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Can dogs and pigs assess the reliability of human informants?

Master thesis

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Submitted by

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Declaration of Independence / Eigenständigkeitserklärung:

I, Kinga Kovács, hereby confirm that I have written this thesis independently and have not used any resources other than those specified. The parts of the work that are taken from other works (this also includes internet sources) in wording or in spirit have been identified and the source has been indicated.

Table of Contents

Abstract

Metacognition in animals has been intensively tested during the last decades, whereby numerous methods have been developed to test related capacities in a non-verbal way. Most of these have been critisied for failing to test for the use of metarepresentation that I define as making thoughts about other thoughts. In my thesis, I aimed at developing a new paradigm that can test for a specific form of belief revision that had been proposed to be a form of reflective thinking without having to rely on metarepresentations: processing undermining defeaters. As dogs can learn about the misleadingness of human informants' cues in a choice task where they can search for food, I used this context to investigate whether dogs and pigs can use this information to make inferences about the reliability of the informants themselves and can adjust their behaviour to them in novel contexts, thereby demonstrating that they are capable of processing undermining defeaters.

For this aim, using identical methods across species, we assessed the capacity of 54 pet dogs and 35 Kune Kune pigs to make inferences about the reliability of 2 informants. The subjects could search for a reward behind one of 2 screens after having watched one of the informants act on one of them. The actions of the reliable informant indicated the location of the reward in all of her trials whereas the unreliable informant indicated the unbaited location in half of the trials. As in progressing trials the informants used novel actions that in no way resembled their preceeding actions, the subjects needed to make an inference about the reliabilities of the persons in order to make a decision whose actions to follow. I expected that they would follow the reliable informant more and would hesitate more in trials of the unreliable informant. Furthermore, I expected that they would show a preference for the reliable informant over the unreliable one once allowed to interact with both simultaneously during transfer tasks.

When comparing the two species, I found no difference between dogs and pigs and no evidence that they would have differentiated between the reliable and unreliable informants. Using the current methods, it is impossible to tell whether these negative results are due to the low number of trials with misleading cues interspersed between many more trials with informative actions, which may have prevented the animals from learning about the reliability of the informants' cues, or it is due to the animals' incapability to generalize this information (if realized) to the persons themselves, to their novel actions and to interacting with them in new contexts. In sum, I found in dogs and pigs no evidence of the basic form of reflective thinking that Melis (2013) had proposed. Furthermore, as a theoretical advancement, I argue in my

discussion that reliability assessments may anyway not be a suitable paradigm to assess whether non-verbal subjects can process undermining defeaters, and I call for tests outside the social domain.

Zusammenfassung

Die Metakognition von Tieren wurde in den letzten Jahrzehnten intensiv untersucht, wobei zahlreiche Methoden entwickelt wurden, um entsprechende Fähigkeiten auf nonverbale Weise zu testen. Die meisten dieser Methoden wurden jedoch kritisiert, nicht auf die Verwendung von Metarepräsentation, also das Nachdenken über Gedanken, zu testen. Das Ziel dieser Studie was es nun, ein neues Paradigma zu entwickeln, mit dem eine bestimmte Form der Glaubensrevision getestet werden kann, die als eine Form des reflektierten Denkens vorgeschlagen wurde, ohne sich auf Metarepräsentationen stützen zu müssen: die Verarbeitung von glaubensuntergrabenden Hinweisen („*undermining defeaters*“). Da Hunde in einer Aufgabe, bei der sie nach Futter suchen können, etwas über die Irreführung durch die Hinweise menschlicher Informanten lernen können, habe ich diesen Kontext genutzt, um zu untersuchen, ob sowohl Hunde als auch Schweine diese Informationen nutzen können, um Rückschlüsse auf die Zuverlässigkeit der Informanten selbst zu ziehen, und ob sie ihr Verhalten in neuartigen Kontexten anpassen können, um so zu zeigen, dass sie in der Lage sind, glaubensuntergrabende Hinweise zu verarbeiten.

Mit artübergreifend identischen Methoden haben wir die Fähigkeit von 54 Haushunden und 35 Kune-Kune-Schweinen untersucht, Rückschlüsse auf die Zuverlässigkeit zweier Informantinnen zu ziehen. Die getesteten Individuen konnten hinter einem von 2 Verstecken nach einer Belohnung suchen, nachdem sie beobachten konnten, dass einer der Informantinnen auf eines der Verstecke mit einer bestimmten Handlung hinwies. Die Hinweise der zuverlässigen Informantin deuteten in allen Versuchen den Ort der Belohnung an, wohingegen die unzuverlässige Informantin die Hälfte der Zeit auf das unbelohnte Versteck hinwies. Da die Informantinnen in folgenden Versuchen neue Hinweis-Handlungen einsetzten, die in keiner Weise ihren vorangegangenen Handlungen ähnelten, mussten die getesteten Individuen einen Rückschluss auf die Zuverlässigkeit der Personen ziehen, um eine Entscheidung zu treffen, wessen Hinweisen sie folgen sollten. Ich erwartete, dass sowohl Hunde als auch Schweine der zuverlässigen Informantin mehr folgen und bei Versuchen mit der unzuverlässigen Informantin mehr zögern würden. Außerdem erwartete ich, dass die Tiere in weiterführenden Tests, in denen sie mit beiden Informantinnen gleichzeitig interagieren durften, die zuverlässige Informantin gegenüber der Unzuverlässigen bevorzugen würden.

Beim Vergleich der beiden Tierarten fand ich weder einen Unterschied zwischen Hunden und Schweinen noch Hinweise darauf, dass sie überhaupt zwischen den zuverlässigen und unzuverlässigen Informantinnen unterschieden hätten. Mit den derzeitigen Methoden ist es mir

nicht möglich zu sagen, ob diese negativen Ergebnisse auf die geringe Anzahl von Versuchen mit irreführenden Hinweisen zurückzuführen sind, die zwischen viele Versuche mit zuverlässigen Handlungen eingestreut waren, was die Tiere daran gehindert haben könnte, etwas über die Zuverlässigkeit der Hinweise der Informantinnen zu lernen, oder die Tiere nicht dazu in der Lage sind, diese Informationen (falls sie wahrgenommen wurden) auf die Personen selbst zu übertragen, beziehungsweise in weiterer Folge auf ihre neuen Handlungen und schließlich auf die Interaktion mit diesen Personen in neuen Kontexten zu verallgemeinern. Zusammenfassend lässt sich sagen, dass ich bei Hunden und Schweinen keine Hinweise auf die Grundform des reflektierenden Denkens gefunden habe, die Melis (2013) vorgeschlagen hatte. Darüber hinaus argumentiere ich in meiner Diskussion als theoretische Weiterentwicklung, dass Zuverlässigkeitsbeurteilungen möglicherweise ohnehin kein geeignetes Paradigma sind, um zu untersuchen, ob nonverbale Individuen glaubensuntergrabende Hinweise verarbeiten können. Ich schlage daher weiterführend Tests außerhalb des sozialen Bereichs vor.

1. Introduction

1.1. What is metacognition and why is it important?

Metacognition can be briefly defined as cognition about cognition (Flavell, 1979). It includes the ability to reflect on one's own mental processes and to control and monitor one's own cognitive activity. For example, I know that I am not good at remembering names of new people who I have just met. If so, when I am in a new environment, I remind myself to pay more attention to this during greetings. As this example shows, metacognition is an important part of our everyday life: it makes us able to assess our mental states such as knowledge and belief, which plays a role in guiding our actions. Of course, beside realizing something about my own mental deficiency, it can also mean the opposite: reflecting on the knowledge which I already have (McMahon et al., 2010). Since reflection involves the articulation of propositional thought (e.g., making conclusions in wording based on a statement, Oswalt 2012), to be able to reflect on someone's mental process requires having concepts and beliefs.

As we, humans, engage in forms of metacognition, we often seem to realize what we know and what we do not know and when we have false beliefs. Such forms of metacognition rely on second-order representations or, in other words, on **metarepresentations** (Perner, 2012, Carruthers and Ritchie, 2012). Metarepresentations can be described as thinking thoughts about other thoughts. To make it clear, I will bring an example. You are walking near a lake, and you see a blue bird flying through in front of you. You start thinking, what kind of bird was that? If you saw the details of it, you might think that you know this bird species, and this was a kingfisher. You can recall from your memory where kingfishers live, what they look like and all other details about the bird that you know. On this reflective basis, you know that you know it was a kingfisher. Or on the contrary, you do not know anything about birds, thus you are not familiar with any details of them either. Reflecting about this, you know that you do not know what kind of bird it was. Metarepresentations are clearly involved in metacognition in this example, as you can verbally report on your thoughts about knowing whether you know or do not know something.

It is much more difficult to address metacognition in human infants and non-human animals that are not able to verbally reflect on their own mental processes. How is it possible to test whether human infants and non-human animals are capable of forming metarepresentations? Since the 1970s, when most studies on metacognition relied on verbal reports, several attempts have been made to develop non-verbal methods to test metacognition, focusing on error monitoring and measuring decision confidence, for instance.

Using such methods, it has been shown that human infants at an early age and also non-human animals are able to monitor their own certainty and to take this into account when making decisions. For example, if they have the option, animals do opt out from choice tasks more often when they do not know what the right choice is, as compared to other trials when they are certain what they shall do (Goupil et al., 2016 and Balcomb & Gerken, 2008). The accumulation of such empirical findings was followed by important theoretical developments, and diverse mechanisms of metacognition have been proposed that can explain the performance of infants and non-human animals without having to rely on metarepresentations. Thus, it appears that metacognition develops progressively in humans from an early age on, and it is initially present in simpler forms that are often referred to as procedural metacognition (Goupil and Kouider 2019). **Procedural metacognition** includes the ability to control and monitor a cognitive state which guides action, without representing the state monitored. In the following part I will present – through some important experimental paradigms – the development of metacognition in humans, from children to adults, with a special focus on the non-verbal methodological paradigms applied and the underlying processes that may explain behavioural performance in these tasks.

1.2. Responding to uncertainty

One of the non-verbal methods of testing for metacognition works with **confidence judgements**. In an experiment by Kornell et al. (2007), rhesus macaques had to differentiate between dots based on their size and the task was to find the biggest dot of all. In addition to having to choose one of the dots, they could make one more choice: they could add to touching one of the dots choosing either a „low risk" or a „high risk" button, kind of to indicate how certain they were that they were choosing the right dot. After pressing the low risk button, they got less reward but they got it regardless of whether they chose the correct dot. In contrast, after having chosen the high risk button, they could get more reward but only if their choice of dot was correct – if not, they did not get anything. The subjects chose the low risk option more frequently in difficult than in easy tasks. This shows us that the animals could experience low or high confidence when having to make a choice between the „risk buttons". Experiencing low or high confidence does not need to rely on a metarepresentation though, but can be explained in at least two ways. First, metarepresentation can of course cause this: if the animals knew that they were not sure about the right choice, they should choose the „low risk" button in order to avoid making a mistake. On the other hand, this performance can also be explained by a low level explanation: the animal may have pushed the „low risk" option simply because it was uncertain about which dot to choose. This does not need to involve that the animal knew that it was uncertain, still it led to the same performance. This means that the selective use of „low and high risk" buttons is no proof that the animals knew that they had low confidence. The same criticism of course applies to this paradigm also when testing children in a way (Ghetti, Hembacher, & Coughlin, 2013).

The next method is called **information seeking**: here it is tested whether the animals gather more information in between cue presentation and choice making if they have a chance to do so.This procedure mostly has two conditions, one is where the animal can see a baiting process, the other one is where the animal cannot see on which side the baiting is happening. According to Call and Carpenter (2001) and Call (2010), great apes behave differently in the two conditions of this task. In front of the animals some tubes were placed. The experimenter baited these tubes according to the previous conditions: the animals could or could not see the baiting process. Importantly, the results have shown that they checked the content of the tubes by looking into them more often in the second condition. In 2011, Beran and Smith also had an information seeking experiment, but with two different conditions. Here the aim was to choose at the end of the experiment the same picture which they had seen previously. In the first condition, the rhesus macaques and the capuchin monkeys had two icons in front of them and a sample picture was presented. With one icon, they could gather more information about the previously shown picture. With the other icon however, they could go on and make a choice out of three stimuli – one picture identical to the sample and two novel pictures. In the second condition, the animals had to face more options at a time, thereby representing a more complicated task. The authors predicted that the subjects will choose the „go on" icon when they already have the answer in front of them, but they will seek more information if they do not know the answer yet. During the less difficult parts – first condition and the half of the second condition – the subjects could use the icons correctly. In the more complicated scenarios, only a few animals could pass the test. These studies also show that some animal species are able to search for more information if they do not know the answer in a task. Even so however, similarly to the confidence judgement paradigm, also in this task successful performance does not mean that the animals knew that they did not know the answer; rather, their choices can be directly driven by uncertainty.

A third method to understand metacognition in animals is the **opt-out procedure**. Here an additional option is provided – next to explicite choices – where the rhesus macaques can decide not to make a choice. In 1997, Smith et al. conducted a test, where the animals had to use a certain rule on how to choose one of two pictures. In the first condition, they could learn the responses to the different pictures. In the second condition, the animals had an additional possibility to not answer the question (i.e. to opt out from a trial where they had a difficulty to know what the correct answer is). The macaques could learn the correct usage of this opt-out option, such that they chose to not answer the question if they were unsure about the accurate answer. This paradigm has also been applied in children (Goupil et al., 2016 and Balcomb & Gerken, 2008): if they were uncertain about the answer, they could also ask the caregiver to give help, next to the opt-out option. These studies have shown that children can appropriately use the opt-out option and can ask for help to avoid error-making. As these examples showed, the opt-out option has to be learned so that the subjects are able to use it properly. But even if the subjects reach this point, it does not mean that they have realised that they do not know the answer, thus it is better not to answer; rather, also in this case their selective choices can be attributed to uncertainty.

The next approach uses **postdecision wagering**. This includes a given answer and a later decision on it: how would the subject bet on the accuracy of their previous answer? In a study (Vo et al. 2014) children had to discriminate between two boxes, one of them containing more dots than the other. Immediately after this, children had to press „low risk" or „high risk" (i.e. lose or gain less or more tokens) based on their certainty about the accuracy of their previous answer. The results showed the ability to bet according to their correct responses: they bet with a higher risk if they are more certain about giving the correct answer. In a more recent study, Goupil and Kouider (2016) provided some data about a similar experiment, but with preverbal infants. Infants had to gaze or point to the toy's direction and wait for the reward (postdecision persistence). They found that subjects' persistence to wait longer for the reward nicely correlated with the correctness with their previous choice, showing that the subjects had a certain kind of access to their former certainty.

Based on these previous studies, Goupil and Kouider (2019) concluded that, already in their first years, children have a core metacognition. This ability is flexible, and with maturation more advanced metacognitive capacities can build on it (Carey, 2009; Spelke & Kinzler, 2007). It is important to realize, however, that successful performance in none of these tasks needs to rely on metarepresentations. Instead of forming a representation of the quality of the subjects' first-order representation of the actual situation (e.g., where food can be found or which choice is right), the subjects' behaviour can be directly driven by the quality of these first-order representations. That is, our **certainty** is, at the first place, encoded as the strength/quality of our neural representation of an external stimulus: when the stimulus evokes a clear and strong neural activation, our certainty is high, when this activation is weak and unclear, our certainty is low (Baer and Kidd, 2022). This certainty – coded by the level of neural activation – can then in principle be also mentally represented but it does not need to be in order to affect behaviour. To act based on certainty or uncertainty, the quality of neural representation or neural activation can be sufficient. In this latter case, there is no metarepresentation involved in solving the task, even if the subjects behave differently in situations that evoke more or less certainty on their side. Whether or not this neural representation of certainty is coupled with a mental representation of it, is hard to distinguish from each other: both can impact the subjects' learning skills and lead to identical performance in the tasks discussed earlier – information seeking, opt out, confidence judgement, postdecision wagering.

Perner (2012) pointed out that purely neural states of uncertainty can lead to metacognitive performance. The following example may make this clearer. If someone enters a hot room, they will feel warm and uncomfortable with time. This feeling can lead to an action, e.g. to open a window or a door, with or without the person realizing that the room is hot. That is, simply based on the observation that one opened the window, we cannot know whether they did so because of feeling hot or because of realizing that they are feeling hot. Similarly, two differently complex explanations can be offered when animals appear to judge the difficulty of a task. As an example, in a test by Smith et al. (1997), rhesus macaques seemed to have done so: as the task got more difficult, the animals opted less often to take the risk of making a potentially wrong choice. This performance again can be explained in two different ways: with or without metarepresentations. If metarepresentation was included in solving this task, meaning that the animals knew that they were uncertain about the correct answer, we would expect to use the opt-out option more often – rather than give a potentially wrong answer. However, a simpler explanation is also possible: they were simply uncertain about the answer and therefore they did not want to choose. This does not mean that they knew that they were uncertain. Still, this hesitation can lead to the same performance, that is, to opting out more often. This example shows the need to not rush into a quick response to explain performance in a task quickly, but to rather think more about it and gain more information if it is necessary. Afterall, subjects are not aware of neural representations, but it can still lead to metacognitive performance which happens after realising a problem. This is the reason why we think that the previously mentioned approaches do not necessarily demonstrate that there is any metarepresentation involved in solving these studies. Today they are thought to test procedural metacognition. Someone can easily opt-out or seek for more information because they are uncertain, but this uncertainty is not equal to knowing that they are uncertain. As Perner also states this generally, being in a state of knowing and knowing that one knows are two different processes. Thus, an observer cannot decide if the subject acts in a way because it knows it is true or because it knows that it knows it is true. With this framing, someone from the outside cannot decide if cognition or metacognition is involved in such sophisticated performances of animals.

To briefly summarize, uncertainty can influence the behaviour in different ways, with or without knowing about one's uncertainty. This is exactly what differentiates metarepresentational and procedural metacognition, respectively.

1.3. Belief revision

After going through the previous methods that address responding to uncertainty, I will continue with **belief revision**. To briefly introduce this topic, I use the thought of O'Madagain et al. (2022). Belief revision means that I have a belief – a proposition in which I am confident – however something else happens, which makes me consider my previous belief – if it is still true or not. A great example to show this is the following: I believe that it is sunny outside, but my dog comes into the house wet. This makes me think about the sunny weather and check if it is raining outside. Thus, I questioned my original belief, suspended my previous judgement on whether it is sunny and rather checked the weather in order to form a new opinion. Different kinds of information may urge us to revise our beliefs, that can be categorised into **overriding and undermining defeaters**.

Briefly, the difference between undermining and overriding defeat is the direct or indirect evidence for or against someone's belief. To have a clear general explanation about the difference between defeats, I use the paper "Understanding undermining defeat" (Melis, 2013). In a simple way, the differentiation can be seen through the fact that overriders provide a new statement that is contradictory with the previous one. That is, they rewrite the previous, but now obviously wrong thought with a new, correct thought. Using our previous example, if I look out through the window and see that it is raining, I give up my belief that it is sunny due to an overriding defeater.

There can be more complicated cases of processing **overriding defeaters** however, as demonstrated in O'Madagain et al.'s experiment (2022). The participants were faced with two baited boxes with windows on their side: in one box the treat was bigger than in the other one. The participants saw the two treats through one side of each box and had to make a first choice which reward and box they wanted to have. Then they got a second view into the boxes before finalising their choice. Here, the box was rotated 90 degrees to make the subjects see the reward from another angle. In consistent trials, the size of the reward was the same from the two angles, while in conflicting trials, the size of the reward was different. This was caused by looking through in m/m lenses – integrated into the side of the boxes – that made the reward appear smaller or bigger than it actually was. In these trials, the participants received two pieces of conflicting (opposite) information. The first belief (e.g., the reward is bigger on the left) which results from the first look was later challenged by counterevidence supporting the contrary belief (e.g., the reward is bigger on the right), which was caused by the second look. Then they could seek for more information by peeking through the top of the box. Great apes and 5 years old children did peek to gather more information in these trials. This could mean that the previous belief got questioned by these participants, thus they were concerned about the choice making. The participants made an extra step to make their belief stronger and to reassure it or to replace it with a new belief. When this belief-change happens – that is, when the first belief (e.g., the bigger reward is on the left) got replaced by the new belief (e.g., the bigger reward now is on the right) – we are talking about an overriding defeat. In my opinion, this study could also be explained without the presence of metarepresentation. The peeking itself could be reasoned only by uncertainty, since the participants saw the size of the reward first smaller and second bigger, which led them to be uncertain. With this, they did not have to realise what was the reason for the size changing (i.e., the lenses mislead them), they just had to seek for more information to reduce their uncertainty.

1.4. Processing undermining defeaters

There is another kind of conflicting information, however, that seems to need even more thinking: the so-called **undermining defeaters**. Here in the previously mentioned wet dog example, the wet dog gave me only indirect information about the weather: I received no information that it is raining outside but I can *infer* that the weather cannot be sunny if the dog is wet. As in this example, underminers do not say the opposite, but still let the reader question their belief and make doubts about the previous statement while reading the new one. The effects of underminers and overriders are also different. In case of overriders, the deficiency of the *source of information* is not taken into account. In clear cases, the reader can just accept the new statement of the overrider, without having any doubts. In contrast, in case of a new statement made by the underminer, the reader cannot just accept it without thinking about her beliefs or thoughts which were deemed correct in the past. Taking these aspects in account, the undermining defeaters need some kind of higher-order epistemic thinking to make such a conclusion and to reform the previously formed statements (Melis 2013). Importantly, Melis (2013) argues that this form of thinking does not need to rely on metarepresentations. To give an example, you think that the keys are on the table, and you go there but then you only see an empty table. With this, automatically your belief changes to the opposite, the keys are not on the table – overriding defeat. In this case, you do not have to identify relevant evidence or what can support your belief. On the other hand, when we are talking about undermining defeat – something happens which makes us question our belief – we need to assess our original reasons to have this belief. Thus, responding to this undermining defeat is not based on any metarepresentation. In other words, to process undermining defeaters, one needs to be able to identify and to assess their reason to have their previous belief. This ascends to the level of reflective thinking but does not require the capacity to formulate thoughts about other thoughts. This kind of thinking can be reflective – as defined at the beginning of the introduction – even if it is not a form of metarepresentational metacognition yet. Therefore, it is an interesting question whether children and animals are capable of this intermediate form of metacognition. However, until now most studies have used overriding defeaters and few have come close to testing the use of undermining defeaters.

Belief revision can be interpreted as a higher-level form of metacognition because, opposite to responding to uncertainty, it can involve some reflection, at least when it takes place due to undermining defeaters. Thus, such forms of belief revision may represent an intermediate step between responding to uncertainty and forming metarepresentations. Uncertainty brings us to become uncertain about something from our previous thinking, but this does not mean that we know that now we are uncertain. We can just act according to our uncertainty, but there is no other thought which would overwrite or make us question our previous thought. In contrast, during belief revision evoked by an undermining defeater, we have for a certain reason the original thought that needs to be questioned and/or be replaced by a new thought. With this, we have to think about our previous thought and the situation which made us question it. We have to consider and make a decision whether we stay with our original thinking, or we shall overwrite it and form a new belief. This means that belief revision may more often rely on reflection and in some cases on metarepresentations – since thinking and revising someone’s own thought is involved – than responding to uncertainty.

1.5. What comes closest to undermining defeaters: judging the trustworthiness of informants

After introducing belief revision, I will take a step closer to undermining defeaters by the **ability of judging the reliability of informants**. Usually we tend, when we meet with new people and there is nothing speaking against them, to automatically assume that they can be trusted and provide reliable information on ordinary matters. However, if they do not tell the truth in several cases and a third person draws our attention to it, then we revise our previous belief ("they are trustworthy") and suspend it to be able to form a new thought that this person is not trustworthy after all. With this, we will no longer rely on them as a source of information. This qualifies as processing an undermining defeater, since this person made us reconsider our previous judgement which was based on a different information. Moreover, we recognise the potential misleadingness of any further information coming from this person because of the unreliability of this person who is the source of information. Recognizing this connection between the information and its source is also a required trait for processing undermining defeat. This defeater is offered by an outsider source; thus its' effect still made us to revise our belief. Still, it is an interesting question whether infants and animals can form such judgements and distinguish between trustworthy and untrustworthy human informants?

In regard to empirical evidence, several studies have been conducted on children using language learning paradigms. Corriveau and Harris (2009) for instance tested whether **children** choose one experimenter over another one in a novel object naming test. Children did use their past experience about informants: they had heard these people name familiar objects with their correct or incorrect names. Based on this, when learning the names of new objects, they decided to trust the previously correct informant but not the incorrect informant, independent of their previous familiarity. More relevant for us, Tummeltshammer et al. (2014) developed a non-verbal paradigm and did an experiment where the experimenter appeared on a screen and looked at one of four empty boxes presented in each corner of the screen, arranged around the face looking at one of them. During the training, always one of 2 faces appeared in the middle of the screen. One of them had always looked at the box where an interesting picture appeared. She was therefore a reliable person. In contrast, when the second, unreliable, face appeared, the picture showed up in the box where she had looked in only25% of the trials – in 75% of these trials the picture showed up in one of the other 3 boxes. In the test phase, the children followed the gazing direction of the reliable face more than that of the unreliable face, showing that the infants were able to track the reliability of informants and use this knowledge in later phases.

Few other studies, going into a similar direction, have been conducted in non-human animals. Takaoka et al. (2015) tried to prove that **dogs** are also able to track the reliability of an informant and to use this knowledge. The dogs could experience which of two containers was baited with food. Then they saw a person point to this or to the other container: more concrete, they could experience one accurate – the pointing happened in the direction where the reward was placed –, one misleading – the pointing happened in the opposite direction where the reward was placed – and then again one accurate pointing phase by the same experimenter. The dogs followed the pointing less in the third phase – even though it was similar to the first one – after having experienced the second phase. The authors suggested that the animals showed some sensitivity of the reliability of the experimenter and they hesitated more after seeing the experimenter mislead them. Alternatively, however, it may be that the second phase simply led to an extinction of point following, which persisted into the third phase. Using similar methods, Pelgrim et al. (2021) made an experiment to investigate whether dogs are able to use past information to choose one informant out of two who provide conflicting information. In this study, the dogs experienced trials with an accurate pointer – who always pointed in the direction of the visible reward – and with an inaccurate pointer – who always pointed to the visibly empty container in pointing trials. In later trials when the 2 people pointed simultaneously thereby providing conflicting information, the dogs were able to remember their accuracy and showed a preference for the accurate pointer also when the content of the containers was no more visible.

As you may have realized by now, all of the above studies which are not based on linguistic tasks – including the children and dog studies – have a common limitation: they used the same cues during the test and training phase. With this, they allowed for the subjects to learn only about the accuracy/misleadingness of the cues, instead of having to think about the reliability of the informants as sources of evidence. That is that subjects could solve the test by simply discriminating between more or less accurate cues. For this reason, these non-verbal methods fail to test the processing of undermining defeaters. That is, instead of having to infer the reliability of the informants and based on that, the misleadingness of any novel information coming from them, the test conditions of these studies applied the already familiar accurate or misleading cues of the 2 informants in new contexts. In the Tummeltshammer et al. (2014) study for instance, even if the direction of the gazing was new (went into a different direction) in comparison to the training, it was still the same face and the same look that had always shown where actually the reward was. The explanation of the Takaoka et al. (2015) and Pelgrim et al. (2021) studies are similar. Even if at the beginning of the training the dogs may have followed the pointing of the inaccurate pointer, they then experienced that the food was not at the place the pointing had indicated. Finding that the place is empty was an overriding defeat that did not need to turn into an undermining defeat, as the subjects were always asked to make a choice based on the same cue of the experimenter(s).

1.6. Our study: testing for processing undermining defeaters

In this study, I wanted to avoid this problem by letting the informants use a series of actions that had no shared components (crouching behind a screen, lifting a container and giving only a sound cue – see the detailed description in methods): by letting the subjects experience the misleadingness of the first actions of one of the informants and thereby make an inference about her unreliability, and by testing whether such an assessment took place by investigating whether they selectively follow her novel actions less than those of a reliable informant. By creating this need to generalize from training cues to novel ones, I aimed to test whether pigs and dogs were able to acquire and respond to undermining defeaters. For this purpose, there was a training in the beginning of the experiment, where the animals could form a belief: if the experimenter acted on one side, the food was there. With this, some level of trust was built up. However, then two new informants showed up: one reliable and one unreliable. This the animals had first of all to experience and figure out themselves: the food could always be found on the side where the reliable informant acted, while this was the case in only 50% of the trials when the unreliable informant acted on a side. In the other 50% of her trials, her action was misleading – the action and the reward were on the opposite side. With this, the animals could detect an overriding defeater. That is, based on the training, they had the first belief that the reward was located where the experimenter acted, but when they chose, they found no food there. Through repeated trials, the animals could experience this and learn about the misleadingness of the unreliable informant’s actions and possibly gather knowledge about the reliability of the informants. That is, the animals could learn about the persons themselves – whether this happened I checked by letting them experience totally novel actions by the two informants that had no shared components with the first action(s). I reasoned that, had they inferred about the reliability of the two people, they would follow the new actions of the unreliably informant less. Furthermore, to reassure their previously gained knowledge, the animals had the opportunity to seek for more information by peeking through a gap in the front part of the screens, one of which hid the food. I expected this would happen more often in trials of the unreliable than those of the reliable informant. Moreover, if they were uncertain, their hesitation could increase to make a choice. Furthermore, in the last part of the experiment, in so-called transfer tasks, the animals were faced with both of the informants at the same time, in contexts that were increasingly different to the above demonstration phase. With this, I aimed to test whether the animals could recall the previous information about the informants and make a choice of the two of them based on that. I predicted that the animals would show a preference for the reliable informant over the unreliable informant.

1.7. Dog-human and pig-human communication

As mentioned earlier, such reliability assessment paradigms work best when the subjects have a spontaneous tendency to follow human action when searching for food. Even if animal species strongly vary in this regard, domesticated species typically perform well in object-choice tasks (Miklósi & Soproni, 2006, Nawroth et al. 2019). In regard to dogs' following of human-given cues, Reid (2009) has provided a nice overview. First pointing, which is the most common and most investigated cue during the previous studies is one of the cues that the dogs follow. Soproni et al. (2002) conducted several types of pointing – with straight or bent arms, crossing the body or in a line with the body – and the authors showed that the pointing gesture is the most efficient if it happens with a straight arm without crossing the body. Several authors (Hare et al., 1998; Soproni et al., 2002; Udell et al., 2008b) concluded that "belly pointing", when the bended arm pointing is crossing the body does not seem to work as a cue for the dogs. Another cue is head turning that the dogs are able to follow above chance level, at least after some experimental training (Miklósi et al. 1998; Udell et al., 2008b). Spontaneous gaze following is more debated however, as the dogs, without training, are not able to follow it without any accompanying human gestures (Hare et al., 1998). Partly due to this reason, it has been questioned whether dogs follow human pointing as humans do it. Kaminski (2009) was the first to propose that dogs do not follow pointing because they, similarly to humans, interpret it as a cooperative and informative gesture: they rather take it as a directive that sends them to a certain location and they are supposed to follow it. Several studies support this interpretation, in which the dogs had to make a choice between less and more pieces of reward. Counterintuitively, after a human indicated her preference for the lower amount, the dogs readily followed her suggestion, thereby making an inefficient choice (Barnard et al., 2019). These studies suggest that the dogs process human gestures as commands, and for this reason, they may make counterproductive choices in different tasks (Marshall-Pescini et al., 2012).

Regarding pigs, Nawroth et al. (2016) did two experiments to investigate their following of human cues. During the first one, the authors used similar pointing gestures to those in Soproni et al. (2002). The results are similar: the pigs followed the pointing gestures when it happened with straight arms and not with bent arms. In their second experiment, they included the head and body movement next to pointing. The results of the pointing remained the same as before, while the other two movements did not show any significant result. Different studies also support this view regards to the ability of pigs to pay attention and learn human gestures (Bensoussan et al. 2016, Nawroth et al, 2013, Nawroth et al. 2014, Albiach-Serrano et al. 2012, Gerencsér et al. 2019). Thus, this already supports the positive findings on the good human cue following in pigs. Nevertheless, dogs likely outperform pigs in following human cues (Fraga et al. 2021), which may be due to higher compliance in dogs than in pigs (see above).

Therefore, I formed two hypotheses in regard to comparing pigs and dogs in my study. First, dogs may perform better in realizing who is misleading and who is not because they follow the actions of the two informants more often than pigs and, therefore, have better chances to learn about their action-food location contingencies. This could lead to faster, stronger differentiation between the two people. However, it is also possible that dogs, since they have a higher compliance towards humans, would follow the informants' gestures regardless of its being misleading. This would mean that the pigs would differentiate better between the informants, than dogs.

2. Materials and Methods

2.1. Participants

This comparative study included 37 Kune Kune pigs (19 boars, 18 sows) and 61 pet dogs of diverse breeds (31 male, 30 female). The pig group lived under semi-natural conditions at the Haidlhof Research Station, Bad Vöslau, and were kept for the purpose of behavioural research. At the time of testing, they were all between 7 and 9 years old (mean: 7.27, SD: 0.49). All the sows had been castrated before age of 7 and the boars had been early vasectomised in their first 5 months. Eighteen pigs received no training prior to the experiment whereas 19 did (see Procedure). To have a bigger sample size, both the trained and untrained pigs were included in the statistical analyses, taking into account the training as a factor. Altogether, two of the pigs were excluded from the analyses, since they were deaf (they were used for piloting). This leads to 35 pigs as the final sample of this species (Table 8 in Appendix).

Regarding the tested dogs, they were recruited from the Clever Dog Lab database of the University of Veterinary Medicine, Vienna and via social media platforms. The pet dogs came from different households and were between 1 and 13 years old (mean: 6.14, SD: 3.50). We had stopped the experiment at various stages for in total 7 dogs, either due to the temperature in the testing room being too hot (3 dogs), lacking food motivation (1 dog), fear of the sound cue (1 dog), fear to pick up the food and thus not moving closer than the edge of the screen (1 dog), and last, fear of strangers (1 dog). In this last case the experiment was stopped during training. Due to the mentioned behavioural or environmental factors these dogs had to be excluded from the statistical analyses, meaning the final sample size was 54 (Table 9 in Appendix).

2.2. Experimenters and Handlers

Three female experimenters (aged between 23-27 years, height between 165 – 175 cm) were, prior to each test run, randomly assigned by a PsychoPy® (© psychopy.org) program, to act as one of the three informant roles (Reliable A, Reliable B, or Unreliable) and wear one of the three differently coloured clothes (black, white, or striped). The differently coloured clothes were used to enable easier differentiation of the experimenters by the subjects, as they were unknown to them. The experimenters assigned to play the role of the two reliable informants always placed the reward where they had performed the cueing action (see Procedure), whereas for the unreliable person, the cueing side and the reward side matched only in 50% of the trials. One of the two reliable informants always served as a "demonstrator". The animals could experience every test with her first, which made the test phase an easier visibility. With this, one person is always demonstrating and by the time when the animals face the next informant, they already know the type of the action. Moreover, the animals could learn that she is the one to whom they could always trust without any test phase. One last reason to include two reliable informants and one unreliable was to avoid a type of generalisation. Including not only one reliable and one unreliable made the animals think more about the informants itself.

In addition to the 3 experimenters, who were assigned with informant roles, there was a fourth person (handler) involved in the experiment. For all tests with dogs, the owner was used as the handler. For all tests with pigs, one female researcher, who was very familiar with the subjects, was present for all tests and acted as the handler. The handler's purpose was to keep the subject at the start position during the presentation of the cueing actions, release it upon a given cue, and call it back to the starting position after the subject had made its choice. From the training phase on, the handler was instructed to pay no attention to either the experimenters' or the subjects' actions to avoid influencing the animal's choice. For this reason, the owners of the dogs wore a cap and looked to the ground (to an "X" sign) in front of them during all of the trials. To prevent any influencing effect on the pigs' behaviour, the handler was standing outside of the observer area and did not have any close contact with the pig, thus she could not have an impact on the behaviour (see Setup).

Picture 1: *The three informants during the experiment. Colours from left to right: black, striped, white.*

2.3. Setup

2.3.1. General Setup

The experimental setup was closely similar in both of the species. The tests were conducted indoors, in a separate closed space. The size of the test hut for the pigs testing was 5.5 m x 5.5 m, while for the dogs testing the test room size was 6 m x 7 m (Picture 2.). The pigs could enter the testing area from an observation compartment, until then the dogs entered through a door (behind the curtains). Meanwhile the dogs stayed in the testing area until the next break, the pigs left it after each trial and went back to the observation area. The handlers were positioned behind the subjects to avoid any possibility to influence the behaviour of the animals.

In the background two opaque **curtains** (grey in the dog experiment and beige for the pigs) (140 cm x 245 cm) were used to avoid any distraction towards the subject and to cover the area where the experimenters were standing and preparing the next tasks. These curtains were fixed with clips on a metal wire, which was taut between both sides of the room. One 40 cm wide space was in the middle of the curtains, making it possible for the experimenters to come to the front.

2.3.2. Setup Demonstration Phase

In front of the curtains two **V-shaped screens** (shorter side length: 60 cm, longer side length: 150 cm) were placed next to each other, with a distance of 40 cm between the short sides (see Picture 2). Between the curtains and the screens, the distance was 40 cm from the longer side of the screen and 70 cm from the shorter side. Most of the cueing actions (see Procedure) happened behind these screens. In the case of the pigs, the screens were 60 cm high, while for the dogs it was 90 cm considering the fact of the higher height of the dogs and the capability to jump over a small barrier. Each screen had a **gap** between its two sides that allowed the subject to smell and see whether there was food reward hidden behind the screen without having to detour it and check its back side. The gap was 2 cm wide for the dogs, and 4 cm for the pigs, to take their weaker eyesight into account.

The inner sides of the two screens were connected with a transparent **barrier** that prevented the animals from approaching the back of the screens in the middle – they could detour the screens only either from the left or right side, thereby forcing them to make a choice in front of the screens. This barrier was 3 horizontal lines of electric wire (without electricity) for the pigs and a transparent plexiglass panel (1 m x 1 m) with 3 horizontal lines taped on it (to avoid any source of injury) for the dogs. Furthermore, 2 additional barriers ran from the inner ends of the 2 curtains to the ends of the inner sides of the screens in order to prevent the animals from crossing from one screen to the other behind the screens (that is, after having made a choice). This was important to make sure that the animals were rewarded only after correct choices. With the pigs, this barrier was again 3 lines of electric wires, wrapped with black tape, and fixed during the whole experiment. In the case of the dogs, two metal fences with wooden frames (150 cm x 104 cm) were prepared behind the curtains and slid forward to the screens after every cueing and placed back to the experimenter area after every choice. This means that whenever one of the informants stepped in front of the curtain, the other two experimenters pushed the two side barriers to the front until they met with the screens (Picture 3.).

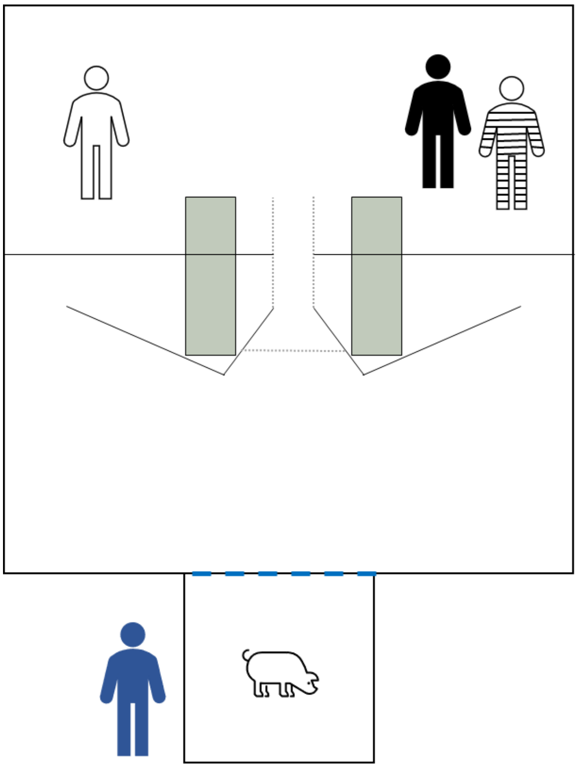
Between each screen and the curtains, a **sliding board** was lying on the floor on which the experimenters placed the reward and with which they could pull the reward back in case the subject made a wrong choice. The colour of the boards matched the colour of the floor (green for pigs, grey for dogs). To enable these boards to move silently, a soft tissue was placed under them. With the pigs this was a green carpet (125 cm x 210 cm) that covered the floor, whereas with the dogs a towel (70 cm x 27 cm) was placed under each board. The sizes of the sliding boards differed slightly for the species, with the pigs the size was 150 cm x 35 cm, while with the dogs it was 70 cm x 27 cm.

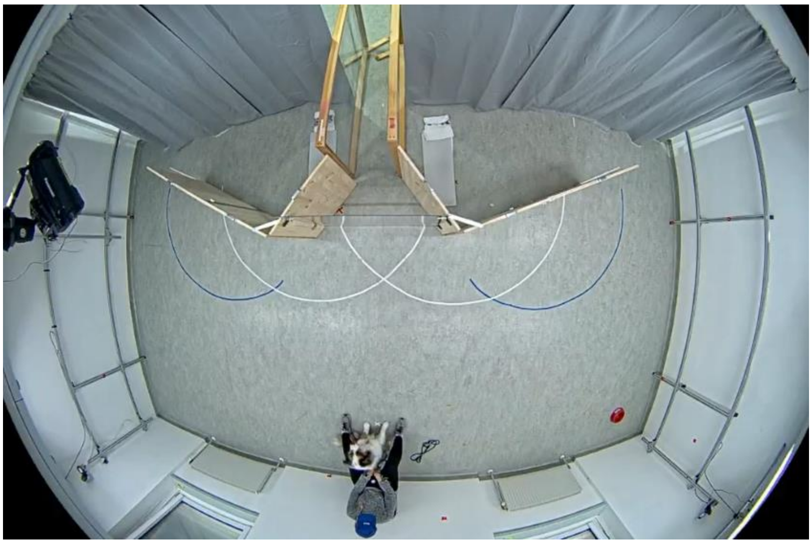
The animals were positioned with 2 m distance in front of the V-shaped screens in the middle. From there, the animals were able to watch and observe the scene. In the case of the **dogs**, the dogs were positioned in front of their handler (usually their owner), who was sitting on a chair, holding the dog on the harness or leash. The handlers were instructed to release the dog, once the experimenter had given a slight “beep” sound, so the dogs could make a choice. This signal was made by one of the experimenters behind the curtains by saying “beep”. The sound always came from the opposite side as the acting informant was during baiting. This sound came when the acting experimenter finished her actions and disappeared. With another “beep” sound, the handler was asked to call their dog back to the starting position. At this time a choice was made by the animal and the trial ended.

The test hut for **pig** testing was not large enough to fit both the setup and a pig observer compartment inside the hut. Therefore, an outside observer area (2 m x 2 m) was used, where the pigs were positioned to observe the experimenters’ actions before they entered the test area. The observer and the test area were divided by two guillotine doors: one transparent and one opaque wooden door. The transparent door was used to coordinate the pig's position when it came to the beginning and the end of a trial. This means, the transparent door was opened when the actions of the experimenter had ended, and the pig had a chance to go to the test room and make a choice. When the pig had made a choice, the handler called them back to the observer area, and when they arrived the transparent door was closed.

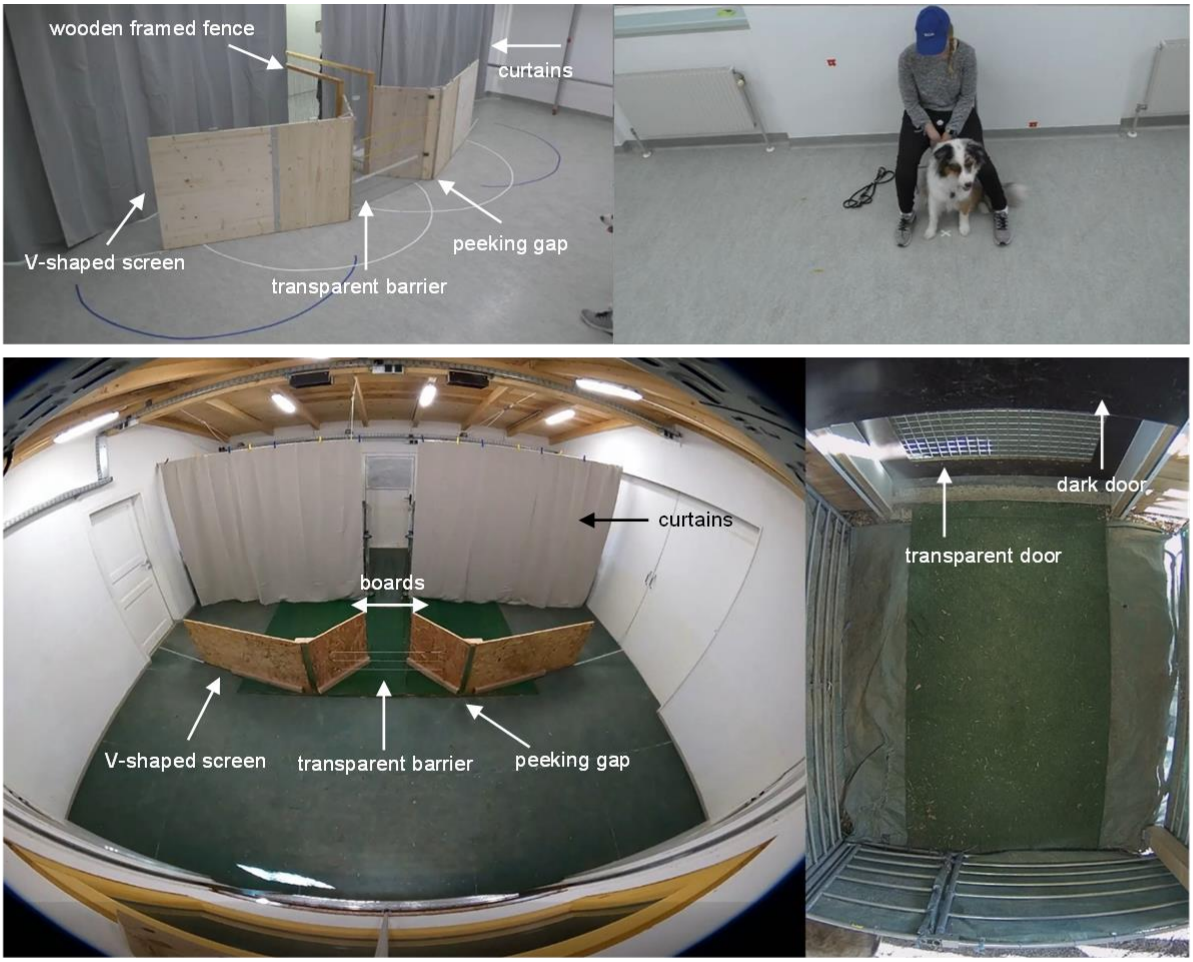
The opaque door was used to control the pigs' view of the testing area, either during a short break, or when the experimenters had to change the setup of the experiment. In this case, both the transparent and the opaque door were closed after a trial. This was done after each of the three cueing actions were completed to enable a short break from the experiment, as well as before the start of the second and fourth transfer task (Pointing and Unsolvable task) to be able to change the setup.

To conduct this phase some additional equipment was used. In the case of the pigs a metal food bowl (diameter: 24 cm) was used during lifting and the same bowl with a wooden lid was applied for the sound action. To keep it as similar as possible for the dogs a similar metal food bowl (diameter: 21 cm) was used for lifting. For the sound action, two plastic boxes of different sizes (12.5 cm x 8 cm x 4.5 cm, 15 cm x 10.5 cm x 5.5 cm) filled with dry food were used for making a noise during the trials.





Picture 2: *Experimental setup of the two species.*
Upper picture: drawing of the experimental setup of the Kune Kune pigs at Haidlhof. Black lines: V-shaped screens and curtain, dotted grey lines: middle and side barriers, dotted blue line: guillotine door, green rectangles: sliding boards.
Picture below: experimental setup with dogs, Clever Dog Lab.



***Picture 3**: Details of the experimental setup.*
Upper left picture: setup of the dogs, upper right picture: position of the owner and the dog.
Picture below on the left: setup with the Kune Kune pigs, picture below on the right: observer area of the pigs.

2.3.3. Setup Transfer Task

2.3.3.1. Screen Choice Task setup

As the start of the transfer tasks, Screen Choice Task was conducted in the same setup as the Demonstration Phase was.

2.3.3.2. Pointing Task setup

To execute the transfer tasks (with exception of the first one, the Screen Choice Task) in the pig test hut, the experimenters set up two barriers (two Patura® Steckfix© metal fences with opaque green plastic tarpaulin covering) to hide the V-shaped screens. This action happened between the last Screen Choice Task and the first Pointing Task. Before the setup was changed, the dark door was closed with the pigs. This step to hide the test area during reorganizing the setup was important. With this solution blocking the view of the pigs did not influence the pigs' behaviour towards any of the experimenters.

With the dogs, the setup also changed after the first type of the transfer tasks. The experimenters removed the V-shaped screens and the plexiglass while the dogs stayed inside the test area.

When it came to the pointing tasks, two metal bowls– similar as during the Demonstration phase – with covering were used. The covering contained two pieces of paper for the dogs and two wooden lids for the pigs.

2.3.3.3. Begging Task setup

The test area remained the same and the previously mentioned metal bowls were included during the Begging Tasks with both of the species.

2.3.3.4. Solvable/Unsolvable Task setup

The other case when the dark door was closed in front of the pigs was before the solvable task. Here after the dark door was closed, the experimenters brought the wooden box (36.5 cm x 48.5 cm x 15 cm) with a lid inside to the test area, which was used during the next trials. Inside the box the same metal food bowl was placed in as previously.

For solvable and unsolvable tasks in the case of the dogs a plastic jar (17.5 cm x 8.5 cm) with its lid fixed to a wooden board (70 cm x 120 cm) was used. To avoid any influence regarding the choice or the behaviour from the handler, the dog owners wore a cap.

2.4. Reward during the experiment

In all of the trials the animals could get a treat, if they performed successfully, which was apple or bread for the pigs and sausage or cheese for the dogs.

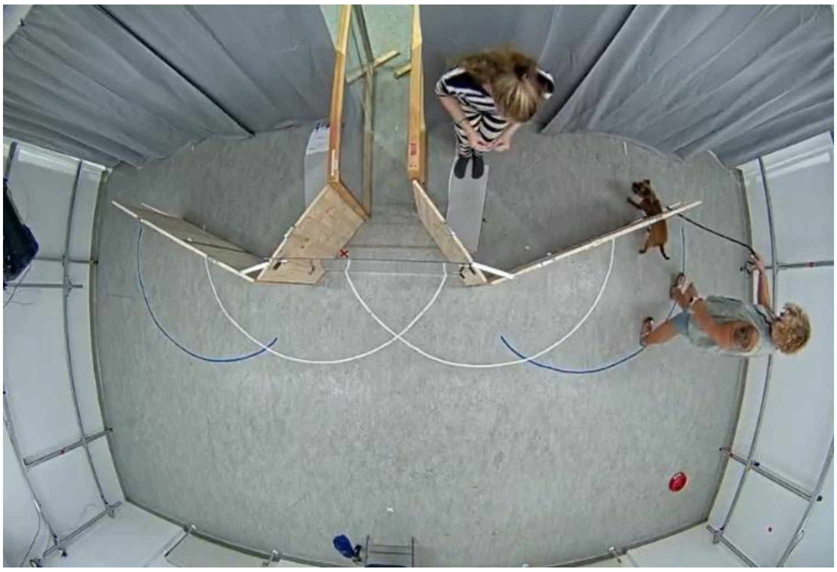
2.5. Procedure

The animals were tested in two phases, the *demonstration phase* and the *transfer phase*. In each phase, the animals were exposed to different cueing actions by the informants or experimental setups in order to investigate whether the role of the informant (reliable or unreliable) had an effect on the animals' behaviour towards them. In order to familiarize the animals with the experimental setup, and make sure that a certain amount of trust was established (since all experimenters were unknown to the animals) we first executed a familiarization, and subsequently a training phase.

2.5.1. Familiarization Phase

The familiarization phase consisted of four consecutive trials. Reliable A showed up between the curtains, walked to the middle between the V-shaped screens, then stepped to either left or right side. The handler walked with the animal to the outer edge of the screen, behind which Reliable A was standing (see Picture 4.). After this step, the informant crouched down, put the food on the sliding board and stood up. This was important to show the animal the purpose of the following actions: to put down the reward on the board and not take it away. When Reliable A stood up, the animal could take the food and then was called back by the handler to the starting position. The informant went behind the curtain on the same side (left or right) where she had placed the food.

During this phase it was also important to familiarize the dogs with the releasing and calling back signals. At the same time the pigs were not familiarized with verbal signals, but they were coordinated by the handler and held in place by the transparent door. When the pig got released, the handler could see where the animal was (but the animal could not see her). Whether the pig made a choice, the handler called back the animal and the experimenters closed the transparent door.



Picture 4: *Familiarization phase.*
Upper picture: example of dogs' familiarization phase.
Picture below: example of pigs' familiarization phase.

2.5.2. Training Phase

The aim of the training was to familiarise the animals with the goal of the actions. The animals could experience that, the informant is placing food on the sliding board instead of taking it away. With this the animals could learn that the side of the action meant the side of the reward, thus they should follow the informant in order to get food. In the case of the dogs at least 10, maximum 20 and in the case of pigs at least 20, maximum 40 trials were conducted.

The criterion to succeed the training was the same with both species, it was calculated by a binomial test (Table 10 in Appendix), if the animals followed the actions of the Reliable A informant significantly more than they did not follow.

The same informant (Reliable A) – who did the familiarization phase – conducted these trials immediately after the familiarization trials. She walked to the middle between the V-shaped screens as before, then stepped to one side (behind the left or the right screen) and crouched down there. While she was crouching, she put a treat on the board and left the scene at the corresponding side of the curtain where she was giving a cue. After this, the animal was released to make a choice. If it was correct, then the subject took the food, if not, the handler called them back.

2.5.3. Familiarization Reminder

After a break, the experiment continued (for pigs on the next day, for dogs on the same day after 5-10 minutes): First Reliable A with the dogs (with the help of the handler) and the handler with the pigs repeated two crouching actions on each side as it is described in the familiarization phase.

2.5.4. Screen-Gap Introduction

After the familiarization reminder, a short presentation of the gap of the screens executed to let the animals know the possibility of seeing or smelling the food through it. With the dogs this included Reliable A going to the middle of the curtains and stepping to one side. The handler walked to the middle of the screen (behind which Reliable A was standing) and let the dog sniff the gap of the screens (here Reliable A was pulling a piece of food vertically behind the gap to get more attention of the dog, see Picture 5). After sniffing around, the dog could take the food by going behind the screen.

This phase slightly differed with the pigs. With them the handler did the movements. The handler walked to one side, while the pig could discover and smell the food through the gap. After this, the pig could also take the food by going behind the screen.

Picture 5: *Screen-Gap Introduction.*
Upper picture: example of dogs' familiarization phase.
Picture below: example of pigs' familiarization phase.

2.5.5. Experimenter Introduction

After familiarizing the animals with the gap, the presentation of the experimenters took place. Presenting all the informants was important, so that the animals could see there are three different individuals acting and not only one changing clothes. For the experimenter introduction, all the experimenters emerged from one side of the curtains and stopped in the middle of the room (in front of the screens, see Picture 1). While standing in front of the animal, the experimenters avoided making eye-contact with the animals, thus they were watching the ground in front of them. After standing there for two seconds, they went to the other side of the curtains and with this, all the experimenters left the scene.

2.5.6. Demonstration Phase

2.5.6.1. General Procedure

This phase included three actions (crouching, lifting, sound, see details below) whereby all three informants cued at only one of the 2 screens. These 3 actions were selected and presented in this fixed order because (1) they had no shared components and therefore, the animals could not generalize across the cues purely based on their similarities, and (2) because they were increasingly novel and therefore difficult for the animals to use them to discriminate between the screens and to search for food based on them.

The whole procedure started with the simplest action (crouching), which was already familiar for the animals as they saw it performed by Reliable A previously (during training). Also, it could have occurred in their everyday life previously. This crouching action also made the animals' ability easier to follow the informants and to gather the information of the trials and of the informants. The next action was already harder, as it was not a casual movement which could be seen previously. Here the animals had to think about the role of the informants more and pay more attention to the actions and informants. Last, in the sound action the animals had to remember the information, which was gathered in the previous actions, since the experimenters themselves did not act on one side, only the sound was giving a cue from the background.

The order in which the informants appeared and performed the actions were the same for the first two actions, but different in the last action. This was done to control for an order effect instead of an effect of the role of the informant. In the first two actions, first Reliable A, second Reliable B and third Unreliable acted. In the last action (sound), the order was reversed in the case of Reliable B and Unreliable. Here the order of actions was: Reliable A, Unreliable and lastly Reliable B. Since the animals were familiarized with Reliable A in the beginning of the experiment, it was important she always started the actions to make sure the animals were paying attention, having motivation still and they were not afraid of any of the actions. In the analyses we did not include the Reliable A trials for two reasons. First, Reliable A was more familiar to the individuals, thus it would not make sense to compare her to an informant who is less familiar. Second, the trials by Reliable B and Unreliable were novel trials, which were new for the animals after having experience with Reliable A.

2.5.6.2. Crouching Phase

The *crouching action* (see Picture 6 and 7) was the same as in the training phase: the informant showed up between the curtains, holding a piece of food with her two hands in front of her chest. She made a few steps forward, stepped left or right behind the screens, put down the treat on one of the sliding boards (or pretended to do so in the case of the Unreliable informant, see Pictures 5 and 6), stood up and then walked behind the curtain on the corresponding side.

This part included 4 trials of Reliable A, 4 trials of Reliable B, 6 trials of Unreliable and at the end, 2 trials from Reliable B again to finish with a positive end and to make the number of trials equal between Reliable B and Unreliable informant. After the crouching actions by all the experimenters, a short break took place. During the break the animals could go out from the testing area with their handler and play or walk for 5-10 minutes. After the break, the Reliable A continued with 2 more crouching actions as a reminder. Then Reliable A started the new action, the lifting action (see Table 1).

2.5.6.3. Lifting Phase

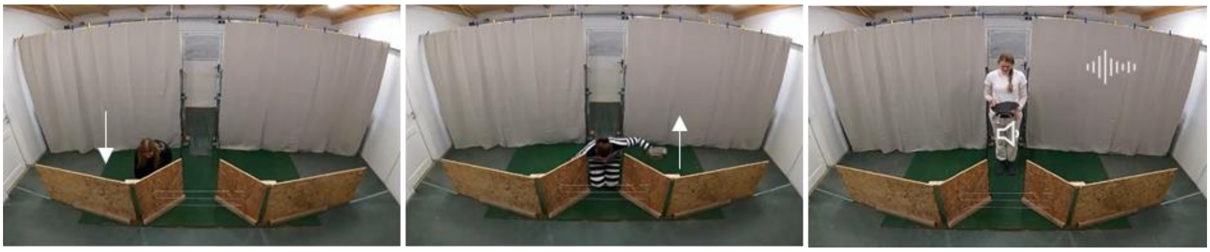
For the *lifting action* two bowls were placed on the boards before the first trial. This was done by pulling the sliding board behind the curtain, placing one bowl on it and sliding it back to behind the screen. This sliding action occurred simultaneously in both sides to not influence the animal's side choice if there were any visible movements. As for the crouching cue the lifting action started with the informant stepping in front of the curtains from the middle. However, instead of stepping left or right, the informant kneeled down between the screens and moved both her hands behind her back simultaneously (see Pictures 6 and 7). During this movement, the food was hidden in her fist, ipsilateral to the screen she was about to cue. To give the lifting cue, she reached both her arms simultaneously behind the screens and grabbed and lifted the food bowl up over the upper edge of the screen she wanted to cue. She then put the bowl back onto the sliding board, put the reward on it (or on the other bowl in case of the Unreliable informant), stood up and left the scene by going behind the curtain in the middle, without turning around.

During the lifting phase Reliable A did 2 trials, Reliable B continued with 4 trials, Unreliable did 6 trials and Reliable B ended this part with 2 other lifting trials. Therefore, the order was the same as in crouching action. The last lifting trial was again followed by another short break. When the break was finished, Reliable A returned with 2 repetition trials of lifting, and she then introduced the new sound action (see Table 1).

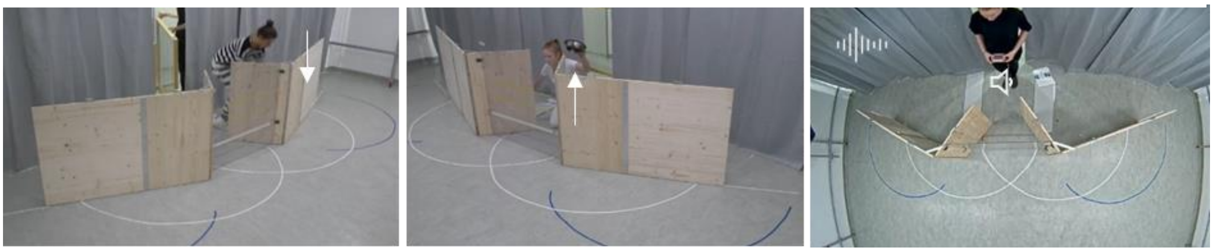
2.5.6.4. Sound Phase

The last action of the demonstration phase was *sound cue*. As in the lifting cue, the informant emerged in the middle of the curtains. She then stepped forward between the V-shaped screens with a sound-object (dogs: plastic container filled with dry food, pigs: metal food bowl with a wooden lid) in her hands. Behind the curtain, one of the other two informants was crouching and gave a sound cue on one side with the same kind of sound-object while the informant in front of the curtain was acting as if making the sound (see Pictures 6 and 7). The informant then walked backwards and disappeared behind the curtains. On the same side where the first sound came, the same informant repeated the sound once more, while no informant was present in front of the curtains. In the case of the dogs, this sound cue was conducted by shaking the plastic food container, while with the pigs a noise was made by clapping the wooden lid on top of the metal food bowl. This difference was important, so the animals heard a noise which they were already familiar with and therefore were not afraid of. In both of the species, this sound was usually associated with feeding time.

During the sound phase Reliable A performed 2 sound trials, then Unreliable continued with 4 trials and Reliable B finished with 4 trials. After finishing the sound trials, the demonstration phase ended with a short break (see Table 1).



Picture 6*: Actions during the demonstration phase with pigs. From left to right: crouching, lifting, sound action.*



Picture 7*: Actions during the demonstration phase with dogs. From left to right: crouching, lifting, sound action.*

***Table 1**: Sequence of the experiment. Black lines: break possibilities.*

	Action	Reliable A	Reliable B	Unreliable
Demonstration phase	Crouching	Training		
		4x	4x	
				6x
			2x	
		2x reminder		
	Lifting	2x	4x	
				6x
			2x	
		2x reminder		
	Sound	2x		
				4x
			4x	
Transfer task	Screen Choice		4x	
	Pointing		2x	
	Begging		2x	
	Solvable/Unsolvable	3x solvable	1x unsolvable	

2.5.6.5. Behavioural Measures

After observing the cueing action, the animals were released either by their handlers (dogs) or through the opening of the guillotine door (pigs) and could choose to walk behind one of the screens (or check both through the gaps before making a choice). If the animals chose the baited side, they could eat the reward. On the other hand, if they chose the unbaited side, on the side of the reward, the reward was pulled back, thus the animal could see that there was a reward on the other side. This pulling occurred by one of the experimenters, she pulled the sliding board behind the curtains without seeing her hands by the animal. After making a choice, the animals were called back by the handler or the owner and they were sitting or standing back to the observation position.

The behavioural analyses included hesitation, peeking and choice of the animal. See the details of these variables in the section Data collection.

This part – when the animal was released – was called hesitation, until the animal made a choice. This variable together with the peeking variable could be a source to give information about the level of the uncertainty of the animal. If the length of the hesitation or the number of peeking increases, the uncertainty is present in a higher amount then previously. The choice variable gave information about the amount of cue following, whether the animals followed the actions of the informants or not.

2.5.7. Transfer Phase

The demonstration phase served as information for the animals. They could learn about the roles of informants across different actions, they could conclude who they should follow or with whom they should hesitate more. Also, it was a good base to compare following of Reliable and Unreliable person which could have an effect during the next trials in the transfer tasks.

The transfer tasks included 4 types of tasks with only Reliable B and Unreliable informants. Reliable A in turn always acted as a demonstrator. Here the aim was to see if the animals were able to distinguish between the informants and if they had formed a preference for one of them. The 4 types of tasks were Screen Choice, Pointing, Begging and Unsolvable Tasks (see details below). The order of the tasks was fixed, as they were presented so that they deviated from the Demonstration phase to an increasing extent. That is, during Screen Choice and Pointing Tasks the problem remained the same: the animals could search for food based on behavioural cues provided by the informants. In the Screen Choice Tasks, the setup remained the same as in the Demonstration phase with both V-shaped screens present, but this time the animals had to make a choice between the two informants, who were now present at the same time. In the Pointing Tasks the context was new, as the food was no longer hidden behind a screen but inside of one of two food bowls. During Begging Tasks and the Unsolvable Task, the informants no longer provided cues to the animals but rather the animals could initiate communication to ask for food or to ask for help in order to get a reward. Therefore, with this sequence of transfer tasks we aimed at investigating whether and how broadly the animals can generalize what they learnt about the reliability of the informants. Also, this order was important to not lose the motivation of the animals since in the Begging and the Unsolvable Tasks they were not rewarded.

2.5.7.1. Screen Choice Task

The Screen Choice Task (see Picture 8) contained 4 subsequent trials, where the Reliable B and the Unreliable person were standing in front of the screens and looking towards the sliding boards until the subject made a choice. On the side of the reliable informant, a reward was always placed, while with the Unreliable side was rewarded only in 2 out of 4 cases.

***Picture 8**: Screen Choice Task. Left picture: pig setup, right picture: dog setup.*

2.5.7.2. Pointing Task

Before this task could begin, a preparation was necessary for the new setup. In the case of the dogs the screens and the transparent barrier were removed from the room by all of the three experimenters. This was important, thus the animal saw all of the experimenters, not only a part of them and this could not influence any later occurred behaviour. These barriers were carried behind the curtains (as a “wall”), thus in the later phases the dog could not go behind the curtains easily. As pigs have a stronger physique, some metal fences were needed with them. Here after the Screen Choice Tasks, both the transparent and opaque guillotine doors were closed, therefore the pig could not see what happened meanwhile. Two metal fences (with green covers) were carried in front of the V-shaped screens to cover them and to avoid any distractions for the animals.

The second transfer task included 2 Pointing Tasks (see picture 9). During this, Reliable A came to the middle and put 2 food bowls on the ground by crouching in front of the animal. Then she bent over and pushed the bowls ~1.5 m away from each other. In one of the trials both bowls were baited, while in the other one trial only the reliable side was baited. The order of one or two bowls being baited was randomly assigned by the PsychoPy® program and counterbalanced over all subjects. After positioning the two bowls, Reliable A went behind the curtains through the middle and Reliable B and Unreliable came outside (from the curtains). They walked to the middle and either stood (dogs) or kneeled (pigs) while pointing towards the corresponding food bowl until the subject made a choice. In the pigs' case, a choice was made if the subjects pushed down the lid from the bowl.

Picture 9: *Pointing Task. Left picture: pig setup, right picture: dog setup.*

2.5.7.3. Begging Task

The third transfer task, which was a Begging Task (see Picture 10), also contained 2 trials. Reliable B and Unreliable came from the opposite side of the curtain to the middle and stood next to each other in front of the subject with a bowl (which contained food) in their hands. The experimenters did not make any eye contact with the subjects by looking at the ground in front of them. The subject had 1 minute to approach the informants. After 1 minute the trial ended, the animal was called back and the informants left, both on the side where they came from. In these 2 Begging trials, the subjects did not get any reward.

Picture 10: *Begging Task. Left picture: pig setup, right picture: dog setup.*

2.5.7.4. Unsolvable Task

The last part was the Solvable-Unsolvable Task (see Picture 11). For this task in the case of the pigs a wooden box with a lid was used, while with the dogs an inverted transparent plastic container was used. For bringing the equipment to the test area, the dark door was closed with the pigs, thus they could not see this process. The dogs could watch Reliable A bringing the board inside from the middle and leave the test area in the same way. Reliable A baited the equipment by walking to the middle, crouched down in front of the animal and put a reward to the wooden box/plastic jar. After baiting, the animal was released and had a chance to solve the task and get the reward. This part included 3 trials. When the 3 trials were finished, Reliable A again baited the equipment, but in this case she also closed it. This means with the pigs, she closed the wooden box with 2 metal lockets on the side of the box. With the dogs, the plastic jar was screwed on the lid to make it impossible to open it. When Reliable A finished the baiting, she went back in the middle gap of the curtains. After her disappearance, Reliable B and Unreliable walked from the opposite sides of the curtain next to the equipment. They faced each other and looked at the ground to avoid any eye contact. With this the Unsolvable Task started. The subject had 2 minutes to interact with the equipment and the informants. When this trial ended, the whole experiment ended.

The whole experiment lasted around 1-1,5 hours.

Picture 11: *Unsolvable Task. Left picture: pig setup, right picture: dog setup.*

2.5.7.5. Behavioural Measures

During transfer tasks different variables were measured than before. First, in all of the transfer tasks, the preferred informant was defined based on the animal's choice or on the first approach to one of the informants. With this, the general preference towards one of the informants could be assessed which could base on the previously gained information about them. Second, the amount of contact to one of the informants was also observed during Begging Tasks and Unsolvable Task. This information could bring a result, which shows both the preference for one informant and the amount of this. It could also show that whether the animals are willing to ask for help or they would rather try to solve the task alone without any human help.

2.6. Data Collection

The experiments were recorded with multiple video cameras as it is visible on Picture 2 and Picture 3 and were coded after the experiments using the Loopy coding software. During testing of the pigs, 2 cameras were used. One wide angle camera was placed above the entrance of the pigs to see the test area and another camera was above the pigs to record the observation area. To keep the pictures as similar as possible, for the dogs 4 cameras were used. One fish-eye camera recorded the test area above in the middle, two cameras were on the left and on the right corner making it able to see the action of the animal and one camera from above to observe the animal. Two coders coded the videos, after having coded 25.93% of all the dog videos (42 videos out of 162) and 28.57% of all the pig videos (30 videos out of 105) for interobserver reliability assessments (conducted in R version 4.2.1).

To code the videos, different variables had to be measured and identified. During the Demonstration phase – which included crouching, lifting and sound – hesitation, peeking and choice was observed. Meanwhile during Transfer tasks – including Screen Choice Task, Pointing Task, Begging Task and Unsolvable Task – the preferred informant and the contact was measured. These variables could give information about the uncertainty of the animals, whether they detect the reliability of informants and if so, whether they differentiate between them. In the following a short description of the variables are presented.

Hesitation was coded as a duration and it measured the time between releasing the subject (after the experimenter finished cue presentation) until the subject made a choice. This release was defined as when the door was opened with pigs or when the owner ceased contact with the dog. Interobserver reliability (IOR) on percentage agreement was 93.7% for the dogs (subjects: 221, raters: 2) and 99.7% for the pigs (subjects: 320, raters: 2).

Peeking was an event (0/1, options: left, right, no), which was coded if the animal's nose was within 10 cm to the gap (on one screen) for at least 1 second. There could be more peeking per trial and it could happen on both of the sides. IOR on percentage agreement was 99.1% for the dogs (subjects: 222, raters: 2) and 99.1% for the pigs (subjects: 320, raters: 2).

Choice was also an event (0/1, options: left, right, no). This meant whether the animals crossed the outer side of one screen. Only one choice could happen during one trial. IOR on percentage agreement was 98.9% for the dogs (subjects: 263, raters: 2) and 99.5% for the pigs (subjects: 373, raters: 2).

The **preferred informant** variable was used across all the transfer tasks as an event (0/1, options: Reliable B, Unreliable, no choice). In Screen Choice and in Pointing, the choice variable was used for this purpose. During Begging the first approach and during Unsolvable Task the side of the first contact was measured as the informant chosen variable. This variable contained the role of the informants and not the side of it. Only one variable was counted per trial.

Contact was again a duration, which was measured during the two trials of Begging and the one Unsolvable Task. This variable contained the information if the animals made close contact (~10 cm) to one, both or none of the experimenters. More contacts could be made per trial and the length of them were summed per informants (Reliable B, Unreliable). Here the minimum criteria to count as contact was also 1 second. IOR on percentage agreement was 97.9% for the dogs on the left side (subjects: 287, raters: 2), 97.6 % on the right side (subjects: 287, raters: 2) and 98.5% for the pigs on the left side (subjects: 410, raters: 2) and 98.3% on the right side (subjects: 410, raters: 2).

For a more detailed description of the coding with all the coded variables see Appendix.

2.7. Data Analysis

We fitted two generalized linear mixed models per dependent variable of the demonstration phase (one for the whole data set, and one for the first trials per action and informant) to investigate the influence of our predictors of interest (informant role; action; species; and all their interactions up to the third order) on the response variables (cue following and hesitation). As the response cue following indicated whether the subject had walked to the same side where the informant had given the cue, we fitted these models with binomial error structure and logit link function (McCullagh and Nelder 1989). The response hesitation in turn described the time it took for the subject to make this choice (see Appendix for a detailed description). In order to fit the assumptions of the generalized linear mixed models, we log-transformed the response. As control predictors we included in all four models action.side (factor with levels left and right) to control for any side bias, and training (factor with levels trained and untrained) to control for any effect of pre-experience.

Additionally, we fitted two generalized linear mixed models to analyze the response to the two informants during the transfer phase, by either looking at whether the subjects had chosen the reliable informant over the Unreliable informant (binomial error structure and logit link function), or by looking at the proportion of time the subjects spent in contact with the reliable informant (beta regression model, overdispersion parameter=1.056). Predictors of interest were species and order of test, or trial respectively. Additionally, we included the position of the reliable informant (factor with levels left and right) as a control predictor in both models. See Tables 11-22 in the appendix for more details on model structure.

To account for repeated observations of the same individual we included the subjects' identity (runID) as random effect in all models. Furthermore, to account for any effects of experimenter dyad identity and clothing colour of said experimenters we included both expID.dyad and colour.dyad as random effects. Models were fitted in R (version 4.2.3) (R Core Team, 2022) using the function "glmer" or "lmer" of the package lme4 (version 1.1-27.1) (Bates et al., 2015) with the optimizer "bobyqa" (Powell, 2009) with 100.000 iterations, or using the function "glmmTMB" of the package glmmTMB (version 1.1.5) (Brooks et al. 2017.).

To avoid overconfident models and to keep the Type I error rate at the nominal level of 0.05 (Barr et al., 2013; Schielzeth & Forstmeier, 2009), we included all possible identifiable random slopes. Factors were manually dummy coded and cantered before including them as random slopes. After fitting the full model, we confirmed that the none of the model assumptions were violated. We verified absence of collinearity by calculating the Variance Inflation Factor (VIF) using the R package "car" version 3.0-12 (Fox & Weisberg, 2019), assuring that none of them were above VIF=3 (Zuur et al., 2010). We visually inspected the best linear unbiased predictors (BLUPs) per level of the random effects to confirm that they were approximately normally distributed (Baayen, 2008). To avoid "cryptic multiple testing" we compared the full model with all terms included, to a null model lacking the predictors of interest (Forstmeier & Schielzeth, 2011), but otherwise being identical. Individual fixed effects were then tested by dropping them from the model one at a time and comparing the simpler with the more complex model using likelihood ratio tests (Barr et al., 2013).

3. Results

When comparing the two species and their reactions of the reliable and unreliable informants, we found only few differences. Of the six models only two showed significant effects.

3.1. Cue Following

3.1.1. Cue following during the whole demonstration phase – model 1

None of the test predictors (informant role, action, and species) had an effect on cue following over all trials of the demonstration phase (Table 2, full-null model comparison: χ^2=15.989, df=11, P=0.142). Even though the dogs seemed to follow the cue of the informants in a higher percentage than pigs did (Table 3: dogs followed the informants in 86% of all trials (SE=0.0373, confidence interval: 0.769-0.918), while the pigs followed the cues in only 60% of the trials (SE=0.0455, confidence interval: 0.506-0.682)), we found no significant difference between species.

Table 2: *Results of the full model of cue following during the whole Demonstration phase. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	Std. Error	z value	χ^2	Df	*P*
(Intercept)	2.195	0.419	5.237			
informant_role^{Unreliable}	-0.034	0.456	-0.075			
action^{lift}	0.200	0.470	0.425			
action^{sound}	-0.574	0.445	-1.290			
species^{pig}	-0.909	0.500	-1.817			
action.side^{Right}	-0.187	0.417	-0.448	0.197	1.000	0.657
training^{untrained}	-0.316	0.333	-0.949	0.869	1.000	0.351
informant_role^{Unreliable}:action^{lift}	-0.287	0.546	-0.526			
informant_role^{Unreliable}:action^{sound}	0.344	0.588	0.585			
informant_role^{Unreliable}:species^{pig}	-0.337	0.600	-0.561			
action^{lift}:species^{pig}	-0.923	0.599	-1.542			
action^{sound}:species^{pig}	-0.246	0.665	-0.370			
informant_role^{Unreliable}:action^{lift}:species^{pig}	0.134	0.799	0.168	**-0.288**	**2.000**	**1.000**
informant_role^{Unreliable}:action^{sound}:species^{pig}	0.171	0.905	0.188			

Table 3: *Results of species comparison of cue following during the whole Demonstration phase.*

Species	Prob	SE	Df	Asymp. LCL	Asymp. UCL
dog	0.859	0.0373	Inf	0.769	0.918
pig	0.597	0.0455	Inf	0.506	0.682

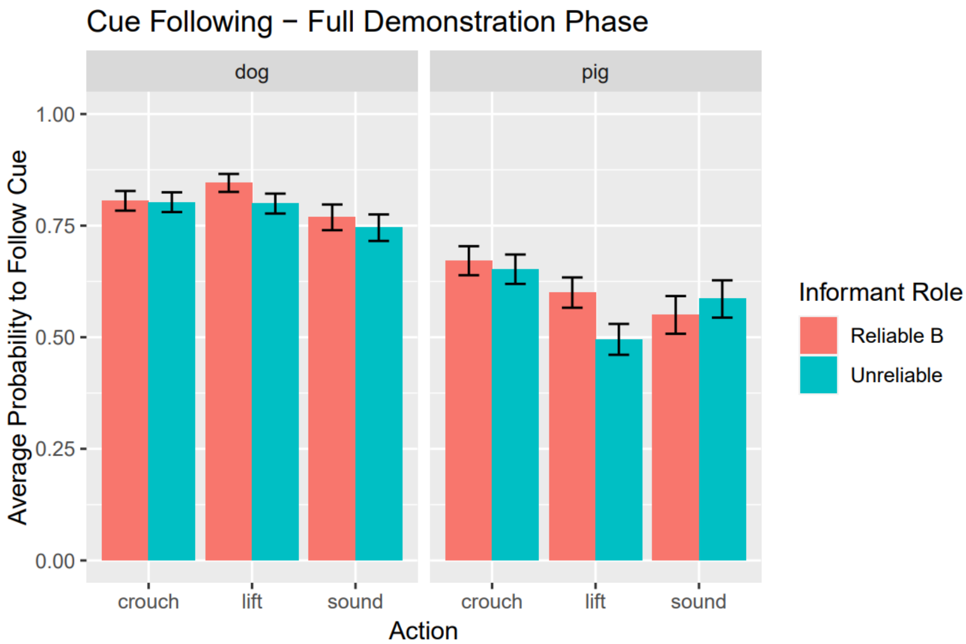


Figure 1*: Plot of the average probability to follow the cue during the whole Demonstration phase (error bars: SE).*

3.1.2. Cue following during the first exposure – model 2

Also, when focusing on cue following in the first single trial of experiencing one of the 3 actions by the reliable or unreliable informants, the full-null model comparison revealed no significant effect of the test predictors (Table 3, χ^2=12.200, df=11, *P*=0.349). That is, a similar percentage of dogs and pigs followed all 3 actions of both informants in their very first such trials.

Table 4: *Results of the full model of cue following during the first exposure of the Demonstration phase. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	**Std. Error**	**z value**	**χ^2**	**Df**	***P***
(Intercept)	1.714	1.035	1.655			
informant_role^{Unreliable}	0.501	1.157	0.433			
action^{lift}	3.429	3.777	0.908			
action^{sound}	0.020	1.126	0.018			
species^{pig}	-0.286	1.510	-0.189			
action.side^{Right}	0.146	0.656	0.222	-49.912	1.000	1.000
training^{untrained}	0.599	1.673	0.358	0.131	1.000	0.718
informant_role^{Unreliable}:action^{lift}	-1.579	2.176	-0.726			
informant_role^{Unreliable}:action^{sound}	-0.270	1.436	-0.188			
informant_role^{Unreliable}:species^{pig}	0.056	2.745	0.020			

$action^{lift}:species^{pig}$	-5.341	4.298	-1.242			
$action^{sound}:species^{pig}$	-2.146	1.911	-1.123			
$informant\_role^{Unreliable}:action^{lift}:species^{pig}$	-1.188	5.440	-0.218	**-76.685**	**2.000**	**1.000**
$informant\_role^{Unreliable}:action^{sound}:species^{pig}$	0.520	3.471	0.150			

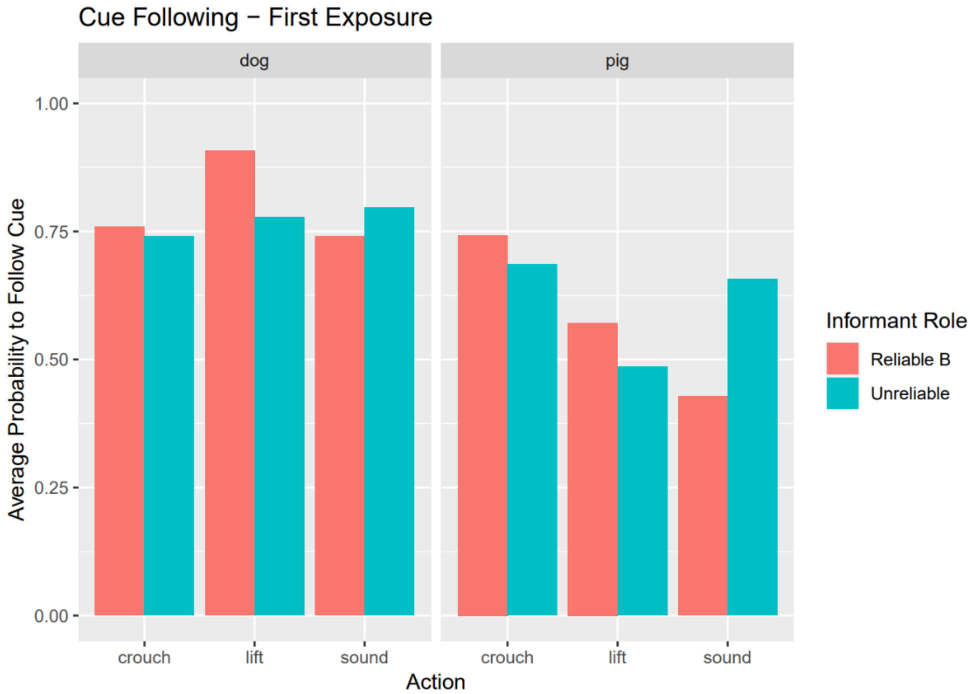


Figure 2*: Plot of the average probability to follow the cue during the first exposure of the Demonstration phase.*

3.2. Hesitation

3.2.1. Hesitation during the whole demonstration phase – model 3

When analysing hesitation (latency to choose one side) over all trials of the demonstration phase, the full and null models differed significantly (χ^2=20.579, df=11, *P*=0.038). However, neither the 3-way nor any of the 2-way interactions revealed a significant effect (Tables 23-25. in appendix). Only the model testing for main effects showed a significant effect of species on the time needed to make a choice (Table 4, χ^2=11.760, df=1, *P*=0.001): pigs needed longer to make a choice than dogs (Figure 3). Moreover, the 2-way interaction of action and species revealed a trend (χ^2=5.718, df=2, *P*=0.057) between the lifting and sound action in the data of pigs.

Table 5: *Results of the single effects model of hesitation during the whole Demonstration phase. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	Std. Error	t value	χ^2	Df	*P*
(Intercept)	1.099	0.071	15.520			
informant_role^{Unreliable}	0.000	0.019	0.025	**-0.538**	**1.000**	**1.000**
action^{lift}	-0.068	0.026	-2.583	**1.569**	**2.000**	**0.456**
action^{sound}	-0.028	0.045	-0.617			
species^{pig}	1.007	0.107	9.402	**11.760**	**1.000**	**0.001**
action.side^{Right}	0.004	0.017	0.271	-0.516	1.000	1.000
training^{untrained}	-0.216	0.116	-1.863	2.703	1.000	0.100
peeked^{peeking}	0.726	0.087	8.375	7.838	1.000	0.005

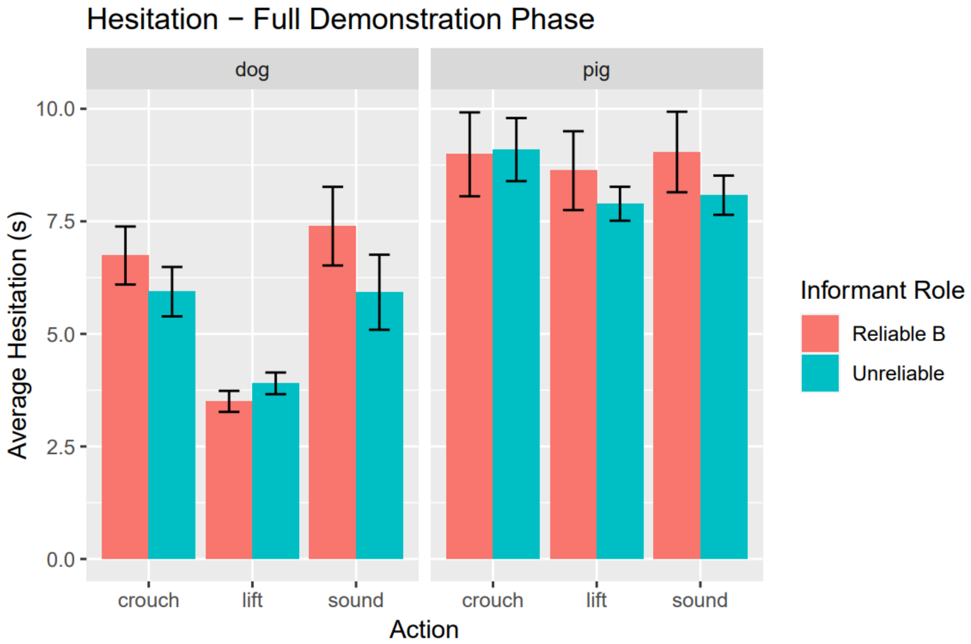


Figure 3: *Plot of the average hesitation during the whole Demonstration phase (error bar: SE).*

3.2.2. Hesitation during the first exposure – model 4

When analysing hesitation during first exposure to the novel actions of each informant, the full-null model comparison again brought a significant result (χ^2=24.010, df=11, *P*=0.013). As previously, the 3-way and 2-way interactions did not show any significant effect (Tables 26-28. in appendix). Thus, we fitted a model with only single effects. This model revealed a significant effect of species (Table 5, χ^2=11.506, df=1, *P*=0.001): already in the very first trials pigs took longer to make a choice than the dogs (Figure 4). Also, a trend appeared for the 2-way interaction between informant role and species (χ^2=3.427, df=1, *P*=0.064).

Table 6: *Results of the single effects model of hesitation during the first exposure of the Demonstration phase. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	Std. Error	t value	χ^2	Df	*P*
(Intercept)	1.033	0.079	13.089			
informant_role^{Unreliable}	-0.004	0.039	-0.106	**0.010**	**1.000**	**0.922**
action^{lift}	-0.134	0.037	-3.650	**4.471**	**2.000**	**0.107**
action^{sound}	-0.090	0.051	-1.762			
species^{pig}	1.163	0.093	12.522	**11.506**	**1.000**	**0.001**
action.side^{Right}	0.013	0.034	0.391	0.058	1.000	0.810
training^{untrained}	-0.285	0.115	-2.474	1.767	1.000	0.184
peeked^{peeking}	0.985	0.149	6.596	7.887	1.000	0.005

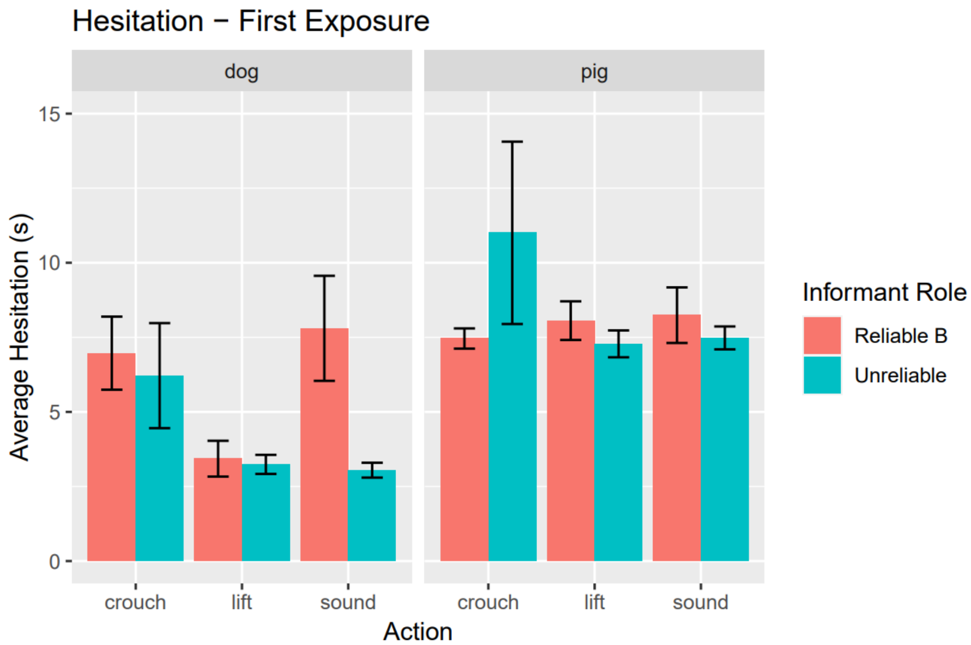


Figure 4: *Plot of the average hesitation during the first exposure of the Demonstration phase (error bar: SE).*

3.3. Preferred informant during all of the transfer tasks – model 5

When investigating if the two species differed in preferring one informant over the other in the transfer tasks, the full-null model comparison did not show any significant result (Table 6, binomial test: χ2=0.187, df=2, P=0.911). That is, neither species had an effect on the preference for a certain informant, nor did this preference change over the course of the four tasks. Rather, both dogs and pigs seemed to have picked one of the informants randomly in all 4 tasks (Figure 5).

Table 7: *Results of the full model of the preferred informant during Transfer tasks. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	SE	z value	χ^2	Df	*P*
(Intercept)	0.231	0.141	1.637			
$species^{pig}$	-0.071	0.166	-0.425	**0.179**	**1.000**	**0.672**
z.task_count	0.008	0.097	0.083	**0.007**	**1.000**	**0.934**
z.trial_count.task	-0.007	0.099	-0.073	0.859	1.000	0.354
$transfer\_reliable\_side^{Right}$	-0.511	0.234	-2.181	4.876	1.000	0.027

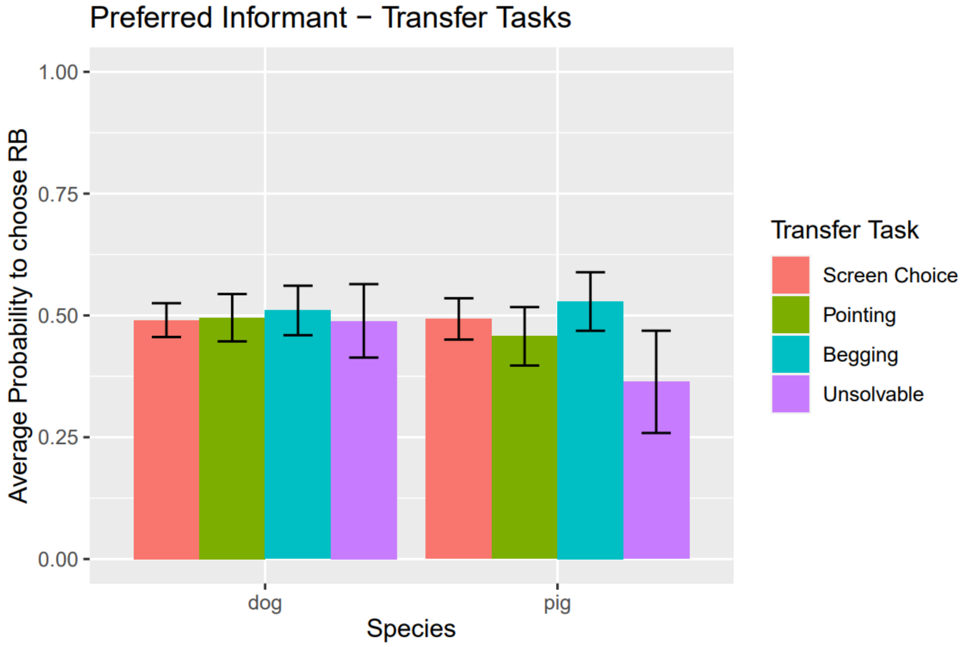


Figure 5: *Plot of the preferred informant during Transfer tasks.*

3.4. Contact during transfer tasks Begging and Unsolvable Task – model 6

We also wanted to see if the animals made contact with any of the experimenters during two of the transfer tasks (Begging and Unsolvable Task), which were designed to elicit communication attempts from the animals towards the humans. For this, we tested whether species had any effect on the proportion of contact with the reliable informant, or whether the proportion of contact with Reliable B changed over the three trials. The model additionally controlled for the effect of side on which Reliable B was positioned per trial. Also, this full-null model comparison did not show any significant result (Table 7, Beta regression model: χ^2=1.440, df=2, *P*=0.487). The animals spent a similar amount of time close to either informant (Figure 6).

Table 8: *Results of the full model of the amount of contact during Transfer tasks. Some statistics are omitted, due to limited interpretation. Test statistics for test predictors (not control predictors) are bold.*

	Estimate	Std. Error	z value	χ^2	Df	*P*
(Intercept)	0.097	0.147	0.657			
$species^{pig}$	-0.083	0.189	-0.438	**0.192**	**1.000**	**0.662**
z.trial_count.total_BU	-0.105	0.092	-1.140	**1.298**	**1.000**	**0.255**
$transfer\_reliable\_side^{Right}$	-0.139	0.183	-0.759	0.576	1.000	0.448

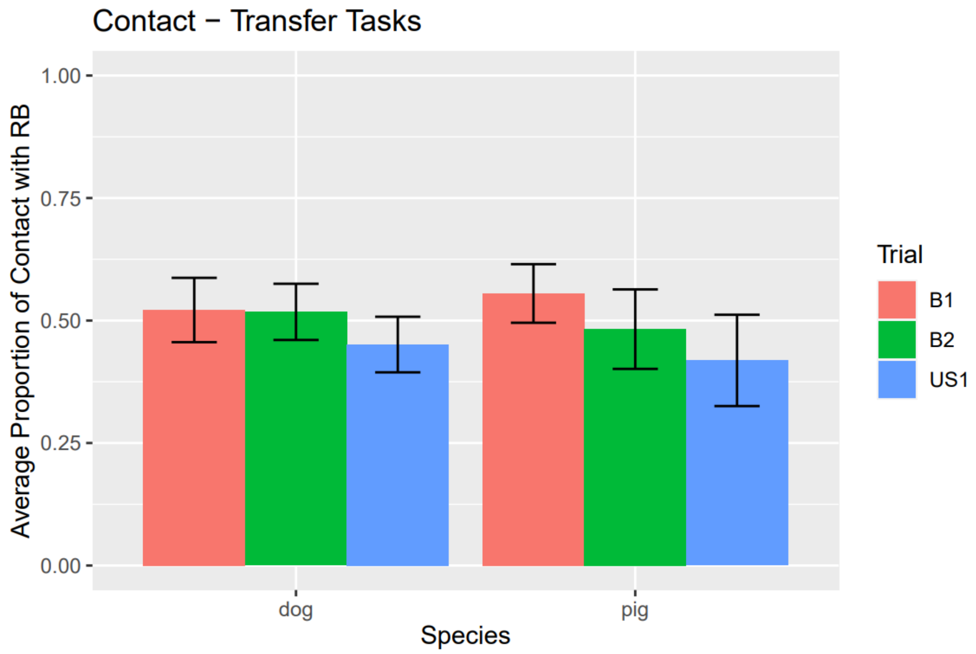


Figure 6: *Plot of the amount of contact during Transfer tasks.*

4. Discussion

In this study I found no evidence that pigs and dogs would be able to assess the reliability of the human informants. This lack of evidence was apparent both during the Demonstration phase and the Transfer tasks. The lack of selective responding to the two informants seems to be in contrast with former studies which argued that dogs can distinguish between informants. These studies are the already mentioned experiments by Takaoka et al. (2015) and Pelgrim et al. (2021). Both of these studies showed that the dogs follow a cue by an accurate informant more than that of an inaccurate informant and they do so even in a conflicting trial, where the subjects have to choose one of the informants who provided contradicting cues simultaneously. Note however that in these studies the dogs had an easier task than in my experiment: the subjects needed to learn about the cues and not about the informants themselves, as in the training and in test trials the same cues were provided to them. In this current study, I tried to go beyond this challenge and investigate if the animals can infer the reliability of the informants themselves based on their diverse cues by testing the behaviour of the animals in a new, novel setup. Our results of the lifting and sound actions during demonstration phase and the results of the transfer tasks – where the Reliable and Unreliable informant were present at the same time – showed that the animals failed to distinguish between informants in this complex study. That is, the animals, after having experienced the reliability of the animals in their crouching trials, could generalize this information neither to the new cues of the informants - that had no shared components with the crouching - in later stages of the demonstration phase nor to new contexts in the transfer tasks. The negative findings of this strict design may mean that dogs and pigs are not able to assess the reliability of informants. In other words, our animals could not use the accuracy vs. misleadingness of the cues and they could not generalize this knowledge to make inferences about the reliability of the informants. Note however that we did not explicitly check whether the animals actually learnt about and realized the accuracy vs. misleadingness of the cues of the two informants before progressing to a new phase of the experiment. We did not aim at training the animals on following the two informants' crouching in a differential manner and we found no evidence in our analyses that they would have distinguished between the two informants in this first phase of the experiment. Therefore, the lack of differentiation between the two informants may also mean that the animals did not realize that the differential misleadingness of their cues. When we consider that they experienced misleading cues in only 3 crouching trials (in half of the unreliable trials) it is easy to see how this information may have got lost when experienced interspersed between 9 rewarded crouching trials. (The same numbers were 8 vs. 24 trials during the course of the entire Demonstration phase.) If the animals paid no attention to these few trials, they of course did not have the necessary information to assess the reliability of the informants either. If the animals did not learn about the misleadingness of the cues during the crouching phase, they had no basis to know how to react to the novel actions of the informants.

It is important to notice that none of these two negative findings is in contrast with the positive findings of former studies. In both of these previously mentioned studies the dogs had direct information about the location of the reward during the training phase: they could either observe the hiding or the food was visible in the two food locations when the informants were presenting their cues. In this way, having direct information, the animals could learn about the accuracy of the cues under much easier conditions. Therefore, it is currently possible that the former studies overinterpreted their positive results not only be claiming that the animals can learn about the accuracy of the informants themselves instead of learning only about the accuracy of their cues, but also by missing the information that even this is possible only when the cue is in obvious contrast with the visible location of the food.

Before forming such a conclusion about the limited capacities of dogs and pigs to learn about the accuracy of human-given cues, we need to consider some additional reasons that could have led to my negative result. First, the duration of the study (1,5-2 hours) might have been too long for the animals to focus. Even though this would predict decreasing performance across the progressing phases of the experiment, we may have failed to find such a decreasing success if an initial success had been prevented by a need to learn first. As an alternative, reducing the Demonstration phase could improve this result, but this would also further reduce the amount of information based on which the subjects could learn about reliability of the informants (which is already critically low, as mentioned above). Another reason could be that engaging in the task might already be a rewarding situation for the animals and the actual reward was not as important anymore. Both the dogs and the tested pigs were human raised, thus they may have enjoyed just being around and interacting with humans without caring much about the additional food reward.

This seems to be supported by the finding that, even though the results of the differentiation between informants lacked evidence, the animals – both the pigs and the dogs – did follow the cues of the informants. This is even more interesting, given that they followed all 3 cues with a similar reliability, even if the lifting and especially the sound cue were much less discriminative and, therefore, more difficult than the crouching cue. Previous studies had demonstrated the ability of pigs (Nawroth et al. 2016) and dogs (Soproni et al. 2002) to follow human gestures such as pointing. In these studies, the ratio to follow the gestures had however decreased with increasingly difficult forms of pointing and other movements. Both species could follow the actions if it was conducted with a straight arm without the arm crossing the body. This pointing cue seem to be an easier cue for the animals, maybe because they meet with this action more often during their everyday life and due to being less novel for them compared to other actions. Even though the cues seemed to be more difficult in this current study, our results show similarities with the previous results: both of the species follow the different human gestures.

Moreover, we found no evidence that the dogs would follow these human-given cues in a higher ratio than pigs did. Even if the dogs seemed to have followed the cues more often (in 86% of all demonstration trials) than the pigs (that followed the cues of the informants in 60% of the trials), this difference was not significant. This result may at first seem contradictory with a previous study (Fraga et al. 2021) in which dogs approached a human earlier and alternated their gaze more frequently between an unsolvable apparatus and the human than the pigs did. This comparative study found that dogs are seeking for the human help sooner compared to pigs in a task very similar to our Unsolvable task. Still, our results did not seem to support this view, even if across a set of more diverse tasks. Importantly, our task was mostly centred around receiving information from human partners and not requesting information from them. The animals may interact differently with humans in these 2 contexts, as demonstrated by a study comparing dogs and cats. In this study (Miklósi et al. 2005), dogs outperformed cats when it came to communicating with humans, but both species performed very similarly when the task was to follow human-given cues.

Given that both dogs and pigs quite nicely followed the cues of both informants, they had also comparable opportunities to experience when the unreliable informant acted on one side and the food was still not there afterwards. That is, the animals experienced an overriding defeat in up to 8 trials, and they apparently still went on following the actions of the unreliable informant as well. In dogs, as argued in the introduction, the inherent compliance of the species may explain this finding. Range et al. (2019) did an experiment to compare dogs and wolves in a string-pulling task by cooperating with a familiar human partner. The results showed that both of the species cooperate with the humans, but a main deviation occurred: while the wolves decided to take the lead, the dogs waited for the human indication and then followed them.

Overall, the dogs showed behaviours to follow more, lead less and look more at the humans than wolves did. These results prove that the dogs evolved a more compliant coordination with humans during domestication. Moreover, the dogs can be more likely to avoid conflicts and follow the lead of the human, which takes the cooperation to an adaptive manner. A review by Range and Marshall-Pescini (2022) included some aspects of dog domestication compared to wolves. The socio-ecology could lead to some of the differences between the species. Since humans could prefer animals who can be easily controlled and inhibited and had some specific skills for their own use, they influenced some behaviour by the selection for specific traits. These studies can give an answer why the dogs are not as sensitive for the reliability of informants as expected. They are used to being under the influence of a human, thus they are not questioning the reliability of human gestures.

This explanation should be less relevant for pigs than for dogs, however, and we still did not find a difference between them. For the pigs, or for both species, an alternative reason to follow the informants' actions may be that these human actions included components that were strongly associated with food. Also, this effect could have been strengthened by using visual cues – the food bowl – and acoustic cues – shaking the food bowl – which were food associated previously.

It is important to mention, all the above mentioned aspects – conflict avoidance, compliant coordination, socio-ecology of dogs and pigs' and dogs' ability to follow cues – can explain why the animals did not differentiate between the two informants during the Demonstration phase. They cannot explain however the lack of this differentiation in the Transfer tasks. These tasks were designed to be increasingly different to the context of the Demonstration phase. In the first 2 tasks – Screen choice and Pointing – the informants went on providing information to the animals, while in the second 2 tasks – Begging and Unsolvable – the animals had the chance to initiate communication with the informants. During the Screen choice trials, the setup remained the same and the movements were similar to the training. The informants indicated that the food is there where they are standing. The task for the animals was also similar, to choose one screen based on which informant is standing in front of it. Based on these, it could be expected the animals would choose according to their gathered information and choose the reliable side. Although this is not represented in the results, the animals did not show any different behaviour during Screen choice compared to the other Transfer tasks.

Analysing the data included 2 variables, the Preferred informant and the amount of Contact to one informant to determine whom they were choosing and to whom they are spending more time. With the Preferred informant we aimed to investigate which informant is the one who the animals chose during all the Transfer test trials. Here, the animals did not show any preference for one informant over the other. This lack of differentiation shows that either the animals were not able to learn about the informants or their cues, or they were not able to transfer the gained knowledge to other contexts. On the other hand, the amount of Contact included a continuous variable, which measured the average length of contact made to one of the experimenters during Begging and Unsolvable trials. In these cases, the animals did not get a reward, thus the amount of contact could have been interpreted as a movement for asking for help from one experimenter to solve the task and gain a reward. Again, the animals did not show different behaviour to one informant over the other. This could mean that the animals did not learn that they would get the reward from the Reliable experimenter every time, since they did not spend more time with her, than with the Unreliable. Importantly, the lack of differentiation did not occur because the animals did not interact with the informants in the Transfer task. The animals did make a choice of them and also did contact the informants, which is in line with former studies that showed that dogs and pigs actively participate in these tasks (Nawroth et al. 2016, Soproni et al, 2002, Fraga et al. 2021).

As mentioned before, these results do not represent the ability of dogs and pigs to distinguish between the informants during novel, informant conflicting trials. Similarly, a recent study also shows this lacking ability in dogs during Transfer tasks. This study by Völter et al. (2022) included an unwilling and an unable person. The dogs faced the informants separately in order to get a reward. In each condition they could behave differently and they waited more during the unable condition, where they already got reward before. The second part of the study included transfer tasks, where the two informants were present at the same time. Interestingly, during this phase the dogs did not show any preference for one informant over the other. Even though the animals could distinguish between similar actions associated with different intentions, they lack any measurable preference in the later phases. This result – with our results can show that the dogs – and possibly also pigs - might not be able to transfer their previously gained knowledge to a novel task.

Since our results did not prove that the animals are able to differentiate between the informants, the idea of the ability to use undermining defeat is also lacking significant evidence. As described during the introduction, processing undermining defeats can take place if someone has a belief and suddenly something makes them question this thought without saying the opposite as clear evidence. The wet dog example showed this perfectly: I think it is sunny outside, but my dog comes in wet (O'Madagain et al. 2022). Thus, I think about my first belief of the sunny weather and question whether it is still sunny or raining, since my dog got wet. With the wet dog a second thought of the weather can replace the first one to check the actual weather from the window. Even though they trusted the informants in such a way as following their cues, they did not have a second thought (e.g., questioning their first belief and reassure or change it) about any of the informants. With this, we cannot say whether the animals are able to express undermining defeat. This study also supports the fact that testing the capability whether animals can process undermining defeaters is a methodological challenge. Using verbal methods seems to be easier for this purpose because the experimenters can simply ask the subjects about their thoughts and the reasons for their thoughts. Also, during the former studies the subjects could learn only about the cues, they did not have to have a belief about the reliability of the experimenters, only about the misleadingness of the cues. Moreover, even if the history and test trials use different cues, still the question remains whether the subjects learn and think about the reliability of the experimenters or the identity of them is only a part of the cue, but not the main source of it. The action itself can be more important to the animals and potentially the identity of the informants is only a secondary aspect to make a decision about them. This can mean that the animals do not necessarily think about the experimenters themselves. To be able to process undermining defeaters, the animals have to identify and assess their previous belief to think what they think at the moment. If it is not the case, the animals do not think about the identity of the experimenters or why they thought what they thought previously, they might not be able to process undermining defeat.

Based on this, the approach of using social informants still remains questionable around testing the ability of dogs to process undermining defeaters. It can cause several issues such as subjects can recognise the smell or the appearance of the experimenters and they can generalise this information over the trials instead of thinking about the experimenters themselves. Since this cannot be always avoided and frequently can lead to problems, a different approach should be worked out for testing the ability to process undermining defeaters. For this I suggest working out a different paradigm – which does not involve any identifiable informants across the stages of the experiment. This paradigm can bring more relevant results in terms of testing the assessment of undermining defeaters.

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6. Appendix

Table 9: *Details of the tested pigs, who were included in the statistical analyses. ID number: the anonym identification of an individual, age: the exact age on the testing day, sex: M: male, F: female, reliable A/reliable B/unreliable: roles of the informants across the three informants, reliable A colour/reliable B colour/unreliable colour: colours of the roles (black, white or striped).*

ID	age	sex	reliable A	reliable B	unreliable	reliable A colour	reliable B colour	unreliable colour
pig1	7.5	M	Franziska	Kea	Kinga	black	striped	white
pig2	8.9	F	Franziska	Kinga	Kea	black	white	striped
pig3	6.6	F	Kinga	Franziska	Kea	striped	black	white
pig4	6.7	M	Franziska	Kinga	Kea	black	white	striped
pig5	6.7	M	Kinga	Kea	Franziska	black	white	striped
pig6	7.5	F	Kinga	Franziska	Kea	black	striped	white
pig7	7.5	M	Kea	Kinga	Franziska	striped	black	white
pig8	7.5	F	Franziska	Kinga	Kea	striped	white	black
pig9	7.5	M	Kea	Franziska	Kinga	white	striped	black
pig10	6.7	F	Kea	Kinga	Franziska	striped	black	white
pig11	6.7	M	Kea	Kinga	Franziska	white	striped	black
pig12	6.7	F	Franziska	Kea	Kinga	white	striped	black
pig13	7.6	M	Franziska	Kea	Kinga	white	black	striped
pig14	7.6	F	Kea	Franziska	Kinga	black	striped	white
pig15	7.5	M	Franziska	Kea	Kinga	white	black	striped
pig16	6.7	F	Kea	Franziska	Kinga	black	white	striped
pig17	7.7	M	Kinga	Kea	Franziska	white	striped	black
pig18	7.6	F	Kea	Franziska	Kinga	white	black	striped
pig19	6.9	M	Kinga	Franziska	Kea	black	white	striped
pig20	7.7	F	Kea	Franziska	Kinga	striped	black	white
pig21	6.9	M	Kea	Kinga	Franziska	black	white	striped
pig22	6.9	F	Kinga	Franziska	Kea	white	black	striped
pig23	6.9	M	Kinga	Kea	Franziska	striped	black	white
pig24	6.9	F	Kinga	Franziska	Kea	white	black	striped
pig25	6.9	M	Kea	Franziska	Kinga	striped	white	black
pig26	7.7	F	Franziska	Kinga	Kea	black	striped	white
pig27	6.9	M	Kinga	Kea	Franziska	white	black	striped
pig28	7.7	F	Franziska	Kea	Kinga	striped	white	black
pig29	6.9	M	Franziska	Kinga	Kea	striped	black	white
pig30	7.7	F	Kea	Kinga	Franziska	black	striped	white
pig31	7.7	M	Kea	Kinga	Franziska	striped	black	white
pig32	6.9	F	Franziska	Kea	Kinga	white	black	striped
pig33	7.8	M	Franziska	Kinga	Kea	white	black	striped

pig34	7.7	F	Kea	Franziska	Kinga	white	black	striped
pig35	7.0	M	Kinga	Kea	Franziska	striped	black	white

***Table 10:** Details of the tested dogs, who were included in the statistical analyses. ID number: the anonym identification of an individual, age: the exact age on the testing day, sex: M: male, F: female, reliable A/reliable B/unreliable: roles of the informants across the three informants, reliable A colour/reliable B colour/unreliable colour: colours of the roles (black, white or striped).*

ID	age	sex	reliable A	reliable B	unreliable	reliable A colour	reliable B colour	unreliable colour
dog1	8.7	F	Kinga	Franziska	Kea	striped	black	white
dog2	12.3	F	Franziska	Kinga	Kea	striped	white	black
dog3	5.8	F	Kea	Franziska	Kinga	white	striped	black
dog4	7.2	M	Franziska	Kinga	Kea	striped	black	white
dog5	3.3	F	Kea	Kinga	Franziska	white	black	striped
dog6	4.4	M	Kea	Franziska	Kinga	white	striped	black
dog7	13.4	M	Franziska	Kea	Kinga	black	striped	white
dog8	2.6	M	Kinga	Kea	Franziska	white	black	striped
dog9	11.1	F	Franziska	Kinga	Kea	black	white	striped
dog10	6.3	F	Kea	Kinga	Franziska	striped	black	white
dog11	4.3	M	Kinga	Franziska	Kea	striped	black	white
dog12	5.8	M	Kea	Kinga	Franziska	white	black	striped
dog13	3.1	F	Kinga	Kea	Franziska	black	striped	white
dog14	6.8	M	Kea	Kinga	Franziska	white	striped	black
dog15	12.1	M	Franziska	Kea	Kinga	white	striped	black
dog16	6.2	M	Kea	Franziska	Kinga	striped	white	black
dog17	4.3	M	Kea	Franziska	Kinga	striped	black	white
dog18	11.4	M	Kinga	Franziska	Kea	striped	black	white
dog19	11	F	Kinga	Kea	Franziska	black	striped	white
dog20	1.9	F	Kea	Kinga	Franziska	black	white	striped
dog21	2.1	F	Kinga	Kea	Franziska	striped	black	white
dog22	6.3	F	Kea	Franziska	Kinga	white	striped	black
dog26	5	M	Franziska	Kea	Kinga	striped	black	white
dog27	5.6	F	Franziska	Kea	Kinga	black	striped	white
dog28	7.2	M	Kinga	Kea	Franziska	black	striped	white
dog29	2.7	M	Kinga	Franziska	Kea	white	striped	black
dog30	10.8	M	Kea	Kinga	Franziska	black	white	striped
dog31	9.3	F	Franziska	Kea	Kinga	black	white	striped
dog32	2.5	M	Kea	Franziska	Kinga	black	striped	white
dog33	12.3	F	Franziska	Kea	Kinga	white	black	striped
dog34	8.4	F	Kea	Kinga	Franziska	striped	black	white
dog35	5.8	M	Franziska	Kea	Kinga	black	white	striped
dog36	2.6	F	Kinga	Kea	Franziska	white	black	striped
dog37	3	F	Franziska	Kea	Kinga	black	white	striped
dog38	2.7	F	Franziska	Kinga	Kea	striped	white	black

dog39	1.4	F	Kinga	Franziska	Kea	black	white	striped
dog42	9.3	F	Kea	Franziska	Kinga	striped	white	black
dog43	8	F	Franziska	Kea	Kinga	white	striped	black
dog44	4.9	M	Franziska	Kinga	Kea	black	white	striped
dog45	5.4	F	Kea	Franziska	Kinga	striped	black	white
dog46	10.1	F	Franziska	Kinga	Kea	white	striped	black
dog47	5.2	M	Kinga	Franziska	Kea	striped	black	white
dog49	1.1	F	Kea	Kinga	Franziska	striped	black	white
dog50	8.8	M	Kinga	Franziska	Kea	striped	black	white
dog51	9.2	M	Kea	Kinga	Franziska	white	striped	black
dog52	3.3	M	Franziska	Kea	Kinga	striped	black	white
dog53	1.3	M	Kinga	Franziska	Kea	white	black	striped
dog54	1.2	M	Franziska	Kinga	Kea	black	striped	white
dog55	6.6	F	Kea	Franziska	Kinga	striped	white	black
dog56	5.5	F	Franziska	Kea	Kinga	striped	white	black
dog57	4.3	F	Franziska	Kinga	Kea	striped	black	white
dog59	5.9	F	Kea	Franziska	Kinga	striped	white	black
dog60	8.3	M	Kea	Kinga	Franziska	white	striped	black
dog61	3.2	M	Franziska	Kinga	Kea	black	white	striped

Table 11: *Calculating the criterion of the training.*

criterion to succeed training	number of trials	correct choices	incorrect choices
binom.test(x = c(9,1))	10	9	1
binom.test(x = c(10,1))	11	10	1
binom.test(x = c(10,2))	12	10	2
binom.test(x = c(11,2))	13	11	2
binom.test(x = c(12,2))	14	12	2
binom.test(x = c(12,3))	15	12	3
binom.test(x = c(13,3))	16	13	3
binom.test(x = c(13,4))	17	13	4
binom.test(x = c(14,4))	18	14	4
binom.test(x = c(15,4))	19	15	4
binom.test(x = c(15,5))	20	15	5
binom.test(x = c(16,5))	21	16	5
binom.test(x = c(17,5))	22	17	5
binom.test(x = c(17,6))	23	17	6
binom.test(x = c(18,6))	24	18	6
binom.test(x = c(18,7))	25	18	7

binom.test(x = c(19,7))	26	19	7
binom.test(x = c(20,7))	27	20	7
binom.test(x = c(20,8))	28	20	8
binom.test(x = c(21,8))	29	21	8
binom.test(x = c(21,9))	30	21	9
binom.test(x = c(22,9))	31	22	9
binom.test(x = c(22,10))	32	22	10
binom.test(x = c(23,10))	33	23	10
binom.test(x = c(24,10))	34	24	10
binom.test(x = c(24,11))	35	24	11
binom.test(x = c(25,11))	36	25	11
binom.test(x = c(25,12))	37	25	12
binom.test(x = c(26,12))	38	26	12
binom.test(x = c(27,12))	39	27	12
binom.test(x = c(27,13))	40	27	13

Coding the variables

In the beginning of coding each of the videos, the initials of the coder, the sex of the animal and in the case of the dogs the breed and the breed group were coded.

Demonstration phase

Trial length

All of the trial length in the demonstration phase was coded from the point where the experimenter stepped through the line (with the first leg) between the curtains. The end point was the point when the animal made a choice.

Cue presentation

The length of the cue presentation was also coded. This meant the time when the experimenter was in front of the curtain. The starting point of this action was the same point as the starting point of the trial length. The end of this point differed slightly. In crouching the end point was when the experimenter disappeared behind the curtains (when there was no part visible from the experimenter to the animal). In lifting the end point was coded when the second leg of the experimenter crossed the line between the two curtains. In sound action the end point was coded after the second sound cue (at this time the experimenter had already disappeared). If the cueing was overlapping with the hesitation (due to high motivation or a mistake by the handler) the cueing ended at the moment when the hesitation started.

Hesitation

Hesitation was defined by the latency between releasing the animal and choice. The starting point with the dogs was the time point when the owner released the subject (i.e., physical contact was ceased and the first movements of the hands were recognised or the owner gave the command to go). In the case of the pigs this was coded in the picture frame, when only the last two lines of the opaque door's grid were visible. The end point was coded in the time when the choice was made.

Peeking

Peeking was coded if the animal was orienting for at least 1 second in front of a screen while its nose was either within 10 cm proximity to a gap or was above the upper edge of a screen. This was coded as an event and could happen more than once. The coding happened from the animal's view and the side of the peeking was also coded. If there was no peeking, then when the trial ended, a no choice button was pressed. Possible peeking: left, right, no peeking.

Choice

Choice was defined as an event, when the animal chose one screen to go behind. This choice was coded in the moment, when one of the ear tips disappeared behind one of the V-shaped screens in the case of the pigs or if the nose of the dog appeared behind one of the screens. This difference was important because of the different camera angles. Only one choice was possible per trial. Possible choices: left, right, no choice.

Transfer tests

Screen choice

Trial length in screen choice

The starting and the ending point were the same as in the demonstration phase.

Approach

Approach was coded as an event (with the corresponding side) for both of the experimenters. At least one, but maximum two approaches possible. For the pigs it meant if the ears approached (when pig's tip of the ear was within the radius) an experimenter within the distance that equals the distance between the corner of the corresponding screen and the experimenter's leg. For easier coding the same measurement was marked on the ground with the dogs. This distance was the blue circle. Approach was measured when the nose of the dog approached (the dog's nose was within the radius) an experimenter within the blue circle on the ground using the fisheye camera.

Body contact

Body contact was coded as a duration for both of the experimenters. The side of the contact was coded and it could happen more than once or did not happen. This meant if the ear tip of the pig was in the same radius as previously described or when the nose of the dog was within the blue circle (using fisheye camera) on the ground in combination to following: body contact with any experimenters body part (nose was within 10 cm, while being oriented to the person for at least 1 second or/and vocalization happened while nose was directed at the experimenter or/and standing, sitting and laying in front of one of the experimenters while nose of the animal was within the radius or the blue circle and nose was directed at E for at least 1 second.

Pointing

Trial length in pointing

The start and the end of these trials were coded similarly. The start point was the point when the handler released the animal and the end point was when the animal made a choice.

Choice in pointing

Choice was made as soon as the movement of the lid (pigs) or the paper (dogs) was visible. Only one choice was possible, either left, right or no choice.

Begging

Trial length in begging

The trial length was coded also in this case. The starting point was the same, when the handler released the animal or when the two last grids were visible with the pigs. The end point was the point after one minute. This was signalled by a second “beep” sound.

Approach

Approach was coded as the same as in screen choice with a different distance. Here the measured distance was a new radius. This radius was the distance that equaled the distance between the 2 experimenters (foot to foot). This was marked with a white circle on the ground of the Clever Dog Lab. In this case only the first approach was coded with the corresponding side.

Contact

This contact was again a duration with each of the experimenters and the side of the contact was also coded. This was measured similarly as the body contact, with the difference of the distance. The radius of the begging approach and the white circle was used for the measurement.

Solvable

Trial length in solvable

The starting point of the solvable task was the same as previously described. The end point was the point when the animal could solve the task or if it could not solve it, then the second “beep” sound.

Success

This success meant the success of solving the task. This point was the point when the pig's forehead was the first time under the lid of the box or if the dog could push the jar and the jar first touched the ground. Success was coded as an event, with yes or no possibilities.

Solvable latency

Here the time was measured, how long did it take to the animal to solve the task successfully in the third solvable trial. The start and the end point were the same as in trial length.

Unsolvable

Trial length of unsolvable

The start point of the unsolvable trial was the same as previously and the end point was the point two minutes after the start point, meaning the second "beep" was coded as an end point.

Contact

In the case of the pigs the contact with any body part (nose is within 10cm), for at least 1 second was coded. Also, vocalization while nose was directed at the experimenter and standing or sitting in front of E within a distance of head length to the food bowl while nose was directed at E, for at least 1 second was coded as contact. Both of the sides were coded any time when contact happened. With the dogs it was similar, again the white circle was used instead of the head length distance.

Unsolvable latency

Here the latency to the first contact was measured. The start point was the same as the trial length starting point. The end point was when the first contact happened or if there was no contact, then two minutes after the releasing (this was communicated with a "beep" sound).

Results

Model 1 – Cue following during full demonstration phase

Table 12: *Details of Model 1 structure – Cue following during full demonstration phase.*

dependent variable	follow_cue
test predictors	informant_role * action * species +
control predictors	action.side + training +
random effects	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained | expID.dyad) +
	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained | colour.dyad) +
	(1 + informant_role.Unreliable*(action.lift+action.sound) + action.side.Right | runID) +
error distribution	binomial
sample size	2848 observations (14 no choice cases included as not following the cue)

Table 13: *Details of the used variables in Model 1.*

variables	type	levels
follow_cue	binomial	0 (no), 1 (yes)
informant_role	factor	Reliable B, Unreliable
action	factor	crouch, lift, sound
species	factor	dog, pig
action.side	factor	left, right
training	factor	trained, untrained

Model 2 – Cue following during first exposure of demonstration phase

Table 14: *Details of Model 2 structure – Cue following during first exposure of demonstration phase.*

dependent variable	follow_cue
test predictors	informant_role * action * species +
control predictors	action.side + training +
random effects	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained | expID.dyad) +
	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained | colour.dyad) +
	(1 + informant_role.Unreliable + (action.lift+action.sound) + action.side.Right | runID) +
error distribution	binomial
sample size	534 observations

Table 15: *Details of the used variables in Model 2.*

variables	type	levels
follow_cue	binomial	0 (no), 1 (yes)
informant_role	factor	Reliable B, Unreliable
action	factor	crouch, lift, sound
species	factor	dog, pig
action.side	factor	left, right
training	factor	trained, untrained

Model 3 – Hesitation during full demonstration phase

Table 16: *Details of Model 3 structure – Hesitation during full demonstration phase.*

dependent variable	Hesitation.length.log
test predictors	informant_role * action * species +
control predictors	action.side + training + peeked +
random effects	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained + peeked.peeking | expID.dyad) +
	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained + peeked.peeking | colour.dyad) +
	(1 + informant_role.Unreliable * (action.lift+action.sound) + action.side.Right | runID)
error distribution	gaussian
sample size	2833 observations of 2848

Table 17: *Details of the used variables in Model 3.*

variables	type	levels
Hesitation.length.log	continuous	min=0.29, mean=1.57, max=5.78
informant_role	factor	Reliable B, Unreliable
action	factor	crouch, lift, sound
species	factor	dog, pig
action.side	factor	left, right
training	factor	trained, untrained
peeked	factor	peeking, no peeking

Model 4 – Hesitation during first exposure of demonstration phase

Table 18: *Details of Model 4 structure – Hesitation during first exposure of demonstration phase.*

dependent variable	Hesitation.length.log
test predictors	informant_role * action * species +
control predictors	action.side + training + peeked +
random effects	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained + peeked.peeking || expID.dyad) +
	(1 + informant_role.Unreliable*(action.lift+action.sound)*species.pig + action.side.Right + training.untrained + peeked.peeking | colour.dyad) +
	(1 + informant_role.Unreliable * (action.lift+action.sound) + action.side.Right | runID)
error distribution	gaussian
sample size	532 observations of 534

Table 19: *Details of the used variables in Model 4.*

variables	type	levels
Hesitation.length.log	continuous	min=0.29, mean=1.53, max=4.72
informant_role	factor	Reliable B, Unreliable
action	factor	crouch, lift, sound
species	factor	dog, pig
action.side	factor	left, right
training	factor	trained, untrained
peeked	factor	no peeking, peeking

Model 5 – Preferred informant during all of the transfer tasks

Table 20: *Details of Model 5 structure – Preferred informant during all of the transfer tasks.*

dependent variable	preferred_informant ~
test predictors	species + z.task_count +
control predictors	z.trial_count.task + transfer_reliable_side +
random effects	(1 + species.pig + z.task_count + z.trial_count.task + transfer_reliable_side.Right || expID.dyad) +
	(1 + species.pig + z.task_count + z.trial_count.task + transfer_reliable_side.Right || colour.dyad) +
	(1 + z.task_count + z.trial_count.task + transfer_reliable_side.Right | runID)
error distribution	binomial
sample size	760 observations of 801

Table 21: *Details of the used variables in Model 5.*

variables	type	levels	example								
preferred_informant	binomial	0 (unreliable), 1 (reliable)	1	0	1	1	0	0	1	0	0
species	factor	dog, pig	dog	dog	dog	dog	dog	dog	dog	dog	dog
task_count	continuous	1 (SC), 2 (P), 3 (B), 4 (US)	1	1	1	1	2	2	3	3	4
trial_count.task	continuous	SC: 1-4, P/B:1-2, US: 1	1	2	3	4	1	2	1	2	1
transfer_reliable_side	factor	left, right	left	right	left	right	right	left	left	right	left

Model 6 – Contact during all of the transfer tasks

Table 22: *Details of Model 6 structure – Contact during all of the transfer tasks.*

dependent variable	contact_reliable.percentage_scaled
test predictors	species + z.trial_count.total_BU +
control predictors	transfer_reliable_side +
random effects	(1 | expID.dyad) +
	(1 | colour.dyad) +
	(1 | runID)
error distribution	beta
sample size	220 observations of 267
warnings/errors	model would not converge with random slopes

Table 23: *Details of the used variables in Model 6.*

variables	type	levels	example					
contact_reliable.percentage_scaled	proportion	min=0.002, mean=0.496, max=0.998	0.776	0.6966	0.237	0.002	NA	0.447
species	factor	dog, pig	pig	pig	pig	dog	dog	dog
trial_count.total_BU	continuous	1 (B1), 2 (B2), 3 (US)	1	2	3	1	2	3
transfer_reliable_side	factor	left, right	left	right	right	left	right	left

Tables of hesitation in full demonstration phase

Table 24*: Description of the hesitation full model - 3way interaction in full demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*	
(Intercept)	1.347	0.117	11.535				
informant_role^{Unreliable}	-0.094	0.065	-1.446				
action^{lift}	-0.279	0.071	-3.92				
action^{sound}	0.017	0.090	0.187				
species^{pig}	0.732	0.158	4.622				
action.side^{Right}	0.009	0.018	0.515	-0.309	1.000	1	
training^{untrained}	-0.150	0.133	-1.129	0.378	1.000	0.539	
peeked^{peeking}	0.691	0.106	6.526	13.130	1.000	0.0003	***
informant_role^{Unreliable}:action^{lift}	0.162	0.092	1.773				
informant_role^{Unreliable}:action^{sound}	-0.040	0.084	-0.474				
informant_role^{Unreliable}:species^{pig}	0.119	0.074	1.612				
action^{lift}:species^{pig}	0.248	0.070	3.537				
action^{sound}:species^{pig}	-0.025	0.142	-0.172				
informant_role^{Unreliable}:action^{lift}:species^{pig}	-0.185	0.099	-1.868	**2.753**	**2.000**	**0.252**	
informant_role^{Unreliable}:action^{sound}:species^{pig}	0.014	0.119	0.116				

Table 25*: Description of the hesitation reduced model 1 - 2way interaction in full demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*	
(Intercept)	1.252	0.108	11.644				
informant_role^{Unreliable}	-0.011	0.052	-0.211				
action^{lift}	-0.192	0.057	-3.365				
action^{sound}	-0.029	0.084	-0.341				
species^{pig}	0.853	0.146	5.828				
action.side^{Right}	0.001	0.017	0.034	-0.003	1.000	1	
training^{untrained}	-0.186	0.130	-1.434	1.131	1.000	0.288	
peeked^{peeking}	0.694	0.105	6.632	10.782	1.000	0.001	**
informant_role^{Unreliable}:action^{lift}	0.025	0.062	0.398	**0.250**	**2.000**	**0.882**	
informant_role^{Unreliable}:action^{sound}	-0.018	0.056	-0.32				
informant_role^{Unreliable}:species^{pig}	0.002	0.045	0.056	**0.585**	**1.000**	**0.445**	
action^{lift}:species^{pig}	0.165	0.055	2.984	**4.726**	**2.000**	**0.094**	
action^{sound}:species^{pig}	0.036	0.116	0.313				

Table 26: *Description of the hesitation reduced model 2 - 2way and single interaction in full demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*	
(Intercept)	1.219	0.091	13.425				
informant_role^{Unreliable}	0.000	0.020	0.019	**0.0002**	**1.000**	**0.987**	
action^{lift}	-0.173	0.041	-4.205				
action^{sound}	-0.028	0.076	-0.363				
species^{pig}	0.886	0.127	6.998				
action.side^{Right}	0.001	0.017	0.056	-0.003	1.000	1	
training^{untrained}	-0.205	0.117	-1.756	2.333	1.000	0.127	
peeked^{peeking}	0.720	0.092	7.813	11.645	1.000	0.0006	***
action^{lift}:species^{pig}	0.166	0.054	3.068	**5.718**	**2.000**	**0.057**	
action^{sound}:species^{pig}	0.018	0.112	0.161				

Tables of hesitation during first exposure

Table 27: *Description of the hesitation full model - 3way interaction in the first exposure of demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*	
(Intercept)	1.314	0.118	11.108				
informant_role^{Unreliable}	-0.166	0.091	-1.817				
action^{lift}	-0.310	0.093	-3.334				
action^{sound}	0.031	0.099	0.308				
species^{pig}	0.745	0.164	4.558				
action.side^{Right}	0.005	0.039	0.121	0.014	1.000	0.907	
training^{untrained}	-0.217	0.123	-1.765	7.390	1.000	0.007	**
peeked^{peeking}	0.887	0.216	4.115	8.047	1.000	0.005	**
informant_role^{Unreliable}:action^{lift}	0.177	0.149	1.193				
informant_role^{Unreliable}:action^{sound}	-0.157	0.124	-1.264				
informant_role^{Unreliable}:species^{pig}	0.235	0.115	2.04				
action^{lift}:species^{pig}	0.363	0.137	2.654				
action^{sound}:species^{pig}	0.025	0.141	0.178				
informant_role^{Unreliable}:action^{lift}:species^{pig}	-0.298	0.183	-1.627	**3.086**	**2.000**	**0.214**	
informant_role^{Unreliable}:action^{sound}:species^{pig}	0.075	0.173	0.433				

Table 28: *Description of the hesitation reduced model 1 - 2way interaction in the first exposure of demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*
(Intercept)	1.209	0.107	11.353			
informant_role^{Unreliable}	-0.083	0.078	-1.059			
action^{lift}	-0.205	0.075	-2.715			
action^{sound}	-0.010	0.079	-0.121			
species^{pig}	0.873	0.149	5.872			

action.side^{Right}	0.004	0.036	0.100	4.621	1.000	0.032	*
training^{untrained}	-0.246	0.117	-2.103	2.539	1.000	0.111	
peeked^{peeking}	0.840	0.207	4.054	5.805	1.000	0.016	*
informant_role^{Unreliable}:action^{lift}	0.010	0.116	0.088	**1.966**	**2.000**	**0.374**	
informant_role^{Unreliable}:action^{sound}	-0.116	0.100	-1.159				
informant_role^{Unreliable}:species^{pig}	0.146	0.061	2.386	**3.427**	**1.000**	**0.064**	.
action^{lift}:species^{pig}	0.164	0.089	1.835	**2.347**	**2.000**	**0.309**	
action^{sound}:species^{pig}	0.040	0.108	0.368				

Table 29: *Description of the hesitation reduced model 2 - 2way and single interaction in the first exposure of demonstration phase.*

	Estimate	Std. Error	t value	χ^2	Df	*P*	
(Intercept)	1.091	0.083	13.114				
informant_role^{Unreliable}	-0.056	0.046	-1.207				
species^{pig}	1.065	0.107	9.93				
action^{lift}	-0.134	0.037	-3.637	**5.130**	**2.000**	**0.077**	.
action^{sound}	-0.086	0.051	-1.683				
action.side^{Right}	0.013	0.035	0.366	0.044	1.000	0.834	
training^{untrained}	-0.291	0.115	-2.524	2.051	1.000	0.152	
peeked^{peeking}	0.948	0.149	6.355	8.544	1.000	0.003	**
informant_role^{Unreliable}:species^{pig}	0.108	0.059	1.837	**1.446**	**1.000**	**0.229**	

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