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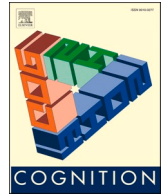
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Changing minds about minds: Evidence that people are too sceptical about animal sentience

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ABSTRACT

Our relationships with other animals are governed by how we view their capacity for sentience and suffering. However, there is currently little agreement as to whether people's beliefs about animal minds are largely accurate or inaccurate. We used an innovative task to examine how people update their beliefs in response to noisy but informative clues about animal minds. This allowed us to compare participants' posterior beliefs to what a normative participant ought to believe if they conform to Bayes' theorem. Five studies (four pre-registered; $n = 2417$) found that participants shifted their beliefs too far in response to clues that suggested animals do not have minds (i.e., overshooting what a normative participant ought to believe), but not far enough in response to clues that suggested animals have minds (i.e., falling short of what a normative participant ought to believe). A final study demonstrated that this effect was attenuated when humans were the targets of belief. The findings demonstrate that people underestimate animal minds in a way that can be said to be inaccurate and highlight the role of belief updating in downplaying evidence of animal minds. The findings are discussed in relation to speciesist beliefs about the supremacy of humans over animals.

1. Introduction

The use of nonhuman animals in industry, medical research, and agriculture prompts important debates about animal rights and welfare (Amiot & Bastian, 2015; Bekoff, 2002; Bentham, 2015; Dhont, Hodson, Loughnan, & Amiot, 2019; Singer, 1975). It is generally agreed that animal sentience, and especially their capacity to suffer, is of central importance to these debates (Animal Welfare (Sentience) Bill, 2021; Bock & Buller, 2013; European Union, 2007). However, agreement is lacking about whether people, on average, overestimate or underestimate animal minds. Some have expressed concern both about the tendency to overestimate animal minds (i.e., anthropomorphism; Burghardt, 1991a, 1991b, 2004; Wynne, 2004, 2007) and others about the tendency to underestimate animal minds (i.e., mind-denial; Rollin, 1989; Singer, 1975). It is currently unclear which of these perspectives is correct because beliefs about animal minds have yet to be investigated in ways that afford claims about accuracy. In the present work, we examined how people update their beliefs about animal minds in response to signals that have a clearly defined probability of being accurate, allowing us to determine the veracity of people's posterior beliefs about animal minds by comparing them to an unbiased benchmark.

1.1. Do people over- or underestimate animal minds?

Questions about how people perceive animal minds have occupied a space in the scientific literature for centuries. Scholars from numerous disciplines have noted that people have a tendency to ascribe nonhuman entities, including animals, emotions and cognitions (for historic overview see Serpell, 2003). This tendency is pervasive enough to prompt some scientists to caution against the use of anthropomorphic language (Burghardt, 1991a, 1991b, 2004; Wynne, 2004, 2007). Contemporary psychological research corroborates the view, showing that people imbue intentionality not only to animals but to minimal stimuli such as animated geometric shapes (Douglas, Sutton, Callan, Dawtry, & Harvey, 2016; Heider & Simmel, 1944; Waytz, Cacioppo, & Epley, 2010). Other findings indicate that when people feel lonely, they view their pets as more sentient, perhaps because doing so enhances the subjective quality of their company (Bartz, Tchalova, & Fenerci, 2016; Epley, Akalis, Waytz, & Cacioppo, 2008; Epley, Waytz, Akalis, & Cacioppo, 2008). This work suggests that people are keen to anthropomorphize animals, perhaps even to the point of overestimating their minds.

Other work, however, suggests that people are motivated to view animals as relatively mindless. Most people subscribe to a view

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analogous to the Great Chain of Being (Lovejoy, 1937) in which humans are superior to animals in their moral and cognitive qualities (Awad et al., 2018; Caviola, Everett, & Faber, 2018; Crimston, Bain, Hornsey, & Bastian, 2016; Demoulin et al., 2004; Gray, Gray, & Wegner, 2007; Leyens et al., 2001). This distinction goes hand-in-hand with *speciesism* (Dhont, Hodson, Leite, & Salmen, 2020; Dunayer, 2004; Singer, 1975, 2009)—the assignment of moral standing based on species membership (Caviola et al., 2018, 2020; Horta, 2010). Given that sentience and mental sophistication are widely perceived as a defining feature of our species (Demoulin et al., 2004; Leyens et al., 2001), it stands to reason that imbuing animals with sophisticated minds threatens the uniqueness of our position in the world. In keeping with this idea, people prefer humans to be distinct from other animals (Goldenberg et al., 2001; Hodson, Dhont, & Earle, 2020) and find it offensive to be likened to them (Haslam, Loughnan, & Sun, 2011). They also tend to speak and write about animals in a way that represents them as less worthy of moral concern compared to humans (Leach, Kitchin, Sutton, & Dhont, 2022; Sealey & Oakley, 2013).

Research on the ‘meat paradox’ points to a similar conclusion in suggesting that people are motivated to see animals as mindless (Bastian & Loughnan, 2017; Loughnan & Davies, 2020). This work frames people as caught in a dilemma—they like and care about animals but often exploit them for their own benefit. This is thought to trigger moral disengagement (Bandura, 1999; Piazza et al., 2015) and to drive people to deny the sophistications of animals’ minds, particularly those animals that are harmed in the processes of meat production and factory farming (Bastian, Loughnan, Haslam, & Radke, 2012; Bratanova, Loughnan, & Bastian, 2011; Loughnan, Haslam, & Bastian, 2010; Rothgerber, 2020). These findings attest to people’s tendency to deny animals’ minds and thereby potentially make an error in seeing them as less sophisticated than they actually are.

This work represents the strides psychological science has made in documenting how people ascribe mental states to animals. However, we submit that these findings cannot speak to the accuracy of peoples’ beliefs about animal minds. This is because the findings document judgements about broad aspects of animal minds (e.g., the extent to which pigs have the capacity to think) that are measured on subjective response scales (e.g., not at all - very much). As such, these judgements have no direct empirical referent and therefore cannot be said to be right or wrong. In principle, researchers could gauge whether people overestimate or underestimate by sampling a narrow subset of beliefs that can be verified in relation to the scientific record (e.g., whether elephants can recognize themselves in a mirror). However, such an approach would be undermined by new evidence and theory—classifications of beliefs as (in)accurate will inevitably need revision. This is compounded by the fact that studying animal minds is notoriously challenging. Indeed, the scientific literature on the matter is incomplete and controversial (Dawkins, 2015; de Waal, 2016), meaning that it arguably cannot provide a comprehensive normative benchmark against which human judgements can be compared. This would seem to present an intractable barrier in the way of determining whether people underestimate or overestimate animal minds.

1.2. Assessing the accuracy of judgements about animal minds

We address this problem by positing that the empirically-tractable question is not whether beliefs about animal minds are ultimately true or untrue. Rather, it is whether beliefs are accurate or inaccurate in relation to the available evidence. This framing opens the door to redefining questions related to truth and accuracy, and in doing so allows us to take an important step towards identifying the veracity of people’s beliefs about animal minds. In the current research, we adopt a research paradigm in which participants are tasked with updating their beliefs in response to noisy but informative clues about their veracity (Hill, 2017; Tappin, Pennycook, & Rand, 2020). In this paradigm, participants provide their initial belief—the prior. They are then provided

with a clue about the veracity of their belief—the signal. Finally, they provide their updated belief—the posterior. Given that the subjective probability of the signals’ accuracy is determined (and known by participants), it is possible to calculate what the posterior, given the prior and signal, ought to be according to Bayes’ theorem. This allows one to measure the extent to which posterior beliefs deviate from what a normative participant ought to believe and, therefore, to gauge the accuracy of participants’ beliefs in relation to what is normative.

We adapt this paradigm to examine the accuracy of participants’ beliefs about animal minds. We illustrate with an example. Take a study in which participants report how certain they are that pigs have various mental capacities, from 0 (certainly do not) to 100 (certainly do), and receive hints about whether their beliefs are true (with an explicitly-defined probability of being accurate of $\frac{2}{3}$). Now take a trial in which a participant initially reports being somewhat certain (60) that pigs have the capacity for empathy—the prior. They then receive a hint that pigs do, in fact, have the capacity for empathy—the signal. And, finally, they report being slightly more certain (65) that pigs have the capacity for empathy—the posterior. Applying Bayes’ theorem we can calculate the belief a normative participant ought to hold on this trial (given the participant’s prior and the signal they received). The benchmark is 75 in this case (further details on how to compute the benchmark are given in subsequent sections). Comparing the participant’s posterior (65) to the benchmark (75) demonstrates that the belief is less certain than normatively prescribed by Bayes’ theorem and, in this sense, underestimates the likelihood that pigs can experience empathy. An analogous pattern of underestimation can also arise when participants receive a signal suggesting pigs *do not* have a capacity and arrive at a posterior belief that is more certain that pigs *do not* have the capacity (e.g., 20) than prescribed by Bayes’ theorem (e.g., 40). An overall pattern of responding like this, we argue, would constitute a systematic underestimation of the animal minds. Evidence of overestimation would be the opposite.

Five studies (four pre-registered; $n = 2417$) employed this paradigm to test the accuracy of people’s beliefs about animal minds. Studies 1a and 1b present an initial investigation into beliefs about whether pigs have various mental capacities, such as empathy and planning. Study 1a focuses on meat-eaters and Study 1b on those who abstain from meat. Study 2 delves into the mechanisms underlying belief updating about animals’ minds and shows that they are attributable to biases in how beliefs are adjusted, as opposed to how evidence is weighed. Study 3 extends the work by examining beliefs about whether genuine evidence of animal minds, as one might come across in popular media and scientific articles, is true or false. Study 3 also tests a potentially important moderator: whether the target of judgment is an animal typically reared for food (pigs) or kept as a pet (dogs). Finally, Study 4 further extends the work by examining if belief-accuracy about minds is moderated by whether the target of judgment is an animal or human. We also document two additional studies in the Supplementary Material (Studies S1 and S2). These studies examine beliefs about fictitious, but allegedly real, animals of which participants have no prior knowledge. The findings conceptually replicate those of Studies 1–4 but are omitted from the Main Body for brevity. The pre-registrations, data, and analysis scripts are available on the *Open Science Framework* (<https://osf.io/tpqsm/>).

2. Study 1a and 1b: Scepticism about animal minds

Studies 1a and 1b present an initial investigation into the accuracy of peoples’ beliefs about animal minds. These studies examined judgements about whether pigs have various mental capacities, such as empathy, planning, and tool use. We focus on pigs because they are a familiar animal (Leite, Dhont, & Hodson, 2019; Possidónio, Graça, Piazza, & Prada, 2019) that is subject to large-scale harms in the processes of meat-production. As such, beliefs about pigs’ minds bear on important moral debates surrounding the treatment of nonhuman animals in industry and agriculture (Amiot & Bastian, 2015; Bekoff, 2002;

Bentham, 2015; Dhont et al., 2020; Singer, 1975).

We tested a number of pre-registered predictions. Most importantly, we tested whether people have an overall tendency to overestimate or underestimate pigs' minds. Here we present two competing predictions. Based on work that highlights humans' tendency towards anthropomorphism (Epley, Waytz, & Cacioppo, 2007; Waytz et al., 2010; Waytz, Cacioppo, & Epley, 2010), we predicted that participants would show a general tendency to overestimate pig minds. This entailed that participants would update too far in response to clues that suggest pigs have minds but not far enough in response to clues that suggest pigs lack minds. Based on work that documents speciesist beliefs about human superiority over animals (Caviola et al., 2018; Dhont et al., 2020; Dhont & Hodson, 2020; Dunayer, 2004; Herzog, 2010; Joy, 2010; Leach, Kitchin, et al., 2022; Singer, 1975, 2009), we derived the competing prediction that participants would show a general tendency to underestimate pig minds. This entailed that participants would update too far in response to clues that suggest pigs lack minds but not far enough in response to clues that suggest pigs have minds. Because research suggests that the desire to eat meat may motivate people to downplay animal minds (Bastian & Loughnan, 2017; Loughnan & Davies, 2020), we examined beliefs in those who consume meat (Study 1a) and those who do not (Study 1b). On the basis of prior work showing that vegetarians tend to afford animals greater moral standing and mind (Rothgerber, 2014), we predicted that they would overestimate pigs' minds, and that their tendency to do so would be significantly greater than meat-eaters.

2.1. Methods

2.1.1. Participants and design

Open science. We report all measures and exclusions. Studies 1a and 1b's hypotheses, sample targets, exclusion criteria, dependent variable transformations, and statistical models were pre-registered (<https://osf.io/n4wxu/>, <https://osf.io/fz7c5/>).

Sample size justification. On the basis of an a priori pre-registered power analysis, we aimed to recruit 400 participants for each study. We approached the power analyses with some general expectations, informed by our prior work (see Studies S1 and S2 in the Supplementary Material), about the likely magnitudes of the effects. In standardized units, we expected differences in updating between signals suggesting pigs have (and do not have) mental capacities and the Bayesian benchmark (0) of the following magnitude: $\beta = \pm 0.10$. This corresponded to a simple-effect difference in updating between signals suggesting pigs have (vs. do not have) mental capacities of the following magnitude: $\beta = 0.20$. The predicted results are illustrated in the Supplementary Material (Figs. S1 and S2). The magnitudes of these effects could be considered small-to-medium, given the typical effect sizes reported in social psychology (Lovakov & Agadullina, 2017). Our prior data also provided some expectations about the likely degree of variance between participants ($SD_{\text{intercept}} = 0.20$) and capacities ($SD_{\text{intercept}} = 0.08$). Simulating 10,000 samples via the *SimR* package (Green & MacLeod, 2016) for *R* (Version 1.2.5001; R Core Team, 2019) suggested that samples of 400 would afford >80% power to detect the smallest expected effects.

Samples. We met our pre-registered sample targets. Four hundred and one self-identified meat-eaters ($n_{\text{female}} = 260$, $M_{\text{age}} = 34.54$, $SD_{\text{age}} = 13.01$) from the United Kingdom participated in Study 1a and four hundred self-identified veg*ns ($n_{\text{female}} = 295$, $M_{\text{age}} = 33.13$, $SD_{\text{age}} = 11.70$) participated in Study 1b. Participants were pre-screened in both studies and indicated their diets by selecting one of five options: "I prefer to eat meat" ($n_{\text{Study 1a}} = 38$, $n_{\text{Study 1b}} = 0$), "I prefer meat and vegetables" ($n_{\text{Study 1a}} = 167$, $n_{\text{Study 1b}} = 0$), "I eat meat, but not very much" ($n_{\text{Study 1a}} = 196$, $n_{\text{Study 1b}} = 0$), "I do not eat meat" ($n_{\text{Study 1a}} = 0$, $n_{\text{Study 1b}} = 128$), or "I do not eat any meat or animal products" ($n_{\text{Study 1a}} = 0$, $n_{\text{Study 1b}} = 272$). Participants were recruited via the crowdsourcing platform *Prolific* in exchange for compensation at a minimum rate of £5.00 per hour. No data were analyzed prior to reaching the target sample size.

Design. Participants in both studies responded to a 2-within (signal: DO have the capacity vs. DO NOT have the capacity) design. The research was approved by an internal ethical review board in compliance with British Psychological Society's code of ethics and conduct. All participants provided informed consent prior to participation.

2.1.2. Procedure and materials

Belief updating task. We employed the same belief updating task in Studies 1a and 1b. This task was adapted from prior work examining how people update their beliefs about the veracity of political statements in response to noisy but informative signals (Hill, 2017; Tappin et al., 2020). Before beginning the main task, participants were informed that they would be making judgements about pigs and that they would receive hints (also referred to as signals) about whether their judgements were accurate (as determined by scientific research). Before starting the task participants were instructed that the signals had a $2/3$ chance of being accurate and $1/3$ chance of being inaccurate. These probabilities followed prior work (Hill, 2017; Tappin et al., 2020). Participants were required to answer two comprehension questions to ensure their understanding ("On average, how many of the signals that you will see ACCURATELY reflect the truth or falsity about pigs?"; "On average, how many of the signals that you will see INACCURATELY reflect the truth or falsity about pigs?"). Participants then moved on to the main belief updating task.

The paradigm was then broadly divided into two phases. A visualization is provided in Fig. 1. The first phase elicits participants' prior beliefs and presents them with signals (hints) about their accuracy. Participants began each trial by judging the likelihood that pigs possessed 1 of 16 mental capacities that feature in work on animal cognition and psychological theory (e.g., "Do pigs have the capacity for empathy?"), from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity). Each capacity was presented on a separate page and in randomized order. Each judgment was accompanied by a short description of the capacity, capturing genuine scientific research on animal cognition. These descriptions were taken from prior work and have been shown to evoke mental-state attributions (Leach, Sutton, Dhont, & Douglas, 2021). A selection of the capacities are presented in Fig. 1. The full list can be found in Table S1. We refer to these judgements as participants' prior beliefs.

Immediately after providing each prior belief participants received a hint (signal) about the veracity of their belief. The signal was either "Pigs DO have the capacity for [capacity]" or "Pigs DO NOT have the capacity for [capacity]" communicating that the scientific evidence suggested that pigs either did or did not possess the capacity. The signal's actual accuracy was undetermined.¹ We therefore chose to randomize the signals to have an equal ($1/2$) probability of occurring on any given trial—although note the subjective accuracy of the signals was defined as being $2/3$ accurate and $1/3$ inaccurate via explicit instruction (and confirmed via comprehension checks).

After providing their prior beliefs and encountering the signals, participants moved on to the second phase which elicited their posterior beliefs. Participants provided these along the same scales, from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity), in response to the same 16 mental capacities one-by-one. Each capacity was presented on a separate page and in randomized order.

¹ Although the capacities capture genuine scientific research on animal cognition (see Leach et al., 2021), they were not compiled solely from research on pigs. As such, each capacity presents multiple statements, only some of which are supported by genuine scientific findings about pigs. Take tool use as an example: there is evidence that pigs can learn how mirrors work (Broom et al., 2009) but, to our knowledge, no evidence to suggest that pigs will use sticks to pull food towards them or get food from hard-to-reach places. Thus, neither signal can be said to be entirely accurate or inaccurate when applied to whether pigs have the capacity to use tools (as it is described here). We address this issue in Study 3 by employing a different set of stimuli whose truth values can be more convincingly verified in relation to genuine research.

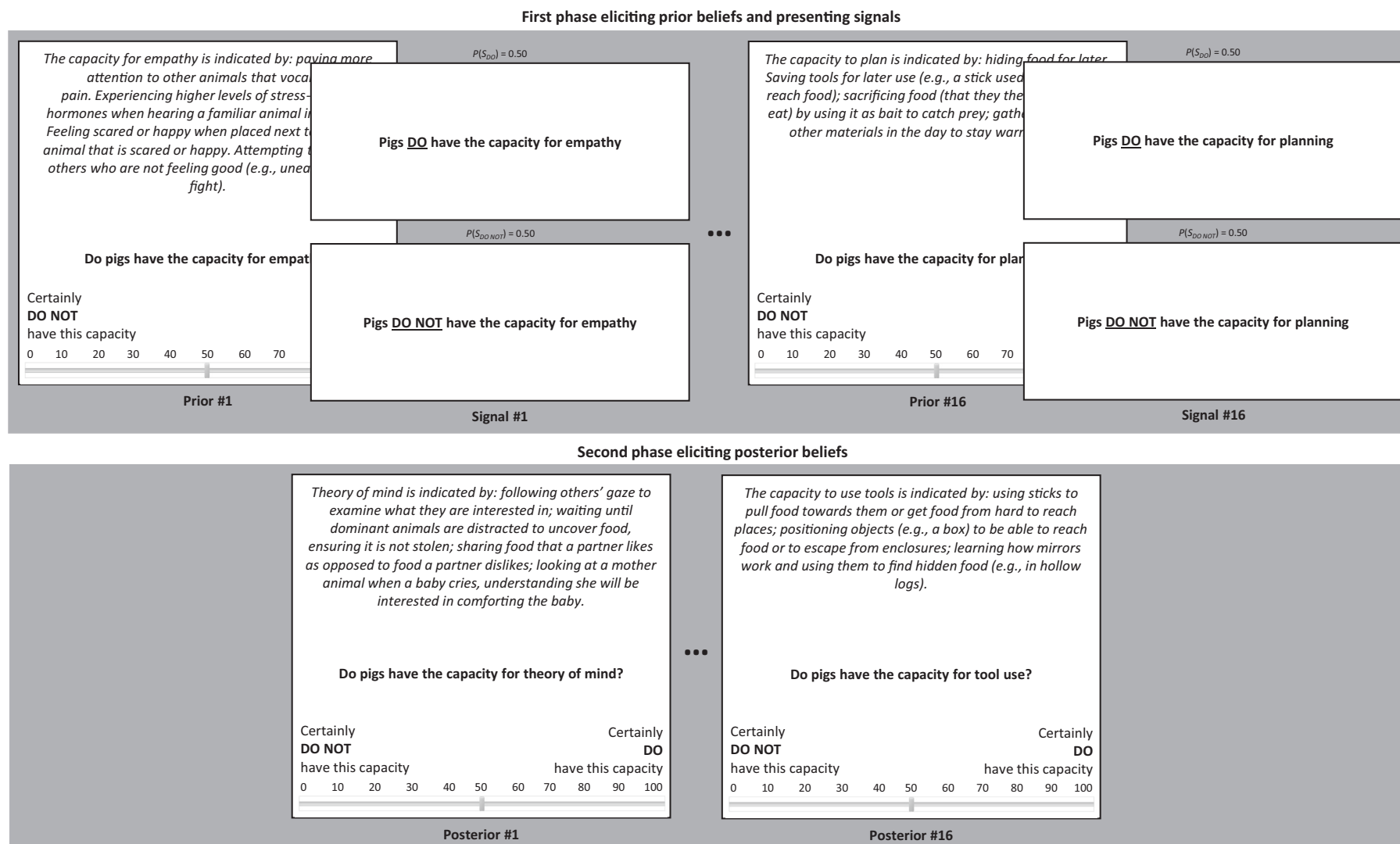


Fig. 1. Belief updating paradigm procedure.

Note. In the first phase, prior beliefs are measured and signals (hints) are given one-by-one in randomized order. In the second phase, posterior beliefs are measured for the same stimuli in randomized order.

Participants did not have access to their self-reported prior beliefs when providing their posterior beliefs.

Additional measures. After fully completing the belief updating task, participants in both studies were asked questions about pigs' minds and moral standing. These followed prior work (Bastian et al., 2012; Leach et al., 2021; Piazza, Landy, & Goodwin, 2014) and served exploratory and validation purposes. They were asked eight of questions about pigs' minds ($as > 0.81$; "To what extent are pigs capable of... 1) thought, 2) self-control, 3) planning, 4) remembering, 5) fear, 6) pain, 7) pleasure, and 8) suffering"), from 1 (not at all) to 7 (very much). Participants in both studies were asked four questions about the morality of harming pigs ($as > 0.84$; "How morally wrong is it to... 1) harm a pig, 2) hurt a pig, 3) kill a pig, and 4) inflict pain on a pig"), from 1 (not at all) to 7 (very much). Participants in Study 1a also completed measures of: Right Wing Authoritarianism ($a = 0.84$; Duckitt, Bizumic, Krauss, & Heled, 2010), Social Dominance Orientation ($a = 0.84$; Ho et al., 2015), and Speciesism ($a = 0.76$; Caviola et al., 2018). These scales were anchored from 1 (strongly disagree) to 7 (strongly agree).

2.2. Results and discussion

2.2.1. Data exclusions

As per our pre-registered analysis plan, we excluded participants who failed either comprehension check ($n_{Study1a} = 7$; $n_{Study1b} = 7$). We also excluded trials on which updating was not possible. That is, trials on which participants' prior belief was 0 and the signal was "DO NOT have the capacity" or participants' prior belief was 100 and the signal was "DO have the capacity" ($n_{Study1a} = 772$, 12%; $n_{Study1b} = 932$, 15%).

2.2.2. Descriptives and validation

We begin by providing a broad description of participants' prior and posterior beliefs about animals' mental capacities. As can be seen in Fig. 2, participants updated their beliefs in response to the signals in the expected manner. Collapsing across capacities, meat-eaters (Study 1a) shifted their beliefs (from prior to posterior) and become more convinced that animals had minds after receiving a signal suggesting they do, $t(393) = 4.40$, $p < .001$, $d = 0.22$, 95% CI [0.12, 0.32], and less convinced after receiving a signal suggesting they do not, $t(393) = -16.31$, $p < .001$, $d = -0.82$, 95% CI [-0.94, -0.71]. The same was true of veg*ns (Study 1b). They were more certain that animals had minds after receiving a signal suggesting they do, $t(392) = 4.32$, $p < .001$, $d = 0.22$, 95% CI [0.12, 0.32], and less certain after receiving a signal suggesting they do not, $t(392) = -13.84$, $p < .001$, $d = -0.70$, 95% CI [-0.81, -0.59]. Consistent with the extant literature, meat-eaters ($M = 61.60$, $SD = 12.60$) were less certain in their prior beliefs that pigs possessed mental capacities compared to veg*ns ($M = 67.80$, $SD = 14.10$), $t(785) = -6.53$, $p < .001$, $d = -0.47$ 95% CI [-0.61, -0.32]. Further descriptive statistics are available in the Supplementary Material (Tables S4 and S5).

2.2.3. Bayesian benchmark

Our primary hypotheses concerned how far people deviate when updating their beliefs from what can be considered normative. To estimate what is normative, we followed prior research by computing a Bayesian benchmark for each trial reflecting the posterior belief a participant would have if they conformed to Bayes' theorem (Tappin et al., 2020). These scores were computed on a 0–1 scale and then rescaled to 0–100. We transformed extreme scores (0 - > 0.5, 100 - > 99.5) for the purposes of computing the Bayesian benchmark. These transformations were pre-registered. Where $P(C|S)$ is the posterior probability pigs have the capacity given the signal received on that trial; $P(C)$ is the prior probability pigs have the capacity provided on each trial; $P(S|C)$ is the probability of receiving the signal assuming pigs have the capacity; $P(-C)$ is the prior probability pigs do not have the capacity; and $P(S|-C)$ is the probability of receiving the signal assuming pigs do not have the capacity; $P(C|S)$ is given:

$$P(C|S) = \frac{P(C)P(S|C)}{((P(C)P(S|C) + P(-C)P(S|-C))} \quad (1)$$

We calculated the deviation between participants' actual posterior judgements and the benchmark. These scores were computed such that positive values reflect a judgment that updated too much, meaning that it went further than the Bayesian benchmark, and negative values reflect a judgment that updated too little, meaning that it fell short of the Bayesian benchmark. To illustrate: a participant reports a prior belief of 60% and receives a signal of "certainly DO have this capacity" for capacity i . Given that the subjective probability of the signal being accurate is $2/3$, the Bayesian benchmark can be computed as:

$$P(C_i | S_{Do}) = \frac{0.60 \times \frac{2}{3}}{(0.60 \times \frac{2}{3} + 0.40 \times \frac{1}{3})} = 0.75 \quad (2)$$

Say the participant subsequently reports a posterior belief of 80%. The Bayesian benchmark for this trial is calculated as 75%, meaning a judgment of 80% went 5% further than the benchmark and is therefore given the score of 0.05 (rescaled to 5.00). Say instead that the participant reported a posterior belief of 65%. The Bayesian benchmark for this trial remains 75%, meaning a judgment of 65% fell 10% short of the benchmark and is therefore given the score of -0.10 (rescaled to -10.00).

2.2.4. Main analyses

Adhering to our pre-registration, we fit linear mixed-effects models to the trial-level data with random effects modeling variations between participants and capacities (Barr, Levy, Scheepers, & Tily, 2013; Brauer & Curtin, 2018; Judd, Westfall, & Kenny, 2012). This approach allowed us to accurately estimate the overall fixed effects of interest (in this case, deviations from the Bayesian benchmark in response to signals suggesting pigs have, and do not have, capacities), while maintaining the nominal Type I error rate by modeling the non-independence of the data across participants and capacities (Bryk & Raudenbush, 1992). All variables were standardized prior to model fitting such that coefficients (β) can be interpreted in standardized units (Nezlek, 2012)—note that the central dependent variable, the deviation from the Bayesian benchmark, was standardized but not mean-centered so as to preserve the meaningful zero-point of the measure.

We focused our main analyses on how far people deviated from the Bayesian benchmark when updating their beliefs about pigs. Our initial goal was to test whether people show a general tendency to overestimate or underestimate pig minds. As can be seen in Fig. 3, participants updated their beliefs more in response to signals that suggested pigs lacked minds compared to signals that suggested they had minds. This was true for participants who consume meat (Study 1a), $\beta = 0.30$, $SE = 0.07$, 95% CI [0.17, 0.43], $p < .001$; as well as those who do not (Study 1b), $\beta = 0.26$, $SE = 0.06$, 95% CI [0.15, 0.37], $p < .001$. Both meat-eaters and veg*ns fell short of the benchmark (0) when encountering a signal that suggested pigs have minds, $\beta_{Study1a} = -0.10$, $SE = 0.04$, 95% CI [-0.19, -0.01], $p = .037$; $\beta_{Study1b} = -0.12$, $SE = 0.03$, 95% CI [-0.18, -0.06], $p < .001$; but went too far when encountering a signal that suggested pigs did not have minds, $\beta_{Study1a} = 0.20$, $SE = 0.04$, 95% CI [0.12, 0.28], $p < .001$; $\beta_{Study1b} = 0.14$, $SE = 0.04$, 95% CI [0.06, 0.22], $p < .001$. Put simply, on receiving a clue suggesting pigs had minds, participants came to be unjustifiably sceptical of the idea. But, on receiving a clue suggesting pigs lacked minds, they came to be unjustifiably accepting of the idea. These results support the idea that people have a tendency to *underestimate* the likelihood that animals have minds.

We next tested if the accuracy of participants' beliefs varied in those who consume meat and those who do not. We did this by comparing the results of Studies 1a and 1b. How far participants deviated from the Bayesian benchmark for signals that suggested pigs have minds (vs. do not have minds) was not moderated by their diet, $\beta = 0.05$, $SE = 0.05$, 95% CI [-0.05, 0.16], $p = .331$. Meat-eaters' and veg*ns updating in

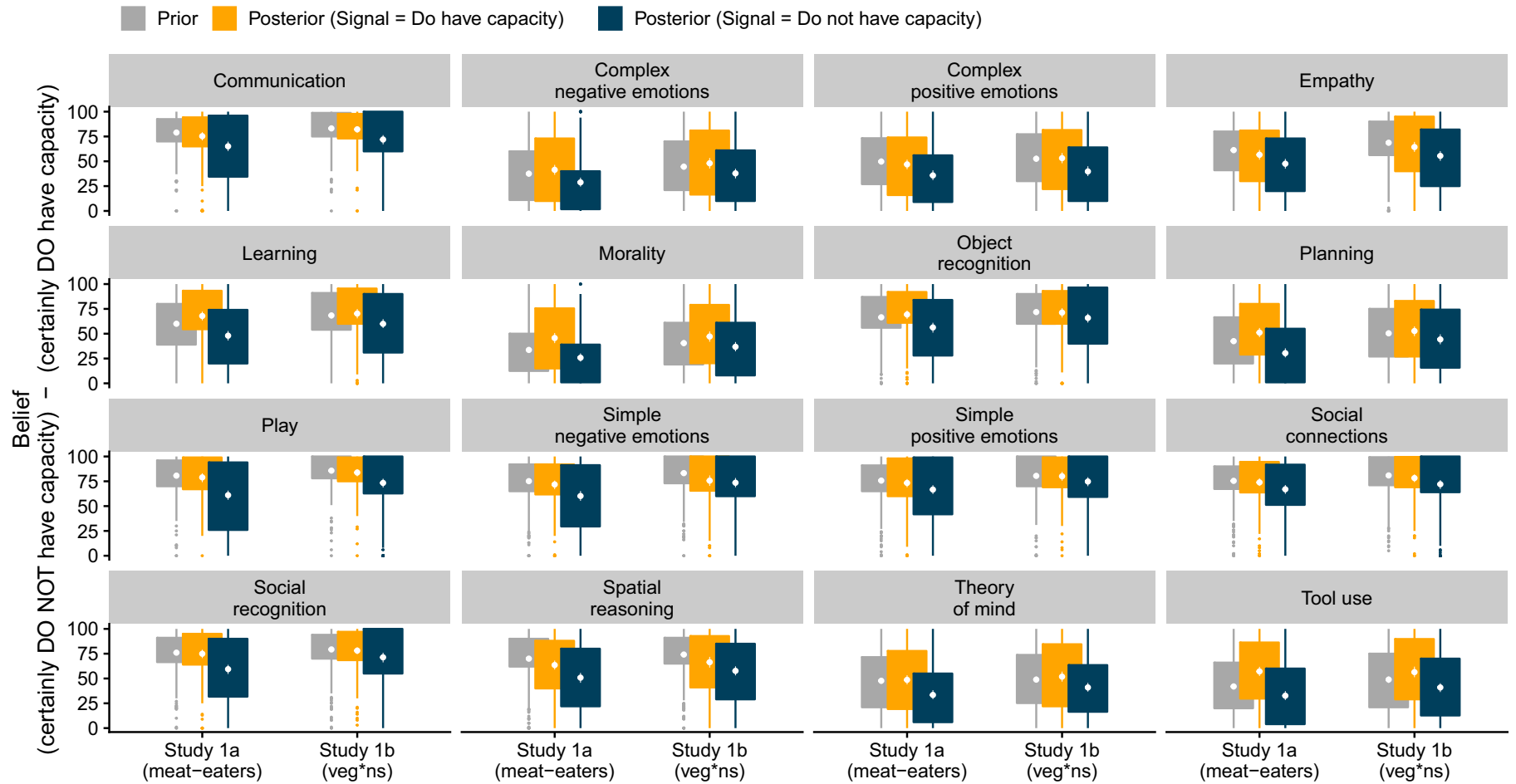


Fig. 2. Studies 1a and 1b: Prior and posterior beliefs about pigs' mental capacities.

Note. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

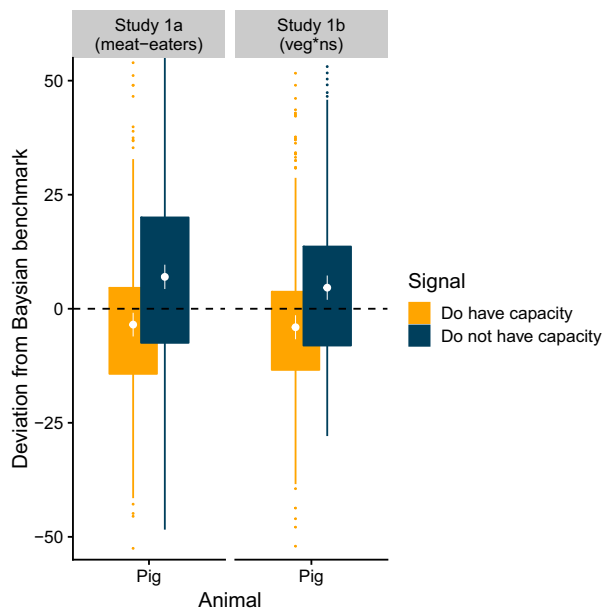


Fig. 3. Studies 1a and 1b: Belief updating in response to signals that suggest pigs have, and do not have, mental capacities.

Note. The Bayesian benchmark is represented at $y = 0$. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

relation to the benchmark was largely the same when the signals suggested pigs had minds, $\beta = -0.02$, $SE = 0.04$, 95% CI $[-0.09, 0.06]$, $p = .659$; and when they suggested pigs did not have minds, $\beta = -0.07$, $SE = 0.04$, 95% CI $[-0.15, 0.01]$, $p = .103$. These results suggest that the tendency to underestimate the likelihood that animals have minds may be largely independent of people's dietary commitments.

2.2.5. Robustness checks

We conducted a series of tests that disconfirmed alternative or trivializing explanations of our central findings. We tested whether our updating results depended on the particular metric we used to operationalize deviations from what is prescribed by Bayes' theorem. There are other metrics, including dividing participants' posterior beliefs by the Bayesian benchmark and comparing both the magnitude and direction of belief change to the Bayesian benchmark (Peterson & Miller, 1965; Phillips & Edwards, 1966; Tappin et al., 2020). Importantly, we find consistent and corroborating evidence when computing these alternative indices. Looking across meat-eaters and veg*ns, beliefs deviated more from what was normative in response to signals that suggested pigs lacked minds compared to signals that suggested they had minds. This was evidenced when dividing posterior beliefs by the Bayesian benchmark, $\beta = 0.48$, $SE = 0.05$, 95% CI $[0.39, 0.57]$, $p < .001$, and when examining the magnitude and direction of belief change, $\beta = 0.18$, $SE = 0.04$, 95% CI $[0.09, 0.27]$, $p < .001$. For further details on these alternative indices see the Supplementary Material.

We also tested and disconfirmed the hypothesis that our focal effect, the tendency to underestimate animal minds, could be an artifact of our stimuli evoking prior beliefs above the scale midpoint. Since priors were, on average, above the midpoint of the scale, participants had greater opportunity to revise their beliefs towards the bottom end of the scale, reflecting greater scepticism about animal minds, than they did towards the top end of the scale, reflecting greater acceptance of animal minds. To test this idea, we fit the same mixed-effects models to the data but constrained our analyses to include only those capacities where prior beliefs were below the scale midpoint (*morality, planning, theory of mind, tool use, complex positive emotions, and complex negative emotions*). Looking across meat-eaters and veg*ns, we again found that they

updated their beliefs more in response to signals that suggested pigs lacked minds compared to signals that suggested they had minds, $\beta = 0.11$, $SE = 0.04$, 95% CI $[0.04, 0.19]$, $p = .002$. This suggests that the tendency to underestimate animal minds is not an artifact of prior beliefs and that it is a robust phenomena that is not constrained to a subset of the stimuli.

We also tested and disconfirmed the hypothesis that our results were an artifact of regression to the mean. Regression to the mean describes the tendency for initially extreme observations to fall closer to the mean on subsequent measurements (Galton, 1886). Prior beliefs tended to fall above the scale midpoint, meaning that there may be a tendency, irrespective of any updating, for posterior beliefs to drop down towards the scale midpoint (Tappin et al., 2020). This could look like participants updating towards believing that animals lack minds. We tested this alternative explanation by simulating 10,000 samples with the same parameters as our observed data but where posterior judgements were independent of any signal. Testing for the presence of our focal effect, differences in belief updating between signals that suggested pigs had and lacked minds, in each of these simulated samples provides a distribution of effects that are subject to random sampling and regression to the mean, but are entirely devoid of any genuine updating processes. If the focal observed effect is merely an artifact of repeated random sampling, it should be highly probable under the simulated distribution. We find this not to be the case as it is larger than 100% of simulated effects. This result can be interpreted as equivalent to $p < .001$. We take this as strong evidence in support of the idea that our data are not an artifact of repeated random sampling and therefore that they genuinely reflect a psychological process of belief updating about animal minds. Further details including validation-checks demonstrating the presence of regression to the mean in the simulated data can be found in the Supplementary Material.

2.2.6. Additional analyses

In Study 1a we pre-registered a prediction about the moderating effect of RWA, SDO, and Speciesism on belief updating. We expected those who were lower (vs. higher) in either RWA, SDO, and Speciesism to update more in response to clues that suggested pigs have minds compared to clues that suggest they lack minds. We found no evidence to suggest that this was true. Neither RWA, SDO, and Speciesism moderated how meat-eaters in Study 1a updated their beliefs in response to different signals, $\beta_{RWA} = 0.00$, $SE = 0.04$, 95% CI $[-0.07, 0.08]$, $p = .928$; $\beta_{SDO} = -0.01$, $SE = 0.04$, 95% CI $[-0.08, 0.07]$, $p = .851$; $\beta_{Speciesism} = -0.05$, $SE = 0.04$, 95% CI $[-0.13, 0.02]$, $p = .177$.

We explored if updating was related to differences in how participants ultimately came to perceive the minds of pigs, captured via the 8-item measure of mind-attribution administered after the updating task. To do this, we computed a single score for each participant, reflecting their overall tendency to update towards believing pigs had minds (posterior - prior). The more meat-eaters (Study 1a) updated towards believing pigs had minds trial-by-trial, the more mind they attributed to pigs on the summary scale, $r(392) = 0.17$, 95% CI $[0.08, 0.27]$, $p < .001$. Veg*ns (Study 1b) showed a similar tendency, $r(391) = 0.26$, 95% CI $[0.17, 0.35]$, $p < .001$. We also examined if updating was related to moral concern for animals, finding it was largely unrelated, both in meat-eaters (Study 1a), $r(392) = -0.02$, 95% CI $[-0.12, 0.08]$, $p = .744$, and in veg*ns (Study 1b), $r(391) = -0.07$, 95% CI $[-0.17, 0.03]$, $p = .183$.

Finally, we explored differences between meat-eaters' (Study 1a) and veg*ns' (Study 1b) perceptions of pigs. Consistent with the extant literature, meat-eaters ($M = 4.92$, $SD = 0.96$) ascribed less mind to pigs than did veg*ns ($M = 5.42$, $SD = 0.90$), $t(785) = -7.40$, $p < .001$, $d = -0.53$ 95% CI $[-0.67, -0.39]$; and extended less moral concern to them ($M = 5.93$, $SD = 1.21$) compared to veg*ns ($M = 6.63$, $SD = 0.87$), $t(785) = -9.28$, $p < .001$, $d = -0.66$ 95% CI $[-0.80, -0.52]$.

3. Study 2: Belief updating mechanisms

Study 2 probed the mechanisms underlying people's scepticism about animals' minds. The biased patterns of belief updating we observed in Studies 1a and 1b could be driven by two different, but equally erroneous, inferences about evidence that animals have minds compared to the opposite. Participants may have faithfully held that both signals were accurate $\frac{2}{3}$ of the time, but selectively adjusted their beliefs in response to those that suggested animals have minds compared to those that suggest the opposite. This account suggests that biases arise because participants failed to adjust their beliefs in accordance with the strength of the evidence. On the other hand, participants may have constructed idiosyncratic beliefs about the accuracy of the signals, perhaps thinking that those which indicated animals have minds were less accurate than those that indicated the opposite. This account suggests that biases arise because participants presumed that the evidence was not of equal strength when in actuality it was.

Study 2 tested these ideas by eliciting subjective perceptions of the signals accuracy, both when it indicates the animal has, and lacks, a mind. This followed prior work closely and allowed us to construct subjective normative benchmarks for each signal and participant (Tappin et al., 2020). It does so by substituting the explicitly-defined accuracy ($\frac{2}{3}$) for participants' subjective self-reports of their accuracy. If belief updating is too sceptical when compared to this new subjective benchmark, we can be more confident that it is driven by failures to adjust beliefs in accordance with the perceived strength of the evidence. Eliciting such perceptions also allowed us to test if participants fail to perceive the evidence as of equal strength by testing if signals that suggest the animal has a mind are perceived as less likely to be accurate than those that suggest the opposite.

3.1. Methods

3.1.1. Participants and design

Open science. We report all measures and exclusions. Study 2's hypotheses, sample targets, exclusion criteria, dependent variable transformations, and statistical models were pre-registered (<https://osf.io/qrx8f/>).

Sample size justification. On the basis of an a priori pre-registered power analysis, we aimed to recruit 400 participants for this study. Our expectations about the likely magnitudes of the effects and variance components were informed by Studies 1a and 1b. In standardized units, we expected differences in updating between signals suggesting pigs have (and do not have) mental capacities and the Bayesian benchmark (0) of the following magnitude: $\beta = \pm 0.10$. This corresponded to a simple-effect difference in updating between signals suggesting pigs have (vs. do not have) mental capacities of the following magnitude: $\beta = 0.20$. The predicted pattern is illustrated in the Supplementary Material (Fig. S3). Simulating 10,000 samples via the *SimR* package (Green & MacLeod, 2016) for *R* (Version 1.2.5001; R Core Team, 2019) suggested that samples of 400 would afford >80% power to detect the smallest expected effects.

Samples. We met our pre-registered sample target. Four hundred and six self-identified meat-eaters ($n_{\text{female}} = 204$, $M_{\text{age}} = 38.88$, $SD_{\text{age}} = 13.50$) from the United Kingdom participated via the crowdsourcing platform *Prolific* in exchange for compensation at a minimum rate of £5.00 per hour. Participants were pre-screened and indicated their diets by selecting one of five options: "I prefer to eat meat" ($n = 75$), "I prefer meat and vegetables" ($n = 227$), "I eat meat, but not very much" ($n = 104$), "I do not eat meat" ($n = 0$), or "I do not eat any meat or animal products" ($n = 0$). No data were analyzed prior to reaching the target sample size.

Design. Participants responded to a 2-within (signal: DO have the capacity vs. DO NOT have the capacity) design. The research was approved by an internal ethical review board in compliance with British Psychological Society's code of ethics and conduct. All participants

provided informed consent prior to participation.

3.1.2. Procedure and materials

We employed the same belief updating task as in Studies 1a and 1b with the addition of measures capturing subjective perceptions of the signals accuracy. Our approach follows prior work closely by sampling perceptions of each individual signal and judgements about the signal's overall accuracy (Tappin et al., 2020). As in Studies 1a and 1b, participants judged the minds of pigs and were instructed that the signals had a $\frac{2}{3}$ chance of being accurate and $\frac{1}{3}$ chance of being inaccurate. They were required to answer two comprehension questions to ensure their understanding. The first phase of the belief updating task was largely identical to Studies 1a and 1b, where participants judged the likelihood that pigs possessed 16 mental capacities, from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity), and were presented with hints (signals) about the veracity of their beliefs ("Pigs DO have the capacity for [capacity]" or "Pigs DO NOT have the capacity for [capacity]"). Following prior work (Tappin et al., 2020), we captured participants' subjective perceptions of each signal's accuracy directly following each signal ("Do you think the hint you received was accurate?"), from 1 (Definitely NOT) to 5 (Definitely YES). After providing their prior beliefs, encountering the signals, and judging their accuracy, participants moved on to the second phase which elicited their posterior beliefs about the same 16 mental capacities, from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity). Finally, participants were asked to make a judgment about the overall accuracy of the signals that suggested pigs had minds ("What percent of hints that said 'Pigs DO have the capacity' do you think accurately reflected the truth about pigs' cognitive and emotional capacities?") and those that suggested pigs lacked minds ("What percent of hints that said 'Pigs DO NOT have the capacity' do you think accurately reflected the truth about pigs' cognitive and emotional capacities?") were accurate, from 50 (Hints were random/uninformative) to 100 (Hints were accurate/informative). This measure allowed us to tap into subjective perceptions of the signal's overall accuracy in a way that can be directly substituted for their explicitly-defined accuracy ($\frac{2}{3}$) to produce a subjective Bayesian benchmark for each participant and signal.

3.2. Results and discussion

3.2.1. Data exclusions

As per our pre-registered analysis plan, we excluded participants who failed either comprehension check ($n = 2$). We also excluded trials on which updating was not possible. That is, trials in which participants' prior belief was 0 and the signal was "DO NOT have the capacity" or participants' prior belief was 100 and the signal was "DO have the capacity" ($n = 701$, 11%).

3.2.2. Descriptives and validation

We begin by providing a broad overview of participants' prior and posterior beliefs. As can be seen in Fig. 4, there was similar variation in prior beliefs across mental capacities as in Studies 1a and 1b. The expected basic effect was present when collapsing across capacities: participants shifted their beliefs (from prior to posterior) and become more convinced that animals had minds after receiving a signal suggesting they do, $t(403) = 4.65$, $p < .001$, $d = 0.23$, 95% CI [0.13, 0.33], and less convinced after receiving a signal suggesting they do not, $t(403) = -11.36$, $p < .001$, $d = -0.57$, 95% CI [-0.67, -0.46]. Further descriptive statistics are available in the Supplementary Material.

3.2.3. Subjective Bayesian benchmark

We sought to test how far people deviated from their own subjectively-defined benchmarks when updating their beliefs about pigs. To do this, we computed a subjective Bayesian benchmark for each participant and trial using self-reported judgements about the overall signal's accuracy. This was done in exactly the same way as in Studies 1a



Fig. 4. Study 2: Prior and posterior beliefs about pigs' mental capacities.

Note. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

and 1b, but instead of using the explicitly-defined accuracy of the signals ($\frac{2}{3}$) we used participants' subjective perceptions. To illustrate: a participant reports that signals suggesting the animal has a mind ("certainly DO have this capacity") have an overall accuracy of 75%. Given this belief, the Subjective Bayesian benchmark for a trial in which they report a prior belief of 60% and receive the signal that pigs have mental capacity i ("certainly DO have this capacity") can be computed as:

$$P(C_i | S_{Do}) = \frac{0.60 \times 0.75}{(0.60 \times 0.75 + 0.40 \times 0.25)} = 0.82 \quad (3)$$

Participants reported their perceptions of the overall accuracy of both signal-types independently of one another. The benchmark for trials in which the signal suggests the animal has a mind is computed using participants' subjective beliefs about this signal-type ("certainly DO have this capacity"), whilst the benchmark for trials in which the signal suggests the opposite is computed using subjective beliefs about the other signal-type ("certainly DO NOT have this capacity"). As in Studies 1a and 1b, we then calculated how far participants' posterior beliefs deviated from the benchmark.

3.2.4. Main analyses

Our first hypothesis concerns how far people deviated from their own subjectively-defined benchmarks when updating their beliefs about pigs. Defining the benchmark in these terms, allowed us to explicitly take into account differences in the perceived accuracy of signals that suggest pigs have, and lack, minds. If a similar pattern of scepticism about animal minds arises under these conditions, we can be confident that it is driven by failures to adjust beliefs in accordance with the perceived strength of the evidence. Consistent with our pre-registration, we tested this by fitting linear mixed-effects models to the trial-level data with random effects modeling variations between participants and capacities (Barr et al., 2013; Brauer & Curtin, 2018; Judd et al., 2012). All variables were standardized prior to model fitting such that coefficients (β) can be interpreted in standardized units (Nezlek, 2012). The deviation from the Subjective Bayesian benchmark was standardized but not mean-centered so as to preserve the meaningful zero-point of the measure.

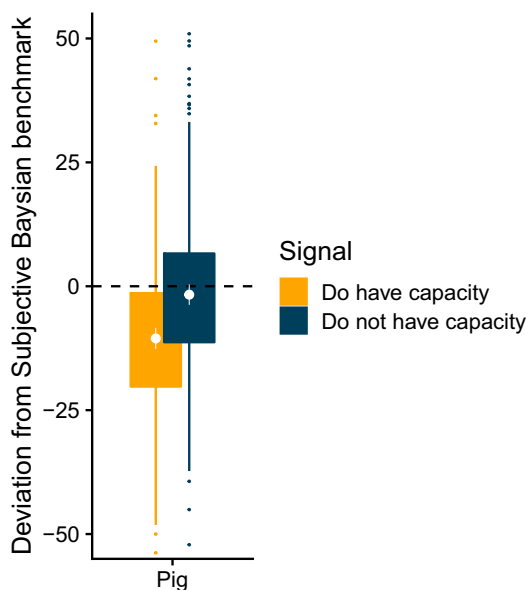


Fig. 5. Study 2: Belief updating in response to signals that suggest pigs have, and do not have, mental capacities.
Note. The Subjective Bayesian benchmark is represented at $y = 0$. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

As expected and can be seen in Fig. 5, participants updated their beliefs more in response to signals that suggested pigs lacked minds compared to signals that suggested they had minds, $\beta = 0.31$, $SE = 0.06$, 95% CI [0.19, 0.42], $p < .001$. Decomposing this effect showed that they fell short of the benchmark (0) when encountering a signal that suggested pigs have minds, $\beta = -0.36$, $SE = 0.04$, 95% CI [-0.44, -0.29], $p < .001$, but were largely indistinguishable from the benchmark when encountering a signal that suggested pigs did not have minds, $\beta = -0.06$, $SE = 0.04$, 95% CI [-0.13, 0.01], $p = .114$. Thus, even when taking into account how participants themselves weighed the accuracy of the evidence (signals) presented to them, they were nevertheless unjustifiably sceptical of the idea that animals have minds. These results again support the idea that people tend to underestimate the likelihood that animals have minds and that this is driven by failures to adjust beliefs in accordance with the strength of the evidence.

Our second hypothesis concerns whether people construct idiosyncratic beliefs about the accuracy of signals that indicate animals have minds compared to the opposite. We first analyzed judgements made directly after each signal. We did this by fitting a linear mixed-effects model to the trial-level data with random effects modeling variations between participants and capacities. This model revealed that participants were, surprisingly, *less* trusting of signals that suggested animals lacked minds ($M = 2.92$, $SD = 0.65$) compared to those that suggested they had minds ($M = 3.74$, $SD = 0.55$), $\beta = -0.66$, $SE = 0.24$, 95% CI [-1.14, -0.18], $p = .016$. We found a similar effect on overall judgements about the accuracy of signals. Participants thought that the signals suggesting animals lacked minds were overall less likely to be accurate ($M = 66.10\%$, $SD = 12.01$) compared to those that suggested they had minds ($M = 74.10\%$, $SD = 13.32$), $t(403) = 9.92$, $p < .001$, $d = 0.49$, 95% CI [0.39, 0.60]. These results suggest that the tendency to underestimate animal minds when updating beliefs is unlikely to be due to people believing that negative evidence is more credible than positive evidence.

3.2.5. Robustness checks and additional analyses

As in Studies 1a and 1b, we conducted a series of checks to examine if our main findings were contingent on the central measure and to test the plausibility of alternative explanations. We found evidence of the same effect when analyzing alternative measures of belief updating. We were able to detect the same biases in belief updating when constraining our analyses to only those capacities where prior beliefs were below the scale midpoint. Our simulations also suggested that the effects could not be accounted for by regression-to-the-mean. Further details can be found in the Supplementary Material.

Finally, we examined if the same belief-updating biases were evident when computing the Bayesian benchmark in accordance with the signals' explicitly-defined accuracy ($\frac{2}{3}$). Consistent with Studies 1a and 1b, belief updating was biased in relation to this benchmark. Participants updated their beliefs more in response to signals that suggested pigs lacked minds compared to signals that suggested they had minds, $\beta = 0.17$, $SE = 0.07$, 95% CI [0.05, 0.30], $p = .016$. This meant that they fell short of the benchmark when encountering a signal that suggested pigs have minds, $\beta = -0.21$, $SE = 0.04$, 95% CI [-0.29, -0.14], $p < .001$, but were indistinguishable from it when encountering the opposite signal, $\beta = -0.04$, $SE = 0.04$, 95% CI [-0.11, 0.04], $p = .367$.

4. Study 3: Validating assumptions

Study 3 extended the work by testing if similar effects could be identified in a more ecologically-valid version of the task. Belief-updating is likely to occur in response to evidence found in, for example, popular media that has a genuine and verifiable grounding in scientific research (e.g., de Waal, 2016). The signals in Studies 1–2 were randomized and, as such, had undetermined truth values. They therefore provided little actual indication of the scientific research. This feature potentially undermines the validity of the task, resulting in a

less-than-perfect image of the updating process and therefore the accuracy of peoples' beliefs about animal minds. Study 3 remedies this by presenting people with a carefully-curated set of evidence that either accurately, or inaccurately, describe genuine scientific findings about animals. Because of this, Study 3's signals were able to faithfully convey the truth or falsity of the evidence in line with their explicitly-defined accuracy. This feature allowed us to better emulate the updating processes as it might occur in response to the types of evidence people encounter in scientific discourse and popular media.

Study 3 also examined a potentially-important moderator, namely, whether the accuracy of peoples' beliefs depends on if the animal is culturally-defined as a source of food or as a companion (Bastian et al., 2012; Bratanova et al., 2011). Informed by our prior findings and work that documents beliefs about humans' supremacy over animals (Caviola et al., 2018; Dhont et al., 2020; Dhont & Hodson, 2020; Dunayer, 2004; Herzog, 2010; Joy, 2010; Leach, Kitchin, et al., 2022; Singer, 1975, 2009), we again predicted that participants would show a tendency to underestimate the minds of pigs. In addition, work highlighting the tendency for people to anthropomorphize companion animals (Bartz et al., 2016; Epley, Waytz, et al., 2008; Waytz, Morewedge, et al., 2010) led us to predict that participants would overestimate dog minds, and that this overestimation would be greater than equivalent tendency for pigs.

4.1. Methods

4.1.1. Participants and design

Open science. We report all measures and exclusions. Study 3 was not pre-registered.

Sample size justification. On the basis of an a priori power analysis, we aimed to recruit 600 participants. Our expectations about the likely magnitudes of the effects and variance components were informed by Studies 1a and 1b. In standardized units, we expected differences in updating between signals suggesting evidence that animals have (and do not have) minds is true (and false) and the Bayesian benchmark (0) of the following magnitude: $\beta = \pm 0.10$. This corresponded to a simple-effects difference in updating between signals suggesting evidence that animals have minds is true (vs. false) of the following magnitude: $\beta = \pm 0.20$; and likewise a simple-effects difference in updating between signals suggesting evidence that animals do not have minds is true (vs. false) of the following magnitude: $\beta = \pm 0.20$. This also corresponded to a moderating effect of animal (pig vs. dog) of the following magnitude: $\beta = 0.40$. The predicted pattern is illustrated in the Supplementary Material (Fig. S4). Our prior data also provided some expectations about the likely degree of variance between participants ($SD_{\text{intercept}} = 0.20$) and evidence ($SD_{\text{intercept}} = 0.08$). Simulating 10,000 samples via the *SimR* package (Green & MacLeod, 2016) for *R* (Version 1.2.5001; R Core Team, 2019) suggested that a sample of 600 would afford >80% power to detect the smallest expected effects.

Samples. We met our sampling target. Six-hundred and ten meat-eaters ($n_{\text{female}} = 451$, $M_{\text{age}} = 35.40$, $SD_{\text{age}} = 11.04$) from the United Kingdom participated via the crowdsourcing platform *Prolific* in exchange for compensation at a minimum rate of £5.00 per hour. Participants were pre-screened to be meat-eaters and indicated their diets in the same way as in Studies 1a and 1b: "I prefer to eat meat" ($n = 117$), "I prefer meat and vegetables" ($n = 292$), "I eat meat, but not very much" ($n = 201$), "I eat fish, but not other meat" ($n = 0$), "I do not eat meat" ($n = 0$), or "I do not eat any meat or animal products" ($n = 0$). No data were analyzed prior to reaching the target sample size.

Design. Participants responded to a 2-between (animal: dog vs. pig) x 2-within (evidence: has a mind vs. lacks a mind) x 2-within (signal: TRUE vs. FALSE) design. The research was approved by an internal ethical review board in compliance with British Psychological Society's code of ethics and conduct. All participants provided informed consent prior to participation.

4.1.2. Procedure and materials

Belief updating task. We employed a similar belief updating task as in Studies 1–2 (Hill, 2017; Tappin et al., 2020), with the difference that participants judged the veracity of evidence about animal minds (as opposed to their certainty that the animal possessed mental capacities). As in Studies 1–2, participants were instructed that the signals had a $2/3$ chance of being accurate and $1/3$ chance of being inaccurate (Hill, 2017; Tappin et al., 2020) and were required to answer two comprehension questions before moving on to the belief updating task. Participants began the task by judging the likelihood that 16 statements about pigs or dogs were true, from 0 (certainly FALSE) to 100 (certainly TRUE). In equal parts, the statements described evidence that suggested pigs or dogs had, or did not have, minds. Likewise, in equal parts the statements were true, describing genuine scientific evidence about pigs and dogs, and false, describing fabricated scientific evidence (Leach et al., 2021). A number of examples are presented in Table 1. The full list can be found in Table S2.

Immediately after providing each prior belief participants received a hint (signal) about the veracity of their belief. The signal was either "TRUE" or "FALSE" communicating that the evidence was either true or false. The signals' accuracy were determined (in relation to genuine research on pigs and dogs) and randomized to have a $2/3$ probability of being accurate. For the eight statements that were truthful descriptions of scientific findings the signal had a $2/3$ probability of reading "TRUE" and a $1/3$ probability of reading "FALSE". For the eight statements that were false descriptions of scientific findings the signal had a $2/3$ probability of reading "FALSE" and a $1/3$ probability of reading "TRUE". Participants then judged each statement again and provided their posterior beliefs along the same scales, from 0 (certainly FALSE) to 100 (certainly TRUE).

Additional measures. Participants completed measures of: Right Wing Authoritarianism ($\alpha = 0.82$; Duckitt et al., 2010) and Social Dominance Orientation ($\alpha = 0.80$; Ho et al., 2015). They also reported, on the same scales as in Studies 1a and 1b, their perceptions of pigs' or dogs' minds ($\alpha = 0.81$) and the moral wrongness of harming pigs or dogs ($\alpha = 0.86$).

Table 1
Examples of true and false evidence about pigs' and dogs' minds used in Study 3.

Evidence	Scientific Basis
Animal has a mind	
<i>Pigs[Dogs] can remember the spatial location of objects. For example, they can remember where food has been placed in a complicated maze.^a</i>	(Macpherson & Roberts, 2010; Siegford, Rucker, & Zanella, 2008)
<i>Pigs[Dogs] can recognize their own reflection. For example, when placed in front of a mirror, they can recognize their reflection and use it to clean themselves.^b</i>	(Gallup Jr. & Anderson, 2020)
Animal lacks a mind	
<i>Pigs[Dogs] cannot manufacture tools. For example, when presented with a long vertical tube with food at the end, and a wire, they will not understand they need to bend the wire into a hook to help them fish out the food.^a</i>	(Hunt, 1996)
<i>Pigs[Dogs] do not have a sense of emotional empathy. For example, when placed next to another animal that is scared or anxious, they will show no changes in their behaviour or physiology.^b</i>	(Reimert, Bolhuis, Kemp, & Rodenburg, 2013; Yong & Ruffman, 2014)

^a Statement is true. There is scientific evidence to suggest the statement is true.

^b Statement is false. As of writing, there is either scientific evidence that directly contradicts the statement or no scientific evidence to suggest the statement is true. See Scientific Basis for supporting evidence.

4.2. Results and discussion

4.2.1. Data exclusions

Consistent with Studies 1–2, we excluded participants who failed either comprehension check ($n = 20$). We also excluded trials on which updating was not possible, namely, where participants' prior belief was 0 and the signal was "FALSE" or participants' prior belief was 100 and the signal was "TRUE" ($n = 805$, 9%).

4.2.2. Descriptives and validation

As in Studies 1–2, we first provide a basic description of participants' prior and posterior beliefs about evidence of animal minds (Fig. 6). Collapsing across evidence, participants were more certain that evidence was true after receiving a signal suggesting it was, $t(588) = -11.19$, $p < .001$, $d = -0.46$, 95% CI $[-0.55, -0.38]$, and more certain it was false after receiving a signal suggesting it was, $t(588) = 9.45$, $p < .001$, $d = 0.39$, 95% CI $[0.31, 0.47]$. We also examined differences in prior beliefs about pigs and dogs. Participants were more certain that evidence suggesting dogs had minds was true ($M = 63.90$, $SD = 12.10$) than they were of evidence suggesting pigs had minds ($M = 55.90$, $SD = 14.60$), $t(587) = 7.26$, $p < .001$, $d = 0.60$ 95% CI $[0.43, 0.76]$. Mirroring this effect, they were less certain that evidence suggesting dogs lacked minds was true ($M = 42.90$, $SD = 11.70$) compared to the same evidence of pigs ($M = 49.50$, $SD = 13.50$), $t(587) = -6.24$, $p < .001$, $d = -0.51$ 95% CI $[-0.68, -0.35]$. Further descriptive statistics are available in the Supplementary Material.

4.2.3. Bayesian benchmark

Our main hypothesis again concerns how far people deviate from what is normative when updating their beliefs about animals' minds. We again followed Tappin et al. (2020) to compute a Bayesian benchmark for each trial reflecting the posterior belief a participant would have if they conformed to Bayes' theorem. Where $P(T|S)$ is the posterior probability the evidence is true given the signal received on that trial; $P(T)$ is the prior probability the evidence is true on each trial; $P(S|T)$ is the probability of receiving the signal assuming the evidence is true; $P(-T)$ is the prior probability the evidence not true; and $P(S|-T)$ is the probability of receiving the signal assuming the evidence not true; $P(T|S)$ is given:

$$P(T|S) = \frac{P(T)P(S|T)}{(P(T)P(S|T) + P(-T)P(S|-T))} \quad (4)$$

We calculated the deviation between participants' actual posterior judgements and the benchmark. These scores were computed such that positive values reflect a judgment that updated too far, meaning that it went further than the Bayesian benchmark, and negative values reflect a judgment that updated not far enough, meaning that it fell short of the Bayesian benchmark.

4.2.4. Main analyses

We approached the main analysis in the same fashion as in Studies 1–2, by fitting linear mixed-effects models to the trial-level data with random effects modeling variations between participants and evidence (Barr et al., 2013; Brauer & Curtin, 2018; Judd et al., 2012). All variables were standardized prior to model fitting such that coefficients (β) can be interpreted in standardized units (Nezlek, 2012). The central dependent variable, the deviation from the Bayesian benchmark, was standardized but not mean-centered so as to preserve the meaningful zero-point of the measure.

We sought to test whether people showed a general tendency to underestimate pig minds, to overestimate dog minds, and if these effects differed from one another. As can be seen in Fig. 7, there no indication that the results were moderated by the target animal, indicated by a null three-way interaction between evidence (has a mind vs. lacks a mind), signal (TRUE vs. FALSE), and animal (pig vs. dog), $\beta = 0.01$, $SE = 0.04$, 95% CI $[-0.07, 0.10]$, $p = .758$. How far participants' deviated from the

benchmark was instead largely a function of whether the evidence suggested the animal had a mind (vs. did not have a mind) and whether the signal indicated the evidence was true (vs. false), $\beta = -0.29$, $SE = 0.07$, 95% CI $[-0.43, -0.15]$, $p < .001$.

Looking at this effect more closely, it was clear that for evidence that suggested the animal had a mind, participants updated more in response to signals that indicated this evidence was false compared to true, $\beta = 0.18$, $SE = 0.05$, 95% CI $[0.08, 0.28]$, $p = .002$. Decomposing this further, participants did not update far enough (compared to the benchmark) when the signal suggested this evidence was true, $\beta = -0.10$, $SE = 0.03$, 95% CI $[-0.17, -0.04]$, $p = .005$, but updated too far when the signal suggested this evidence was false, $\beta = 0.07$, $SE = 0.03$, 95% CI $[0.01, 0.14]$, $p = .044$.

The opposite was true for evidence that suggested the animal did not have a mind. Here, participants updated more in response to signals that indicated it was true compared to false, $\beta = 0.12$, $SE = 0.05$, 95% CI $[0.03, 0.21]$, $p = .024$. Decomposing this effect, participants did not update far enough (compared to the benchmark) when the signal suggested this evidence was false, $\beta = -0.14$, $SE = 0.03$, 95% CI $[-0.21, -0.08]$, $p < .001$, but did not deviate significantly from the benchmark when the signal suggested this evidence was true, $\beta = -0.03$, $SE = 0.03$, 95% CI $[-0.09, 0.04]$, $p = .413$.

In other words, on receiving a clue suggesting evidence that animals have minds was true, participants became unjustifiably sceptical of this evidence. In a similar way, on receiving a clue suggesting evidence that animals do not have minds was false, participants became unjustifiably accepting of this evidence. These results again support the idea that people have a tendency to underestimate animal minds.

4.2.5. Robustness checks and additional analyses

We found the same effects when computing alternative indices of belief updating. We were also able to detect the same biases in belief updating when constraining our analyses to evidence where prior beliefs were below the scale midpoint. Likewise, our simulations suggested that the effects could not be accounted for by regression-to-the mean. Further details are provided in the Supplementary Material.

We examined if updating was related to differences in how participants came to perceive animals. The more participants updated towards believing evidence that animals had minds was true, the more mind they attributed them, $r(587) = 0.11$, 95% CI $[0.03, 0.19]$, $p = .006$. Updating beliefs about evidence that animals lacked minds was unrelated to mind attribution, $r(587) = -0.04$, 95% CI $[-0.13, 0.04]$, $p = .276$. However, updating was largely unrelated to moral concern for animals, $r(587) = 0.04$, 95% CI $[-0.04, 0.12]$, $p = .328$; $r(587) = -0.02$, 95% CI $[-0.10, 0.06]$, $p = .688$.

We examined the general measures of mind perception and moral standing as well. These revealed that participants attributed dogs more mind ($M = 5.64$, $SD = 0.73$) than pigs ($M = 4.96$, $SD = 0.98$), $t(587) = 9.50$, $p < .001$, $d = 0.78$ 95% CI $[0.61, 0.95]$; and dogs greater moral standing ($M = 6.87$, $SD = 0.51$) than pigs ($M = 5.86$, $SD = 1.22$), $t(587) = 13.02$, $p < .001$, $d = 1.07$ 95% CI $[0.90, 1.25]$.

Lastly, we explored if there were any overall differences in how responsive participants were to positive information (signals that suggested evidence was true) compared to negative information (signals that suggested evidence was false). Looking across animals and evidence types, there were no marked differences in how sensitive participants were to different signals when updating their beliefs, $\beta = 0.03$, $SE = 0.04$, 95% CI $[-0.05, 0.11]$, $p = .462$.

5. Study 4: Human supremacy

Studies 1–3 suggest that people have a reliable tendency to underestimate animal minds. Somewhat surprisingly though, this tendency seems to be largely the same in meat-eaters and in veg*ns; and when pigs and dogs are the targets of belief. Study 4 sought to investigate just how far this might extend by examining an important boundary condition:

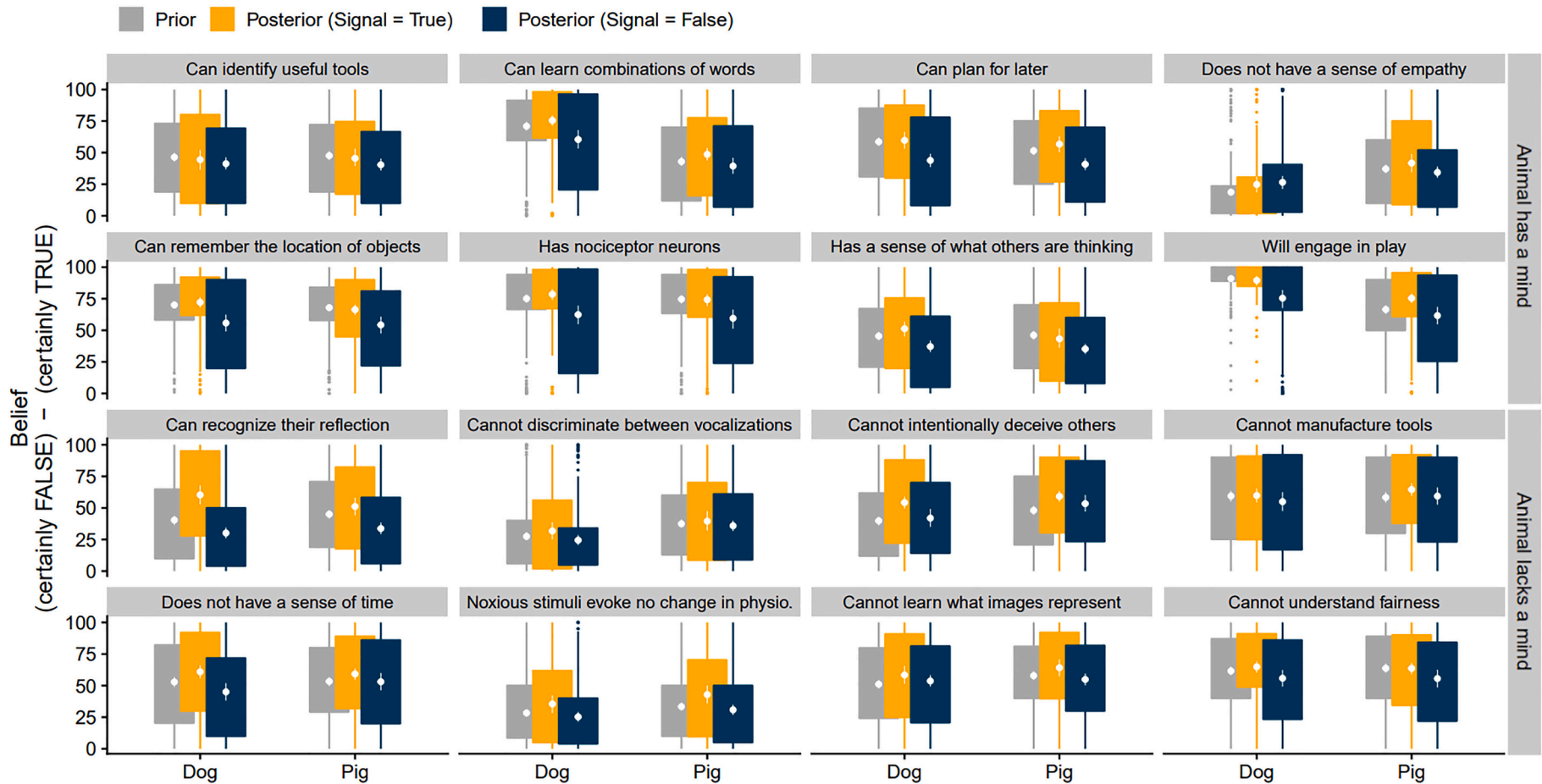


Fig. 6. Study 3: Prior and posterior beliefs about evidence that pigs and dogs have and lack minds.
 Note. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

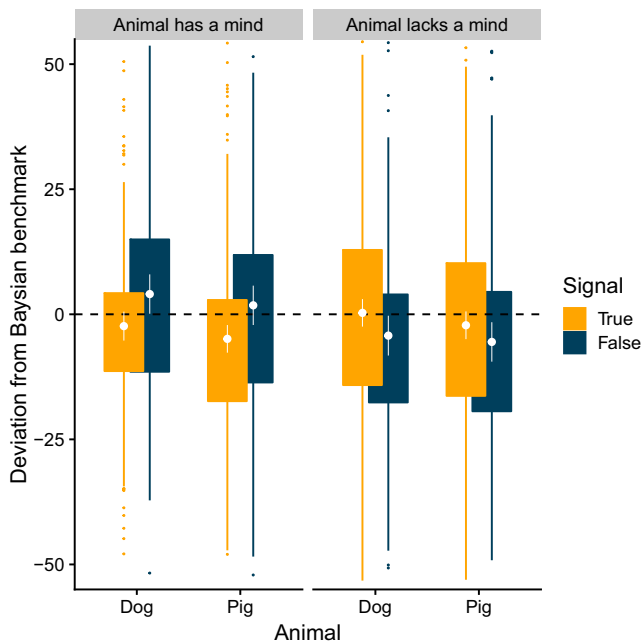


Fig. 7. Study 3: Belief updating in response to signals that suggest evidence that pigs and dogs have and lack minds is true and false.

Note. The Bayesian benchmark is represented at $y = 0$. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

human minds. Off the back of work that documents beliefs about humans' supremacy over animals (Caviola et al., 2018; Dhont et al., 2020; Dhont & Hodson, 2020; Dunayer, 2004; Herzog, 2010; Joy, 2010; Leach, Kitchin, et al., 2022; Singer, 1975, 2009), we predicted that participants would show a greater tendency to underestimate the minds of animals than they would the minds of humans.

5.1. Methods

5.1.1. Participants and design

Open science. We report all measures and exclusions. Study 4's hypotheses, sample target, exclusion criteria, dependent variable transformations, and statistical models were pre-registered (<https://osf.io/eq9d6/>).

Sample size justification. On the basis of an a priori pre-registered power analysis, we aimed to recruit 600 participants. Our expectations about the likely magnitudes of the effects and variance components were informed by Studies 1–3. In standardized units, we expected differences in updating between signals suggesting pigs have (and do not have) mental capacities and the Bayesian benchmark (0) of the following magnitude: $\beta = \pm 0.10$. This corresponded to a simple-effect difference in updating between signals suggesting pigs have (vs. do not have) mental capacities of the following magnitude: $\beta = 0.20$. We expected no differences in updating between signals for humans, meaning we expected a moderating effect of entity (human vs. animal) on updating in response to different signals (has mental capacities vs. does not have mental capacities) of the following magnitude: $\beta = 0.20$. The predicted pattern is illustrated in the Supplementary Material (Fig. S5). Simulating 10,000 samples via the *SimR* package (Green & MacLeod, 2016) for *R* (Version 1.2.5001; R Core Team, 2019) suggested that a sample of 600 would afford >80% power to detect the smallest expected effects.

Samples. We met our pre-registered sample target. Six hundred adults ($n_{\text{female}} = 424$, $M_{\text{age}} = 32.81$, $SD_{\text{age}} = 12.06$) from the United Kingdom participated via the crowdsourcing platform *Prolific* in exchange for compensation at a minimum rate of £5.00 per hour. Participants indicated their diets in the same way as in Studies 1–3: “I prefer to

eat meat” ($n = 95$), “I prefer meat and vegetables” ($n = 281$), “I eat meat, but not very much” ($n = 132$), “I eat fish, but not other meat” ($n = 33$), “I do not eat meat” ($n = 36$), or “I do not eat any meat or animal products” ($n = 23$). No data were analyzed prior to reaching the target sample size.

Design. Participants responded to a 2-between (entity: human vs. animal) \times 2-within (signal: DO have the capacity vs. DO NOT have the capacity) design. The research was approved by an internal ethical review board in compliance with British Psychological Society's code of ethics and conduct. All participants provided informed consent prior to participation.

5.1.2. Procedure and materials

We employed the similar belief updating task as in Studies 1–2, with a small number of changes. Participants judged the likelihood that a fictitious and novel, but ostensibly real, group of animals or humans (Leach et al., 2021; Piazza & Loughnan, 2016) possessed mental capacities, from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity). The animals and humans in this study were both described as having developed in isolation from any known civilization on a Pacific Island and called the “trablans”. To minimize differences in prior beliefs between animals and humans, we described the animals as “surprisingly intelligent” and the humans as “surprisingly unintelligent”. We selected and adapted a smaller subset of capacities ($i = 8$) from Studies 1–2 to apply to both animals and humans. These can be found in the Supplementary Material (Table S3). After providing their initial beliefs, participants encountered signals communicating that the scientific evidence suggested that the animal or human either did or did not possess the capacity (“Trablans DO have the capacity for [capacity]” or “Trablans DO NOT have the capacity for [capacity]”). These signals were randomized to have an equal ($\frac{1}{2}$) probability of occurring on any given trial. Finally, participants again judged the likelihood that the animals or humans possessed mental capacities, from 0 (certainly DO NOT have this capacity) to 100 (certainly DO have this capacity).

5.2. Results and discussion

5.2.1. Data exclusions

As per our pre-registered analysis plan, we excluded participants who failed either comprehension check ($n = 9$). We also excluded trials on which updating was not possible ($n = 344$, 7%).

5.2.2. Descriptives and validation

We began by examining participants' prior and posterior beliefs about humans and animals. Participants shifted their beliefs (from prior to posterior) in the expected manner (Fig. 8). Looking across capacities, they were more convinced that humans and animals had minds after a signal suggested they did, $t(586) = 4.91$, $p < .001$, $d = 0.20$, 95% CI [0.12, 0.28], and less certain after a signal suggested they did not, $t(586) = -19.69$, $p < .001$, $d = -0.81$, 95% CI [-0.91, -0.72]. We also examined differences in participants' prior beliefs about the targets of judgment. There was no strong evidence to suggest that participants were initially more certain that the novel humans ($M = 65.30$, $SD = 15.60$) possessed mental capacities compared to the novel animals ($M = 63.20$, $SD = 11.30$), $t(589) = 1.88$, $p = .061$, $d = 0.15$, 95% CI [-0.01, 0.32]. This might seem somewhat surprising, given the greater moral standing typically attributed to humans compared to animals (Caviola et al., 2018; Caviola, Schubert, Kahane, & Faber, 2022). We attribute this to the malleability of mind perceptions directed towards novel entities (Leach et al., 2021; Piazza & Loughnan, 2016; Sytma & Machery, 2012) and consider it a desirable feature of the procedure, as it means that any eventual differences in updating are unlikely to be driven by differences in initial beliefs about humans compared to animals. Descriptive statistics are available in the Supplementary Material.

5.2.3. Main analyses

We computed a Bayesian benchmark for each trial in the same way as

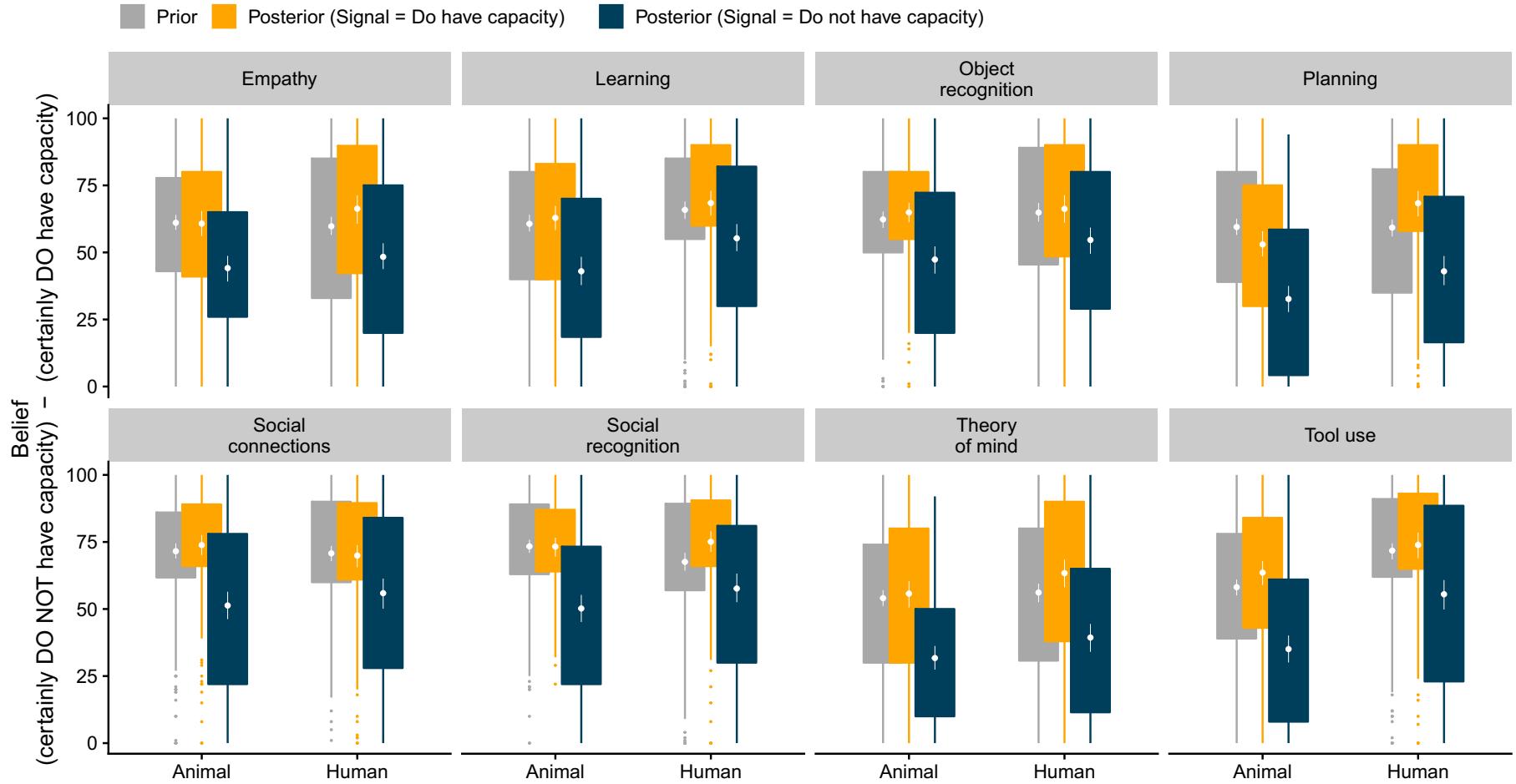


Fig. 8. Study 4: Prior and posterior beliefs about humans' and animal's mental capacities.

Note. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

in Studies 1–3. Consistent with our pre-registration, we fit linear mixed-effects models (Barr et al., 2013; Brauer & Curtin, 2018; Judd et al., 2012) to the trial-level data with random effects modeling variations between participants and capacities. All variables were standardized prior to model fitting such that coefficients (β) can be interpreted in standardized units (Nezlek, 2012). Deviation from the Bayesian benchmark was standardized but not mean-centered so as to preserve the meaningful zero-point of the measure.

We tested if the tendency to underestimate minds can be, at least to some degree, accounted for by differences between humans and animals. A confirmatory pattern of results could entail that participants either update more in response to signals that indicate humans have minds compared to animals, or update less in response to signals that indicate humans do not have minds compared to animals, or both. As can be seen in Fig. 9, the pattern of deviation scores in response to signals that suggested the entity had a mind (compared to did not have a mind) was moderated by whether the entity was an animal or a human, $\beta = -0.30$, $SE = 0.07$, 95% CI $[-0.44, -0.17]$, $p < .001$. Participants updated more in response to signals that suggested humans had minds compared to the same signals for animals, $\beta = 0.15$, $SE = 0.05$, 95% CI $[0.05, 0.24]$, $p = .003$. In a similar fashion, participants updated less when the signals suggested humans lacked minds compared to when it suggested animals lacked minds, $\beta = -0.16$, $SE = 0.06$, 95% CI $[-0.27, -0.04]$, $p = .007$.

This entailed that participants' updating was more accurate for humans than it was for animals. Updating in response to signals that suggested humans had minds was largely indistinguishable from the Bayesian benchmark, $\beta = -0.04$, $SE = 0.04$, 95% CI $[-0.11, 0.03]$, $p = .243$, whilst updating for animals in response to the same signals significantly undershot the Bayesian benchmark, $\beta = -0.19$, $SE = 0.03$, 95% CI $[-0.26, -0.12]$, $p < .001$. Turning to signals that suggested entities did not have minds, participants updated further than the benchmark in response to these signals for both humans, $\beta = 0.18$, $SE = 0.04$, 95% CI $[0.09, 0.26]$, $p < .001$, and animals, $\beta = 0.34$, $SE = 0.04$, 95% CI $[0.26, 0.43]$, $p < .001$; although, as mentioned above, this tendency was exaggerated for animals compared to humans. These results establish an important moderator and suggest that the tendency to underestimate minds is more pronounced for animals than it is for humans.

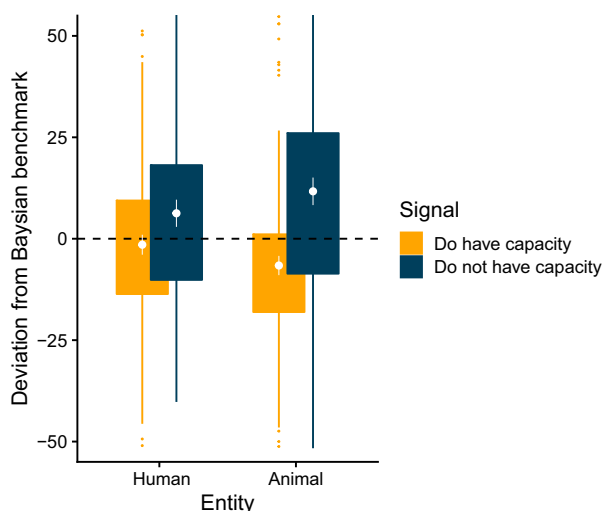


Fig. 9. Study 4: Belief updating in response to signals that suggest humans and animals have, and do not have, mental capacities.
Note. The Bayesian benchmark is represented at $y = 0$. Figure depicts box plots representing interquartile ranges (boxes), outliers (points), and predicted means with 95% confidence intervals (white diamonds and whiskers).

5.2.4. Robustness checks

The findings of Study 4 replicate when computing alternative indices of belief updating. We were also able to detect the same biases in belief updating when constraining our analyses to those capacities that participants were most sceptical of. Likewise, our simulations suggested that the effects could not be accounted for by regression-to-the mean. Further details are provided in the Supplementary Material.

6. General discussion

Beliefs about animal minds are central to debates about their welfare and treatment (Amiot & Bastian, 2015; Bekoff, 2002; Bentham, 2015; Bock & Buller, 2013; Dhont et al., 2019; European Union, 2007; Singer, 1975). Despite this, it is currently unclear whether people's beliefs about animals' minds are largely accurate or inaccurate. The present studies used an innovative task (Hill, 2017; Tappin et al., 2020) to examine how people update their beliefs about minds in response to noisy signals that have a clearly defined probability of being accurate. This allowed us to compare updated (posterior) beliefs about minds to an unbiased benchmark and therefore to test if these beliefs were accurate or inaccurate in relation to this benchmark.

6.1. Evidence for the systematic underestimation of animal minds

We found that participants consistently underestimated animals' minds, both in terms of the likelihood that they had mental capacities and that evidence of their minds was true. On receiving a noisy but informative clue, participants shifted their beliefs more when it suggested the animal did not have a mind compared to when it suggested the animal did have a mind. This meant that they overshot a normative benchmark in response to clues that suggested animals did not have minds, but undershot the same benchmark when receiving clues that suggested animals did have minds. In other words, on receiving information about the veracity of their beliefs concerning animal minds, participants integrated this information in a way that resulted in them being more sceptical of animal minds than could be justified by normative standards (i.e., Bayes' theorem). In this sense, participants' beliefs were inaccurate in a way that underestimated animals' minds.

The results also demonstrated that participants underestimated animal minds more than human minds. On judging the same mental capacities and receiving the same clues, participants updated their beliefs more when a clue suggested a human had mental capacities compared to an animal. The opposite was true when they received clues that suggested a human or animal did not have mental capacities. That is, given exactly the same information, participants' beliefs about animals came to be more inaccurate and more skewed towards believing they did not have minds compared to their beliefs about humans. These findings align with work that documents the tendency to deny animals' minds (Bastian and Loughnan, 2017; Bastian et al., 2012; Loughnan & Davies, 2020) and to represent them as less worthy of moral concern compared to humans (Caviola et al., 2018, 2022; Dhont & Hodson, 2020; Leach et al., 2022).

The primary contribution of the work is its ability to speak to long-standing claims about whether we over- or underestimate animals' minds (Burghardt, 1991a, 1991b, 2004; de Waal, 2016; Rollin, 1989; Singer, 1975; Wynne, 2004, 2007). By employing a task that provides a normative benchmark (Hill, 2017; Tappin et al., 2020), we were able to examine the accuracy of a wide set of beliefs about animals' mental capacities and about genuine scientific evidence that one might come across in popular media (e.g., de Waal, 2016). To define our relationships with other animals in a way that gives appropriate weight to their suffering requires that we be appropriately sensitive to evidence of their mental sophistication. If we are, as our data suggest, systematically getting it wrong in this regard, it is important that we become aware of this so that we may better deal with the existential and ethical questions arising from our relationships with other animals.

Claims about whether we over- or underestimate animals' minds are to some degree orthogonal to theoretical accounts of the psychological mechanisms that lead people to attribute minds to nonhuman entities (Bastian & Loughnan, 2017; Epley et al., 2007; Loughnan & Davies, 2020). More relevant to these accounts is the observed tendency for people to view pigs as having less sophisticated minds than dogs (Bastian & Loughnan, 2017; Loughnan & Davies, 2020) and to be generally accepting of the idea that animals have minds, irrespective of any updating. This latter effect echoes people's tendency to project minds onto insentient objects (Douglas et al., 2016; Heider & Simmel, 1944; Waytz, Cacioppo, & Epley, 2010), their interest in sentient animals (Amiot & Bastian, 2015; Wilson, 1984), and the widespread appeal of literature and media documenting animals' cognitive capacities (see e. g., Berlowitz, Gunton, Brickell, Tom, & Attenborough, 2016; de Waal, 2016; Herzog, 2010). These patterns in no way conflict with our main conclusion: that people are too sceptical of animal minds. It is entirely plausible and theoretically-consistent that people express belief in animal minds and are indeed motivated to do so (Epley et al., 2007), but that their belief is nonetheless too sceptical when assessed against a stringent normative criterion. Here, that criterion is provided by Bayesian reasoning applied to the pieces of evidence about animal minds that people have available to them.

6.2. Caveats, limitations, and future directions

Study 2 allowed us to delve deeper into the mechanisms underlying people's scepticism about animal minds. By eliciting subjective perceptions of the evidences' strength (Tappin et al., 2020), we found that participants' updating was still too sceptical even when compared to their own subjectively-defined benchmark. At the same time, participants were surprisingly trusting of evidence that suggested animals had minds compared to evidence of the opposite. This latter finding might again reflect people's interest in literature and media documenting animals' cognitive capacities (Berlowitz et al., 2016; de Waal, 2016; Herzog, 2010). These results support the idea that scepticism about animal minds is driven by failures to adjust beliefs in accordance with the perceived strength of the evidence. Indeed, the errors people made that resulted in them being too sceptical of animal minds are arguably even more marked given their purported trust of evidence that suggested animals had minds.

Studies 1–2 found little evidence that the accuracy of people's beliefs about animals' minds was moderated by their dietary commitments or by the species of the animal in question (pig vs. dogs). It was also present when considering those capacities that people were most sceptical about to begin with. These results reassure us that the overall pattern of belief updating is not simply an artifact of differences in priors (see also Studies S1 and S2 which found similar patterns of belief updating for novel animals that participants had little prior knowledge of). These findings could be interpreted as a form of negativity bias, where participants are more sensitive to negative evidence compared to positive (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Rozin & Royzman, 2001; Skowronski & Carlston, 1989). However, this interpretation cannot account for the observed differences between humans and animals. It is also at odds with the overall patterns observed in Study 3, where participants were no more sensitive to negative signals (those that suggested evidence was false) compared to positive signals (those that suggested evidence was true). A different way of interpreting these findings is as an expression of how we collectively construe animals' minds. For the vast majority of history, the default assumption seems to have been that animals do not have minds. Descartes was famously reluctant to consider animals anything more than mere automata. It is arguably only recently (historically speaking) that this has begun to change via a collective shift by human beings towards including animals into social life (Serpell, 2003). The cultural remnants may remain (Leach, Kitchin, et al., 2022; Sealey & Oakley, 2013) and perhaps explain why we find a somewhat immovable tendency to underestimate

animal minds.

Future research could explore if people deviate from normative standards in other domains, whether this be in a way that is unjustifiably anthropomorphic or mind-denying. For example, biases may exist in how people remember information (Callan, Kay, Davidenko, & Ellard, 2009; Dawtry, Cozzolino, & Callan, 2019; Hennes, Ruisch, Feygina, Monteiro, & Jost, 2016; Kouchaki & Gino, 2016; Sedikides & Green, 2000), communicate it to others (Ekstrom & Lai, 2020; Kashima, 2000; Lyons & Kashima, 2003; Mesoudi, Whiten, & Dunbar, 2006) and reason about it (Gampa, Wojcik, Motyl, Nosek, & Ditto, 2019; Janis & Frick, 1943; Morgan & Morton, 1944). Recent work has shown that a desire to eat meat predicts a pattern of exposure-preferences for evidence about animals' minds that is arguably mind-denying (Leach et al., 2022). It could also be fruitful to further explore how perceptions of animal minds relate to feelings of moral concern for them. We found that updating predicted mind-attribution but not moral concern, suggesting that moral concern may be more indirect or contingent than otherwise assumed (Piazza & Loughnan, 2016). These avenues promise to further advance our understanding of judgements about animals that bear on important existential and ethical questions.

7. Conclusion

Five studies examined the accuracy of participants' beliefs about animals' minds. We found that participants shifted their beliefs too far in response to clues that suggested animals lacked minds (overshooting what a normative participant ought to believe), but not far enough in response to clues that suggested they had minds (falling short of what a normative participant ought to believe). A final study demonstrated that this effect was attenuated for beliefs about humans. The findings bear on the legitimacy of our relationships with animals by demonstrating a cognitive stumbling block to seeing animals as they truly are.

Author note and declarations

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Data availability

The raw data and analysis scripts are available via the Open Science Framework (<https://osf.io/tpqsm/>).

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.cognition.2022.105263>.

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