-value**	**condition**
Harriet	A	9	0.00	true belief
Harriet	B	3	0.76	true belief
Harriet	C	0	0.01	true belief
Janis	A	0	0.01	true belief
Janis	B	8	0.03	true belief

Janis	C	4	1.00	true belief
Kai	A	2	0.36	true belief
Kai	B	6	0.23	true belief
Kai	C	4	1.00	true belief
Kofi	A	3	0.76	true belief
Kofi	B	4	1.00	true belief
Kofi	C	5	0.55	true belief
Murphy	A	6	0.23	true belief
Murphy	B	5	0.55	true belief
Murphy	C	1	0.07	true belief
Pico	A	4	1.00	true belief
Pico	B	4	1.00	true belief
Pico	C	4	1.00	true belief
Quito	A	3	0.76	true belief
Quito	B	5	0.55	true belief
Quito	C	4	1.00	true belief
Romi	A	0	0.01	true belief
Romi	B	9	0.00	true belief
Romi	C	3	0.76	true belief
Zazou	A	2	0.36	true belief
Zazou	B	9	0.00	true belief
Zazou	C	1	0.07	true belief
Harriet	A	11	0.00	false belief
Harriet	B	1	0.07	false belief
Harriet	C	0	0.01	false belief
Janis	A	1	0.07	false belief
Janis	B	8	0.03	false belief
Janis	C	3	0.76	false belief
Kai	A	3	0.76	false belief
Kai	B	5	0.55	false belief
Kai	C	4	1.00	false belief
Kofi	A	4	1.00	false belief
Kofi	B	4	1.00	false belief
Kofi	C	4	1.00	false belief
Murphy	A	4	1.00	false belief
Murphy	B	3	0.76	false belief
Murphy	C	5	0.55	false belief
Pico	A	3	0.76	false belief
Pico	B	7	0.12	false belief
Pico	C	2	0.36	false belief
Quito	A	3	0.76	false belief
Quito	B	4	1.00	false belief
Quito	C	5	0.55	false belief
Romi	A	2	0.36	false belief
Romi	B	7	0.12	false belief
Romi	C	3	0.76	false belief
Zazou	A	3	0.76	false belief
Zazou	B	6	0.23	false belief

Zazou	C	3	0.76	false belief
Harriet	A	25	0.00	displacement, invisible to raven
Harriet	B	10	0.60	displacement, invisible to raven
Harriet	C	1	0.00	displacement, invisible to raven
Janis	A	1	0.00	displacement, invisible to raven
Janis	B	28	0.00	displacement, invisible to raven
Janis	C	7	0.08	displacement, invisible to raven
Kai	A	7	0.08	displacement, invisible to raven
Kai	B	13	0.73	displacement, invisible to raven
Kai	C	16	0.16	displacement, invisible to raven
Kofi	A	6	0.03	displacement, invisible to raven
Kofi	B	16	0.16	displacement, invisible to raven
Kofi	C	14	0.48	displacement, invisible to raven
Murphy	A	14	0.48	displacement, invisible to raven
Murphy	B	17	0.11	displacement, invisible to raven
Murphy	C	5	0.01	displacement, invisible to raven
Pico	A	13	0.73	displacement, invisible to raven
Pico	B	11	0.86	displacement, invisible to raven
Pico	C	12	1.00	displacement, invisible to raven
Quito	A	12	1.00	displacement, invisible to raven
Quito	B	11	0.86	displacement, invisible to raven
Quito	C	13	0.73	displacement, invisible to raven
Romi	A	9	0.38	displacement, invisible to raven
Romi	B	15	0.29	displacement, invisible to raven
Romi	C	12	1.00	displacement, invisible to raven
Zazou	A	7	0.08	displacement, invisible to raven
Zazou	B	20	0.01	displacement, invisible to raven
Zazou	C	9	0.38	displacement, invisible to raven
Harriet*	A	20	0.01	displacement, visible to raven
Harriet*	B	16	0.16	displacement, visible to raven
Harriet*	C	0	0.00	displacement, visible to raven
Janis*	A	3	0.00	displacement, visible to raven
Janis*	B	25	0.00	displacement, visible to raven
Janis*	C	8	0.21	displacement, visible to raven
Kai	A	14	0.48	displacement, visible to raven
Kai	B	11	0.86	displacement, visible to raven
Kai	C	11	0.86	displacement, visible to raven
Kofi	A	11	0.86	displacement, visible to raven
Kofi	B	13	0.73	displacement, visible to raven
Kofi	C	12	1.00	displacement, visible to raven
Murphy	A	12	1.00	displacement, visible to raven
Murphy	B	13	0.73	displacement, visible to raven
Murphy	C	11	0.86	displacement, visible to raven
Pico	A	12	1.00	displacement, visible to raven
Pico	B	12	1.00	displacement, visible to raven
Pico	C	12	1.00	displacement, visible to raven
Quito	A	12	1.00	displacement, visible to raven
Quito	B	11	0.86	displacement, visible to raven

Quito	C	13	0.73	displacement, visible to raven
Romi	A	10	0.60	displacement, visible to raven
Romi	B	14	0.48	displacement, visible to raven
Romi	C	12	1.00	displacement, visible to raven
Zazou	A	12	1.00	displacement, visible to raven
Zazou	B	12	1.00	displacement, visible to raven
Zazou	C	12	1.00	displacement, visible to raven
Harriet*	A	14	0.48	No displacement, visible to raven
Harriet*	B	16	0.16	No displacement, visible to raven
Harriet*	C	6	0.03	No displacement, visible to raven
Janis*	A	4	0.00	No displacement, visible to raven
Janis*	B	24	0.00	No displacement, visible to raven
Janis*	C	8	0.21	No displacement, visible to raven
Kai	A	12	1.00	No displacement, visible to raven
Kai	B	11	0.86	No displacement, visible to raven
Kai	C	13	0.73	No displacement, visible to raven
Kofi	A	10	0.60	No displacement, visible to raven
Kofi	B	12	1.00	No displacement, visible to raven
Kofi	C	14	0.48	No displacement, visible to raven
Murphy	A	10	0.60	No displacement, visible to raven
Murphy	B	14	0.48	No displacement, visible to raven
Murphy	C	12	1.00	No displacement, visible to raven
Pico	A	12	1.00	No displacement, visible to raven
Pico	B	13	0.73	No displacement, visible to raven
Pico	C	11	0.86	No displacement, visible to raven
Quito	A	12	1.00	No displacement, visible to raven
Quito	B	14	0.48	No displacement, visible to raven
Quito	C	10	0.60	No displacement, visible to raven
Romi	A	9	0.38	No displacement, visible to raven
Romi	B	18	0.05	No displacement, visible to raven
Romi	C	9	0.38	No displacement, visible to raven
Zazou	A	12	1.00	No displacement, visible to raven
Zazou	B	12	1.00	No displacement, visible to raven
Zazou	C	12	1.00	No displacement, visible to raven

Sup. Information Tab. 3: A Wilcoxon one sample test, two sided, was used to check if the ravens selection rate was different from the chance level. A " * " indicates a significat difference $p<0.05$ (Sig.).

Phase	Condition	Test	μ	V	Exact p-value	Sig
FP1	Visible with displacement	Wilcoxon one sample	3	45	0.008789	*
	Visible without displacement	Wilcoxon one sample	3	45	0.008789	*
	Invisible with displacement	Wilcoxon one sample	3	12	0.7921	
	Invisible without displacement	Wilcoxon one sample	3	24.5	0.3889	
FP2	Visible with displacement	Wilcoxon one sample	6	28	0.02225	*
	Visible without displacement	Wilcoxon one sample	6	28	0.02201	*
	Invisible with displacement	Wilcoxon one sample	6	25.5	0.06251	
	Invisible without displacement	Wilcoxon one sample	6	27	0.03301	*
true belief – false belief phase	Visible with displacement	Wilcoxon one sample	12	28	0.02225	*
	Visible without displacement	Wilcoxon one sample	12	28	0.02178	*
	Invisible with displacement	Wilcoxon one sample	12	28	0.02225	*
	True Belief	Wilcoxon one sample	4	0	0.05676	
	False Belief	Wilcoxon one sample	4	6	0.3991	

Sup. Information Tab. 4: A Wilcoxon two sample test (Wtst), two-sided, was used to check if the ravens selection rate differed between two condition. A " * " indicates a significant difference $p<0.05$ (Sig.).

Phase	Condition 1	Condition 2	Test	W	Exact p-value	Sig.
FP1	Visible with displacement	Invisible with displacement	Wtst	81	0.0003634	*
	Visible without displacement	Invisible without displacement	Wtst	81	0.0003792	*
FP2	Visible with displacement	Invisible with displacement	Wtst	47	0.004797	*
	Visible without displacement	Invisible without displacement	Wtst	35.5	0.1734	
	Visible without displacement	Visible With displacement	Wtst	24.5	1	
	Invisible without displacement	Invisible with displacement	Wtst	35	0.1953	
	Visible without displacement	Invisible with displacement	Wtst	43	0.02088	*
true belief – false belief phase	Visible with displacement	Visible without displacement	Wtst	25	1	
	Visible without displacement	Invisible with displacement	Wtst	40	0.05342	
	Invisible with displacement	Visible with displacement	Wtst	42	0.02912	*
	True Belief	False Belief	Wtst	18	0.4335	