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Are we smart enough to remember how smart animals are?

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Investigation	Lead	Supporting	Supporting		
Methodology	Lead	Supporting	Supporting	Supporting	Supporting
Project administration	Supporting	Lead			
Resources	Lead		Supporting		
Software					
Supervision					
Validation					
Visualization	Lead				
Writing – original draft	Equal	Equal			Supporting
Writing – review & editing	Lead	Supporting	Supporting	Supporting	Supporting

Note. See https://credit.niso.org/ for role definitions.

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Public Significance Statement

The capacity for sentience and suffering in nonhuman animals is a critical factor in moral debates surrounding their use in various industries, such as agriculture and medical research. The work presents some of the first empirical data on the accuracy of people's judgments about nonhuman animals' capacity for sentience and suffering.

Abstract

Some theoretical perspectives suggest people overestimate animals' mental capacities (anthropomorphism), while others suggest they underestimate them (mind-denial). However, studies have generally not employed objective criteria against which the accuracy or appropriateness of people's judgements about animals can be tested. We employed memory paradigms, in which judgments are clearly right or wrong, in 9 experiments (8 pre-registered; *n* = 3162). When tested shortly after exposure, meat-eaters' memory about companion-animals (e.g., dogs) but not food-animals (e.g., pigs) showed an anthropomorphic bias: more information consistent with animals having vs. lacking a mind was correctly remembered (Experiments 1-4). Vegetarians and vegans memory, on the other hand, consistently showed an anthropomorphic bias regarding food and companion animals alike (Experiments 5 and 6). When tested a week after exposure, both those who eat meat and those who do not showed signs of shifting toward a mind-denying bias (Experiments 2, 3, and 6). These biases had important consequences for beliefs about animal minds. Inducing mind-denying memory biases caused participants to see animals as possessing less sophisticated minds (Experiments 7-9). The work demonstrates that judgments about animals' minds can depart predictably from reality and that such departures can contribute to biased perceptions of their minds.

Are we smart enough to remember how smart animals are?

The title of a best-selling scientific book “Are we smart enough to know how smart animals are?” (de Waal, 2016) indicates that we find understanding animal minds to be important and challenging (Bock & Buller, 2013; Dawkins, 2015). It matters whether animals have minds (Gray et al., 2007; S. Leach et al., 2021) because their mental capacity affects the quality and legitimacy of our relationships to them--ranging from love to labour, entertainment, research, medicine, and food. For example, it is generally agreed that animals’ minds, and especially their capacity to suffer, is crucial in deciding how to regulate animal research and agriculture (Bock & Buller, 2013; European Union, 2007). Despite this, there is disagreement about how cognitively sophisticated animals truly are (Bock & Buller, 2013; Dawkins, 2015) and concern is often expressed about the tendency for people to inaccurately perceive their minds, with some believing that we overestimate them (i.e., anthropomorphism; Burghardt, 1991, 2004, 2007; Wynne, 2004, 2007) and others that we underestimate them (i.e., mind-denial; Rollin, 1989; Singer, 1975). The latter is thought to contribute to our sense of human superiority and the exploitation of animals. We describe a programme of research that speaks to whether people’s judgements objectively over- or underestimate animal minds. In this sense, the research provides empirical data answering the question: Are we smart enough to know how smart animals are?

Perceiving minds

Because we have no direct access to others' minds, we are faced with an inherent risk of ascribing more or less sophisticated mental states and capacities than are objectively warranted. On the one hand, people are chronically prone to anthropomorphism: perceiving mental states and capacities where none exist. This is seen in the animism of many human cultures and in the tendency to ascribe intentionality to weather systems (Waytz et al., 2010) and geometric shapes (Douglas et al., 2016; Heider & Simmel, 1944). These are clearly ‘anthropomorphic’ errors because we know, for example, that geometric shapes are incapable of mental states. In other cases, people make the opposite error by failing to appreciate mental states and capacities where they clearly do exist.

Studies on intergroup conflict and discrimination show that people selectively underestimate the minds of other humans when this perception aligns with their interests or the interests of their group (Castano & Giner-Sorolla, 2006; Haslam et al., 2005; Leyens et al., 2000; Loughnan et al., 2010; Paladino et al., 2002; Viki et al., 2006). These are clearly errors in the opposite direction, of a ‘mind-denying’ flavour.

Whether our judgements about the fuzzier, less cut-and-dried matter of animals’ minds (vs. objects and humans) are accurate is less clear. Nevertheless, the literature provides some support for the hypothesis that these could be anthropomorphic. Our relationship with pets and other domestic animals may be more effective if we understand how they think, and more satisfying if we perceive them as having a mind--perhaps more so than they actually do (Serpell, 2003). Research confirms that people are motivated to ascribe more intentionality to pets when their need for companionship is chronically or situationally unmet by their relationships with human beings (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008).

In contrast, other work suggests that people are prone to deny animal minds. Specifically, research on the so-called ‘meat paradox’ (Bastian & Loughnan, 2017; Loughnan & Davies, 2020) shows that people are caught in a moral dilemma: they like and care about animals, but also eat them, and so are implicated in their suffering and death (Dhont & Hodson, 2020; Rothgerber, 2020; Rothgerber & Rosenfeld, 2021). This triggers moral disengagement (Bandura, 1999) in the form of psychological justifications for meat consumption (Piazza et al., 2015). Importantly, similar motives seem to drive people to downplay the minds of food animals (Bastian et al., 2012; Bratanova et al., 2011; Kunst & Hohle, 2016; Leach et al., 2022; Rothgerber, 2014a). These findings show that motivational processes affect beliefs about animal minds, and suggest that people might be making an error in seeing the animals they eat as less cognitively sophisticated than they actually are.

In sum, researchers have made strides in discovering what makes people perceive animals’ as having more, or less, sophisticated minds. However, we submit that they have not made significant progress in determining whether these perceptions are accurate. One reason for this is that our present scientific understanding of animal minds is too limited to provide a comprehensive normative benchmark against which the accuracy of lay people's judgements can be measured. Although the study of animal minds is advancing at a rapid pace it is subject, like other scientific fields, to continual uncertainty and revision in light of new evidence. This uncertainty is compounded by the inherent difficulties of studying animal minds including, for example, the vast morphological and behavioural differences between animal species that makes it very difficult to test and compare their cognitive capacities on an equitable basis (Dawkins, 2015; de Waal, 2016). In addition, the judgements about animals solicited in most studies are generally not of a form that can be said to be right or wrong. The dependent measures in most psychological studies are taken on subjective response scales (e.g., agree-disagree) and many also require participants to make judgements about broad competencies (e.g., whether animals possess minds) that are not empirically specified. All of this means that at present, psychological science, even in combination with advances in the study of animal behaviour, cannot offer definitive answers to questions about whether human beings grant too much or too little mind to animals.

Assessing accuracy and error in human judgments about animal minds

It is important to build conceptual and methodological bridges over this impasse. Conceptually, we propose to reframe the question of human accuracy about animal minds. Instead of asking whether people's judgments about animal minds are accurate in relation to *ultimate truths* about animals, we can ask whether they are accurate in relation to the *available evidence*. Since we are only able to draw on available evidence (including that arising from scientific studies of animals) to assess the accuracy of people's beliefs, this reframing opens up an apparently intractable question to empirical scrutiny. Methodologically, answering this reframed question demands that we solicit judgments from participants that have indubitable truth value (correct or incorrect) in relation to available evidence. To isolate psychological processes, it is also necessary to achieve experimental control over the evidence with which participants have been exposed. For example, studies suggest that elephants can recognize themselves in a mirror (Plotnik et al., 2006). Research participants may deny that elephants can do this simply because they have not encountered the relevant evidence. However, if they have been exposed to the evidence as part of the experimental procedure, then we know their error has a psychological basis.

The study of human memory provides experimental paradigms that are well suited to these requirements. In memory research, participants are first exposed to information, and asked later to recall it, or to judge whether or not they recognise it as having been presented. A participant's judgement about whether or not they were shown a statement like "elephants can recognize themselves in a mirror" is right or wrong regardless of what participants knew before the experiment and whether the statement is ultimately true--meaning that the veracity of memory judgments about animals can be evaluated even against the backdrop of an incomplete, evolving scientific literature on animal sentience featuring mixed, sometimes contradictory findings (Bock & Buller, 2013; Browning & Birch, 2020; Dawkins, 2015; for a review of scientific uncertainty more generally, Ioannidis, 2005). Thus, errors in people's memory, and their direction, can index psychological processes that lead to anthropomorphism or mind-denial.

As well as conferring these advantages, memory tasks provide an interesting and novel approach to the study of human-animal relations. Far from being a literal store, human memory involves interpretation and reconstruction, and is prone to systematic and motivated distortions (Anderson & Hulbert, 2021; Engen & Anderson, 2018; Loftus, 1975; Schacter et al., 2011). These distortions sometimes meet social or moral needs, helping people to feel better about themselves and their pasts (D'Argembeau & Linden, 2008; Nairne et al., 2017; Wildschut et al., 2006). For example, when people are experimentally presented with trait information about themselves (but not other people), they later recall positive traits (e.g., 'kind') more readily than negative traits (e.g., 'dishonest'; Sedikides & Green, 2000). Some studies on 'ethical amnesia' have shown that over time, people's memories of their unethical actions become less vivid and detailed (Kouchaki & Gino, 2016; see also Stanley et al., 2018). Memory biases extend to moralised beliefs, including those that explain and validate ideologies and social injustices (Callan et al., 2009; Dawtry et al., 2019; Hennes et al., 2016; O'Sullivan & Durso, 1984). Since representations of animals and disadvantaged human groups share much in common (Dhont et al., 2014, 2016), we propose that similar biases may extend to memory about animals and their minds.

Present research

Nine experiments (n = 3162) tested the accuracy of participants' memory for animal minds and probed the down-stream consequences for beliefs. Experiments 1-6 provide an investigation into whether people's judgments of animals are more generous than empirically warranted, consistent with the anthropomorphism perspective on animal-human relations, or too stringent, consistent with the mind-denial perspective. They did so by balancing the to-be-learned evidence so that half was indicative of having a mind (e.g., can use tools) and half of being mindless (e.g., cannot recognize itself in a mirror). By comparing recall and recognition memory for each type of evidence, we captured participants' bias for evidence that suggests animals have minds over evidence of the opposite (mind - mindlessness) and obtain an intuitive scale that reflects the degree to which memory is biased. On this scale, positive scores reflect greater memory for evidence that suggests animals have minds (anthropomorphic bias), scores of zero reflect equal memory for both types of evidence (no bias), and negative scores reflect greater memory for evidence that suggests animals lack minds (mind-denying bias).

Experiments 1-4 iteratively honed in on the role that animals' cultural status plays in shaping memory by examining how meat-eaters remember companion animals (where anthropomorphic biases are theoretically most likely) versus food animals (where mind-denial biases are theoretically most likely to occur). Experiments 5-6 gets at this idea in a different way, by examining those with dietary commitments (vegetarians and vegans, henceforth referred to as veg*ns) associated with greater moral concern for animals (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012). This design allowed us to directly compare memory in meat-eaters and veg*ns. Furthermore, by inviting participants to return and complete the same memory tests again seven days after encoding, we examined how memory errors shift over time in both meat-eaters (Experiments 2 and 3) and veg*ns (Experiment 6).

The inclusion of multiple measures of memory performance allowed us to better understand the psychological mechanisms that may lead to errors about the minds of animals. In addition to the general memory biases captured in participants' spontaneous reproductions of evidence in their own words (recall memory), we also captured a more nuanced picture via their judgments about whether evidence had previously been encountered (recognition memory discrimination and response bias). These latter indices, derived from recognition memory paradigms, provided insight into the cognitive mechanisms underlying memory biases about animal minds by indicating whether they are likely attributable to differences in the decisional processes associated with the *reporting* of evidence or to differences in the *availability* of evidence in memory (Tulving & Pearlstone, 1966; Heit, 1993; Rhodes & Jacoby, 2007).

In addition, the work explores the moderating effects of ideological beliefs on moral memory biases. Various theoretical frameworks suggest that perceptions of animal minds are ideologically motivated. Preferences for cultural conservatism and social inequality are predictive of lower attributions of mind to animals and concern for their welfare (Dhont & Hodson, 2014; Dhont et al 2016; Monteiro et al., 2017; Piazza et al., 2015). Moreover, those who ground moral status in species membership and accept animal exploitation (Caviola et al., 2018, 2022) are more likely to believe that animals possess relatively unsophisticated minds (Bilewicz et al., 2011; Piazza et al., 2015). To understand the role that such ideological beliefs potentially play in our effects, we measured individual differences associated with disengagement from the moral issues surrounding animal welfare, specifically: right-wing authoritarianism (RWA; Altemeyer, 1998), social dominance orientation (SDO; Pratto et al., 1994, 1999), and speciesism (Caviola et al., 2018, 2022; Dhont et al., 2020; Ryder, 2010; Singer, 1975).

Finally, Experiments 7-9 investigated the downstream effects of memory on later beliefs about animal minds. By manipulating what people remember about animal minds, these final experiments tested if memory is a plausible mechanism through which perceptions of animal minds are formed. This final strand complimented the former by showing that memory biases have knock-on consequences for people's generalised evaluations of animals' mental capacities.

Experiments 1-4: Memory in meat-eaters

Experiments 1-4 tested how meat-eaters remember evidence about different types of animals. The propensity to see close animals as having minds (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008) suggests that meat-eaters would be likely to anthropomorphize animals that are typically thought of as companions, such as dogs. Research on the 'meat paradox', on the other hand, suggests that moral disengagement mechanisms are likely to lead meat-eaters to downplay the minds of those animals that are culturally defined as sources of food, such as pigs (Bastian & Loughnan, 2017; Loughnan & Davies, 2020). Experiments 1-4 tested these ideas by comparing how meat-eaters remember information about the minds of animals that are typically kept as companions compared to those that are typically reared for food.

Experiment 1

We begin by describing an initial test of how meat-eaters remember information about the minds of animals that are typically kept as a companion compared to one that is typically reared for food. We focus on dogs and pigs because they are common and familiar animals that have distinct culturally-defined relationships with humans that are likely to be associated with errors about the qualities of their minds. Dogs are typically thought of as companion animals (Serpell, 2003) and so ought to be particularly prone to being anthropomorphised (Bartz et al., 2016; Epley, Akalis, et al., 2008; Epley, Waytz, et al., 2008). Pigs, on the other hand, are typically reared for food and so ought to be particularly prone to being denied mental sophistication, at least by those who eat meat (Bastian & Loughnan, 2017; Loughnan & Davies, 2020).

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 1's hypotheses, sample target, exclusion criteria, and statistical models were pre-registered (https://osf.io/njcwb/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis. We approached the power analyses with some general expectations about the likely magnitudes of the memory biases between animals that are typically cared for (dog) and those that are reared for food (pig): $d = 0.36$. Given these expectations, we aimed to recruit 250 participants so as to afford 80% to detect the expected effects (two-tailed, $a = .050$).

Sample. We met our pre-registered sample target. Two hundred and fifty-four self-identified meat-eaters ($n_{\text{male}} = 107$, $n_{\text{female}} = 146$, $n_{\text{non-binary}} = 1$; $M_{\text{age}} = 36.50$, $SD_{\text{age}} = 12.62$) from the United Kingdom participated via *Prolific* in exchange for £1.25. Participants were prompted to report their gender (male, female) and provided with the option to self-identify via an open text box. Ethnicity and race were not recorded. Participants were pre-screened and their diets were confirmed via self-report: *I prefer to eat meat* ($n = 44$), *I prefer meat and vegetables* ($n = 150$), *I eat meat, but not very much* ($n = 60$). No data were analysed prior to reaching the target sample size.

Design. Experiment 1 followed a 2-between (animal: dog vs. pig) design.

Procedure and Materials

Memory stimuli. We compiled a set of 32 statements about animal minds to serve as memory stimuli. Half suggested the animal had a mind (e.g., [animal] can use a stick to fish out food from narrow holes) and half that the animal lacked a mind (e.g., [animal] cannot recognize themselves in a mirror). These statements were selected on the basis of prior research and capture behaviours and mental traits documented in genuine studies on animal cognition (e.g., de Waal, 2016; Shettleworth, 2001) and in psychological theory (Demoulin et al., 2004; Gray et al., 2007; Haslam & Loughnan, 2014; Leyens et al., 2000), including: empathy (e.g., feeling what others feel), morality (e.g., cooperation, fairness, benevolence), primary emotions (e.g., pleasure, pain), secondary emotions (e.g., awe, shame), social connectedness (e.g., seeking comfort with others), recognition (e.g., recognizing self and others, classifying images), learning (e.g., learning commands), theory of mind (e.g., following other's gaze), planning (e.g., hiding food for later), tool use (e.g., using rocks to break nuts), and spatial reasoning (e.g., remembering location of food). These statements have been shown to reliably indicate the capacity for experience and agency (S. Leach et al., 2021).

The 32 statements were put into matched pairs based on whether they indicated an animal had, or lacked, a mind. For example, the statements '[animal] can position a box to stand on to reach food' and '[animal] can use a stick to fish out food from narrow holes' were paired as they both indicate the animal has a mind. This allowed us to use one statement from each pair as a target stimuli (present in the initial learning phase and in the subsequent recognition task) and one as a foil stimuli (not present in the initial learning phase but present in the subsequent recognition task). We randomly selected one statement from each pair to serve as a target and the other as a foil for each participant. These statements were then embedded in a mock, but allegedly real, scientific article describing the cognitive and emotional capacities of a single animal. Each participant read about a single animal, meaning that targets and foils always referenced the same animal for a given participant.

Procedure. Participants were told they would read an article about dogs [pigs] that contained a number of scientific observations documenting how they think, feel, and behave. They then read the article (~450 words), which contained 16 of the memory stimuli described above: eight statements that suggested the animal had a mind and eight that suggested it did not (for the full article see Supplementary Materials). Participants were required to read the article for at least four minutes. Following that, they completed an image-matching filler task, similar to a so-called 'CAPTCHA' test, containing 12 trials and lasting just over two minutes.

Participants then completed a surprise recall and recognition task. The recall task prompted them to report any and all information they could from the article via an open text box. Participants were not prompted to be accurate or confident in their responses, but simply requested to report any and all information they could via an open text box. We provided no upper or lower limits with regards to the amount of information required to be recalled. After logging their recall, they were prompted with the recognition task requiring them to judge 32 statements one-by-one (16 targets included in the text; 16 matched foils not included in the text). Responses were required via a forced-choice judgement (yes vs. no). The timing of the recall and recognition tasks was self-paced. The order of the statements, and which served as targets and foils, was randomised for each participant.

Next, participants were asked eight questions regarding the extent to which the target animal had various mental capacities (*α* = .81; thought, self-control, planning, remembering, fear, pain, pleasure, suffering; Bastian et al., 2012; Leach et al., 2021) and four questions regarding the morality of eating and harming the target animal (*α* = .80; "How morally wrong is it to eat[harm] a dog [pig]?", "How guilty would you feel to eat[harm] a dog [pig]"?), from 1 (not at all) to 7 (very much; see e.g., Leach et al., 2021). These items only asked about the target of the memory stimuli. Finally, participants completed measures of right-wing authoritarianism (*α* = .87; Duckitt et al., 2010), social dominance orientation (*α* = .86; Ho et al., 2015), and speciesism (*α* = .72; Caviola et al., 2018). These scales were anchored from 1 (strongly disagree) to 7 (strongly agree).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages apa (0.3.3; Gromer, 2020), psych (2.2.5; Revelle, 2022), and ltm (1.2.0; Rizopoulos, 2006).

Indices of memory

We compiled three indices of memory which allowed us to gauge the degree of bias and its underlying cognitive mechanisms. The first was recall which captured how participants spontaneously reproduced information from memory in their own words. It provides a general index of memory that reflects differences in how evidence was encoded, its accessibility and availability in memory, and how it was reported from memory (Tulving & Pearlstone, 1966). Recall was quantified by coders according to a standardised scoring guide (see Supplementary Materials). Coders produced two scores for each text reflecting the number of correctly recalled statements suggesting the animal: 1) had a mind, and 2) lacked a mind. Duplicate information, intrusions, and information that did not present a clear affirmation, or denial, of mind were ignored. The final recall scores reflected the mean from two independent coders. One coder was blind to the experimental manipulations. This was achieved by redacting references to the target animals (‘pig’ and ‘dog’) from the recall responses. Coders achieved a high level of agreement for statements suggesting the animal had and lacked a mind (rs > .95).

The second derived from recognition judgements and provided insight into the degree to which biases were attributable to differences in the availability of evidence in memory. Discrimination reflects the ability to accurately distinguish between information that was previously encountered from information that was not (Tulving & Pearlstone, 1966). It provides a measure of the relative strength of the memory trace for evidence of animal minds and therefore whether biases arise due to differences in the availability of evidence in memory. We calculated discrimination by subtracting participants’ false alarm rate (P(“yes” | F)) from their hit rate (P(“yes” | T)), where F are foils and T are targets. Higher values on this measure reflect a greater ability to discriminate targets from foils (Snodgrass & Corwin, 1988). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), ds > 1.63, ts > 26.03, ps < .001.

The third and final index derived from recognition judgements and provided insight into the degree to which moral memory biases are attributable to differences associated with the reporting of evidence from memory. Response bias reflects the overall tendency to respond that information was previously encountered, compared to not, when uncertain (Tulving & Pearlstone, 1966). It provided a measure of the tendency to believe that evidence of animal minds was encountered and therefore whether biases arise due to differences in the decision-making processes responsible for the reporting of evidence from memory. We calculated response bias by dividing participants’ false alarm rate by 1 – discrimination, after applying a conventional correction procedure (+0.50 to hit and false alarm rates). Higher values on this measure reflect a more liberal response bias (i.e., a greater tendency to assume that information was encountered; Snodgrass & Corwin, 1988).

We computed a relative index of memory (mind - mindlessness) for recall, response bias, and discrimination. This index quantified participants' bias for evidence that suggests animals have minds over evidence of the opposite. Positive scores reflect greater memory for evidence that suggests animals have minds (anthropomorphic bias), scores of zero reflect equal memory for both types of evidence (no bias), and negative scores reflect greater memory for evidence that suggests animals lack minds (mind-denying bias). Descriptive statistics for hits, false alarms, response bias, and discrimination are available in the Supplementary Materials.

Main analyses

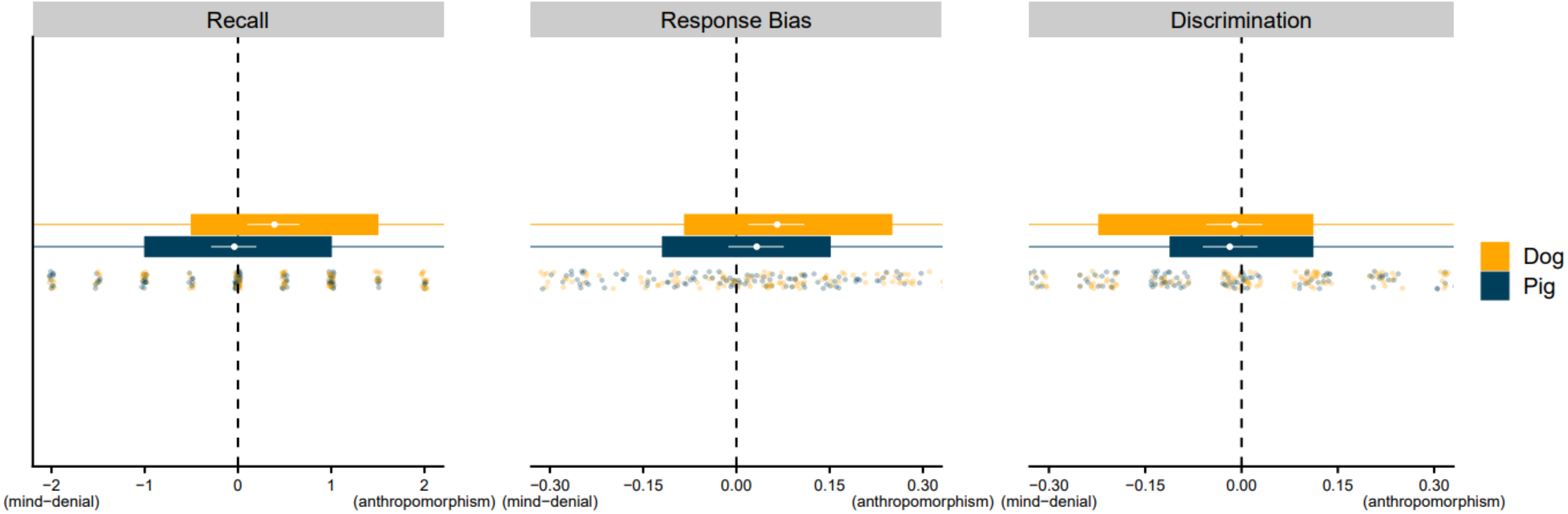
We began by focusing on how participants spontaneously reproduced evidence of animal minds in their own words (recall). As can be seen in Figure 1, participants were more anthropomorphic in their recall for dogs compared to for pigs, $t(252) = 2.23$, $p = .026$, $d = 0.28$, 95% CI [0.03, 0.53]. This meant that they showed an anthropomorphic bias for dogs, recalling more evidence that suggested they had minds compared to lacked them, $t(137) = 2.76$, $p = .006$, $d = 0.24$, 95% CI [0.07, 0.40]. However, they were largely even handed in their recall of evidence about pigs' minds, showing neither an anthropomorphic nor mind-denying bias, $t(115) = -0.31$, $p = .758$, $d = -0.03$, 95% CI [-0.21, 0.15].

The biases in recall we observed could be driven by differences in the tendency to believe that certain evidence was encountered over others (response bias) or by differences in how evidence is encoded and available in memory (discrimination). Participants showed largely the same expectations about whether evidence was previously encountered (response bias) for dogs and pigs, $t(252) = 1.00$, $p = .317$, $d = 0.13$, 95% CI [-0.12, 0.37]. Their ability to discriminate between evidence that was present and absent was also largely the same for dogs and pigs, $t(252) = 0.26$, $p = .799$, $d = 0.03$, 95% CI [-0.21, 0.28]. Thus, the psychological mechanisms associated with the aforementioned biases in recall are unclear at this stage.

These findings are consistent with the idea that meat-eaters’ cultural relationship with animals drives them to make objective errors about the quality of their minds. Moreover, the one-sided nature of the errors, only arising in an anthropomorphic way for companion animals, may impose constraints on claims about errors on the part of meat-eaters towards the animals they eat.

Figure 1

Memory biases in meat-eaters for dogs and pigs.



Note. Positive scores reflect an anthropomorphism bias (greater recall, response bias, and discrimination for evidence of minds compared to mindlessness). Negative scores reflect a mind-denial bias (greater recall, response bias, and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Additional analyses

Various theoretical frameworks suggest that perceptions of animal minds are ideologically motivated. On the basis of these, we pre-registered the expectation that those who were lower (vs. higher) in RWA, SDO, and speciesism would show a greater anthropomorphic bias in memory. We found little evidence to support these predictions. RWA, SDO, and speciesism were largely unrelated to biases in recall, response bias, and discrimination, *r*s < .10, *ps* > .109.

The more meat-eaters' recall and response bias were anthropomorphic, the more they believed the target animal possessed a sophisticated mind, *r*(252) = .21, 95% CI [.09, .32], *p* < .001; *r*(252) = .23, 95% CI [.11, .35], *p* < .001. We found no such relationship between their ability to discriminate, *r*(252) = -.00, 95% CI [-.12, .12], *p* = .992. We also examined the relationships between memory biases and moral concern for animals. We found no evidence to suggest that recall, response bias, or discrimination were related to moral concern for animals, *r*s < .11, *ps* > .077. Replicating prior work, dogs were perceived to possess more sophisticated minds than pigs, *t*(252) = 5.13, *p* < .001, *d* = 0.65, 95% CI [0.39, 0.90], and extended greater moral concern, *t*(252) = 13.01, *p* < .001, *d* = 1.64, 95% CI [1.35, 1.92].

Experiment 2

Experiment 1 demonstrated that recall was objectively anthropomorphic for dogs, but neither anthropomorphic nor mind-denying for pigs. This finding is consistent with the idea that the cultural status of the animal in question drives people to make objective errors about the quality of their minds (Bastian & Loughnan, 2017; Loughnan & Davies, 2020). However, alternative explanations remain viable. People generally hold that dogs have more sophisticated minds than pigs and our data from Experiment 1 supported this (Possidónio et al., 2019). This means that differences in memory for the minds of dogs and pigs could stem from processes that have little to do with the tension associated with animals' status as a food object. Errors could reflect an unmotivated reconstruction of what people already believe about animal minds, regardless of how convenient it may be to represent companion animals as more sophisticated than food animals. Experiment 2 addressed this by holding the target animal's species constant whilst manipulating its cultural status. We contrasted memory for the minds of pigs that are treated with compassion (in sanctuary farms) with pigs that are exploited for food (in slaughterhouses). By comparing the same species, this effectively honed in on the central variable of interest: the cultural status of the animal. In addition, Experiment 2 examined the longevity of errors about animal minds. The more long-lasting and stubborn these errors are, the more likely they are to have important implications for our relationships with animals. To test this, Experiment 2 sampled memory seven days post-encoding.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 2's hypotheses, sample target, exclusion criteria, and statistical models were pre-registered (https://osf.io/x7bdm/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis which was guided by a similar set of expectations as outlined in Experiment 1. As such, we again aimed to recruit 250 participants so as to afford 80% to detect the expected effects (d = 0.36, two-tailed, a = .050).

Sample. We met our pre-registered sample target. Two hundred and forty-eight self-identified meat-eaters (n_{male} = 80, n_{female} = 167, $n_{\text{undisclosed}}$ = 1; M_{age} = 37.46, SD_{age} = 13.81) from the United Kingdom participated via *Prolific* in exchange for £1.25. Demographics were recorded in the same way as in prior experiments. Participants were pre-screened and their diets were confirmed via self-report: *I prefer to eat meat* (n = 38), *I prefer meat and vegetables* (n = 122), *I eat meat, but not very much* (n = 88). No data were analysed prior to reaching the target sample size. One-hundred and ninety-nine (n_{male} = 63, n_{female} = 135, $n_{\text{undisclosed}}$ = 1; M_{age} = 37.40, SD_{age} = 13.50) returned seven days later to participate in a follow-up memory test via *Prolific* in exchange for £1.00.

Design. Experiment 2 followed a 2-between (animal: sanctuary-farm pigs vs. slaughter-house pig) x 2-within (retention time: short vs. long) design.

Procedure and Materials

We employed a paradigm that was almost identical to that of Experiment 1, with the singular change that the target animal was either a pig that was: 1) cared-for on a sanctuary farm and was to live out the remainder of its natural life there, or 2) reared for food and was destined to be sent to an abattoir and slaughtered for meat (Bastian et al., 2012). As in Experiment 1, participants then read the article containing eight statements that were suggestive of minds and eight that were suggestive of mindlessness. Following that, participants completed the same image-matching filler task and were prompted with the same surprise recall and recognition task. Participants completed the same eight questions regarding the extent to which the target animal had various mental capacities (α = .82) and four questions regarding the morality of eating and harming the target animal (α = .84). Finally, participants completed measures of right-wing authoritarianism (α = .84; Duckitt et al., 2010), social dominance orientation (α = .84; Ho et al., 2015), and speciesism (α = .74; Caviola et al., 2018). After seven days (+/- 6 hours) participants were invited to return to complete a second memory test via *Prolific.* After confirming they had participated in the initial experiment, they were presented with the same recall and recognition task as they previously completed. They were then asked the same eight questions regarding the extent to which the target animal had various mental capacities (α = .82) and four questions regarding the morality of eating and harming the target animal (α = .84).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages apa (0.3.3; Gromer, 2020), psych (2.2.5; Revelle, 2022), ltm (1.2.0; Rizopoulos, 2006), and afex (1.1.1; Singmann et al., 2022).

Indices of memory

Recall was quantified in the same way as in Experiment 1. Coders achieved a high level of agreement for statements suggesting the animal had and lacked a mind (*r*s > .95). Discrimination and response bias were also computed in the same fashion as in Experiment 1 (Snodgrass & Corwin, 1988). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *d*s > 1.05, *t*s > 14.88, *p*s < .001. As in Experiment 1, we computed a relative index of memory (mind - mindlessness) for recall, response bias, and discrimination capturing participants' tendency towards anthropomorphism versus mind-denial.

Main analyses

We began by examining meat-eaters' recall shortly after encoding, as in Experiment 1. As can be seen in Figure 2, participants were more anthropomorphic in their recall for pigs if they were cared-for in sanctuary farms than if they were reared for food, *t*(246) = 4.45, *p* < .001, *d* = 0.57, 95% CI [0.31, 0.82]. This meant that they showed an anthropomorphic bias for those pigs that were treated with compassion in sanctuary farms, recalling more information that suggested they had minds compared to lacked them, *t*(124) = 4.85, *p* < .001, *d* = 0.43, 95% CI [0.25, 0.62], but showed no bias in either direction for pigs that were destined to be slaughtered for food, *t*(122) = -1.09, *p* = .279, *d* = -0.10, 95% CI [-0.28, 0.08].

Meat-eaters' differential recall for the minds of pigs in sanctuary-farms compared to those in slaughter-houses persisted over time. It was detectable across both time points, *F*(1, 197) = 11.69, *p* < .001, η_p^2 = .06, and there was no strong evidence that it diminished when sampled after seven days (compared to after a few minutes), *F*(1, 197) = 3.78, *p* = .053, η_p^2 = .02. This meant that, even after seven days, meat-eaters were still unjustifiably anthropomorphic in their recall of evidence about the minds of pigs in sanctuary-farms, *t*(94) = 2.32, *p* = .022, *d* = 0.24, 95% CI [0.03, 0.44], and were still largely unbiased about pigs in slaughter-houses, *t*(103) = 0.06, *p* = .949, *d* = 0.01, 95% CI [-0.19, 0.20].

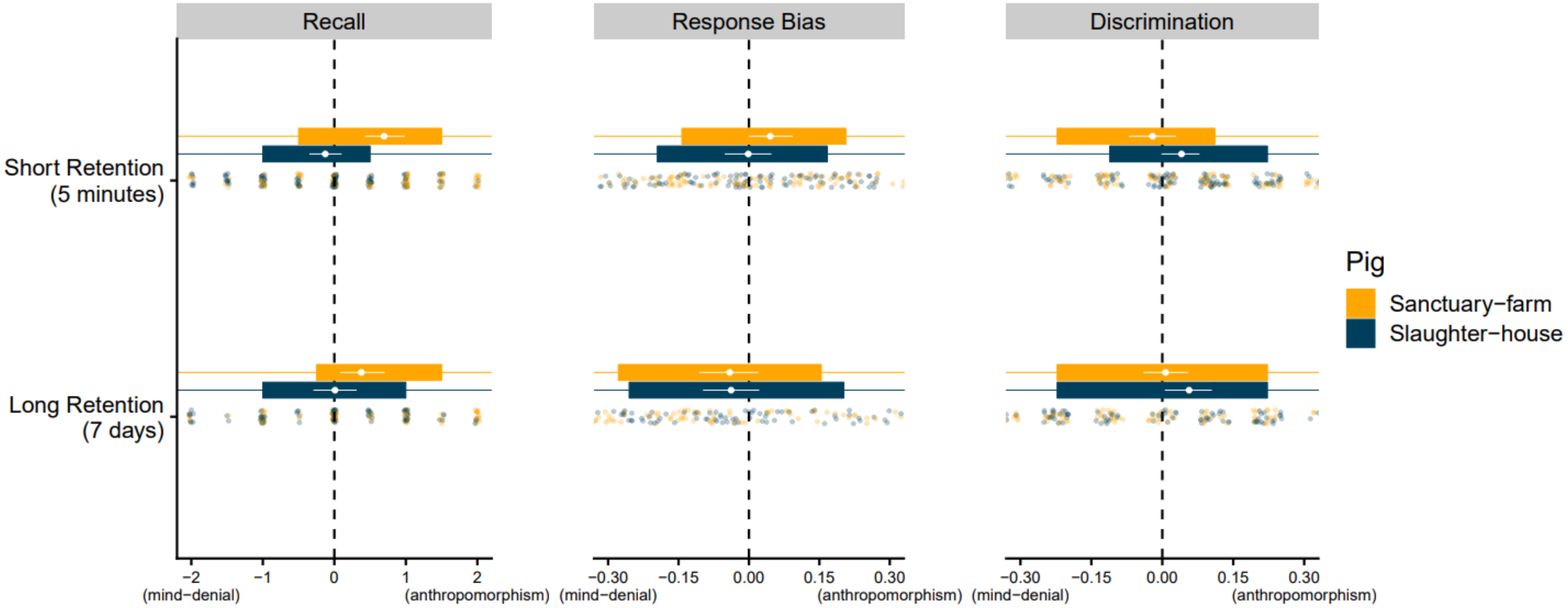
We tested if recognition memory could provide any indication about the potential cognitive mechanisms underlying the biases observed in recall. We found no evidence of differential anthropomorphism or mind-denial on recognition memory. The status of the pig did not affect meat-eaters' expectations about whether they had seen one type of evidence over another (response bias), *t*(246) = 1.33, *p* = .185, *d* = 0.17, 95% CI [-0.08, 0.42], nor their ability to differentiate between evidence that was present or absent (discrimination), *t*(246) = -1.84, *p* = .067, *d* = -0.23, 95%

CI [-0.48, 0.02]. These effects showed no indication of changing over time, *F*s < 1.03, *p*s > .311, $\eta_p^2 < .01$.

These findings support the idea that errors in how we see the minds of animals are directly linked to their cultural status. They also showed that errors are stubborn, holding for at least seven days post encoding. Moreover, the findings again suggested that it is animals that are treated with compassion that are unjustifiably anthropomorphised, more than it is the animals that are treated instrumentally that are unjustifiably denied minds.

Figure 2

Memory biases in meat-eaters for pigs treated with compassion in sanctuary-farms and reared for food in slaughter-houses after varying retention times.



Note. Positive scores reflect an anthropomorphism bias (greater recall, response bias, and discrimination for evidence of minds compared to mindlessness). Negative scores reflect a mind-denial bias (greater recall, response bias, and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Additional analyses

We found some evidence that memory drifted towards mind-denial over time, irrespective of the animal in question. Meat-eaters were more likely to assume they had seen evidence that suggested the animal lacked a mind (response bias) after seven days compared to after five minutes, $F(1, 197) = 18.33$, $p < .001$, $\eta_p^2 = .09$. There was also some very weak evidence to suggest that recall had a tendency to shift towards mind-denial over time, $F(1, 197) = 2.33$, $p = .129$, $\eta_p^2 = .01$. We drew no firm conclusions on the basis of this effect at this stage, but note it as motivating subsequent confirmatory tests documented in Experiment 3. We found no evidence to suggest that discrimination shifted in an analogous way over time, $F(1, 197) = 0.48$, $p = .491$, $\eta_p^2 < .01$.

We again tested if those who were lower (vs. higher) in RWA, SDO, and speciesism showed a greater anthropomorphic memory bias. These analyses focused on memory biases sampled after a short delay. Neither RWA, SDO, and speciesism were related to biases in recall, response bias, and discrimination, *r*s < .10, *ps* > .102. The more meat-eaters' memories were anthropomorphic, the more they believed pigs possessed a sophisticated mind. This was true for recall, response bias, and discrimination, *r*s > .14, *ps* < .031. We found no evidence to suggest that recall, response bias, or discrimination were related to moral concern for pigs, *r*s < .07, *ps* > .304. Pigs in sanctuary-farms were not attributed more mind than were pigs in slaughter-houses were, $t(246) = -1.55$, $p = .122$, $d = -0.20$, 95% CI [-0.45, 0.05]. But they garnered less moral concern, $t(246) = 3.74$, $p < .001$, $d = 0.47$, 95% CI [0.22, 0.73].

Experiment 3

Experiments 1 and 2 compared companion and food animals and have therefore lacked a baseline in which people have neither relationship with animals. It remains unclear then whether being a companion excites mind attribution or being a source of food depresses it, or both. Experiment 3 presented meat-eaters with animals that were either companions, reared for food, or living in the wild. This introduces a new category of animal that represents an important baseline:

being neither typically cared for nor used for food. Experiment 3 achieves this by using a novel, but allegedly real, animal (Piazza & Loughnan, 2014; Sytsma & Machery, 2012). This makes for an even more controlled test by effectively manipulating the animals' relationship with humans, as a companion, source of food, or wild, whilst keeping all other aspects, including prior knowledge, constant. In addition, Experiment 3 follows up on an interesting but inconclusive effect observed in Experiment 2. We found some indication that memory shifted towards mind-denial as time went on, irrespective of the animal in question. Experiment 3 puts this idea to the test by again sampling memories seven days post-encoding.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 3’s hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/ds4tu/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis which was guided by a similar set of expectations as outlined in Experiments 1 and 2. As such, we aimed to recruit 375 participants so as to afford 80% to detect the expected effects (d = 0.36, two-tailed, a = .050).

Sample. We met our pre-registered sample target. Three-hundred and seventy-nine self-identified meat-eaters (n_{male} = 252, n_{female} = 125, n_{other} = 1, $n_{\text{undisclosed}}$ = 1; M_{age} = 35.98, SD_{age} = 12.87) from the United Kingdom participated via *Prolific* in exchange for £1.25. Participants reported their demographics in the same way as in prior experiments. They were pre-screened and their diets were confirmed via self-report: *I prefer to eat meat* (n = 68), *I prefer meat and vegetables* (n = 208), *I eat meat, but not very much* (n = 103). No data were analysed prior to reaching the target sample size. Two-hundred and ninety-three (n_{male} = 197, n_{female} = 94, n_{other} = 1, $n_{\text{undisclosed}}$ = 1; M_{age} = 35.80, SD_{age} = 12.90) returned seven days later to participate in the follow-up memory test via *Prolific* in exchange for £1.00.

Design. Experiment 3 followed a 3-between (animal: companion vs. wild vs. food) x 2-within (retention time: short vs. long) design.

Procedure and Materials

The paradigm was again essentially identical to that of Experiments 1 and 2, but with the singular change that the target animal was replaced for a fictitious but allegedly real one: the trablan (Piazza & Loughnan, 2014; Sytsma & Machery, 2012). Prior to engaging with the memory task, participants were introduced to the trablans as a species of animal from Papua New Guinea with a large and steady population that has never been threatened by extinction. They were then told either: 1) Trablans are kept as pets. The indigenous population cares for the trablans and will feed them and build shelters for them, 2) Trablans are wild. The indigenous population rarely see the trablans and they rarely approach villages, or 3) Trablans are hunted for food. The indigenous population eat the trablans and have a number of traditional cooking practices to preserve the tenderness and flavour of the meat. They then read the article about trablans containing eight statements that were suggestive of minds and eight that were suggestive of mindlessness and then completed the image-matching filler task and were prompted with the same surprise recall and recognition task. Participants completed the same eight questions regarding the extent to which trablans had various mental capacities (a = .75) and four questions regarding the morality of eating and harming them (a = .82). We included two additional measures of moral concern, following prior work examining people's views on fictitious, but allegedly real, animals (Bratanova et al., 2011). Participants were asked whether trablans would suffer more if harmed and if they were deserving of moral treatment, from 1 (not at all) to 7 (very much). Finally, participants completed measures of right-wing authoritarianism (a = .84; Duckitt et al., 2010), social dominance orientation (a = .83; Ho et al., 2015), and speciesism (a = .77; Caviola et al., 2018). As in Experiment 2, participants were invited to return to complete a second memory test via *Prolific* seven days (+/- 6 hours) after the initial test. They completed the same recall and recognition task, and then the same questions about the target animal's mental capacities (α = .82) and the morality of eating and harming the target animal (α = .84).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), *ltm* (1.2.0; Rizopoulos, 2006), and *afex* (1.1.1; Singmann et al., 2022).

Indices of memory

Recall, discrimination, and response bias were compiled in the same fashion as in Experiments 1 and 2 (Snodgrass & Corwin, 1988). Recall coders achieved a high level of agreement (*r*s > .93) and participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *d*s > 0.93, *t*s > 15.94, *p*s < .001. As in Experiments 1 and 2, we computed a relative index of memory (mind - mindlessness) for all indices of memory.

Main analyses

As in Experiment 2, we began by examining meat-eaters' recall shortly after encoding. Figure 3 shows the biases for companion and food animals replicate. Participants recalled more evidence of minds (vs. mindlessness) for companion animals than they did for food animals, $t(256) = 4.37$, $p < .001$, $d = 0.54$, 95% CI [0.30, 0.79]. This meant that recall was anthropomorphic in an absolute sense for companion animals, $t(128) = 4.81$, $p < .001$, $d = 0.42$, 95% CI [0.24, 0.60], but was neither anthropomorphic nor mind-denying for food animals, $t(128) = -1.56$, $p = .121$, $d = -0.14$, 95% CI [-0.31, 0.04]. These results again add to the growing evidence base showing that an animal's status, as a cared-for pet versus a source of food, affects what is remembered about its mental capacities.

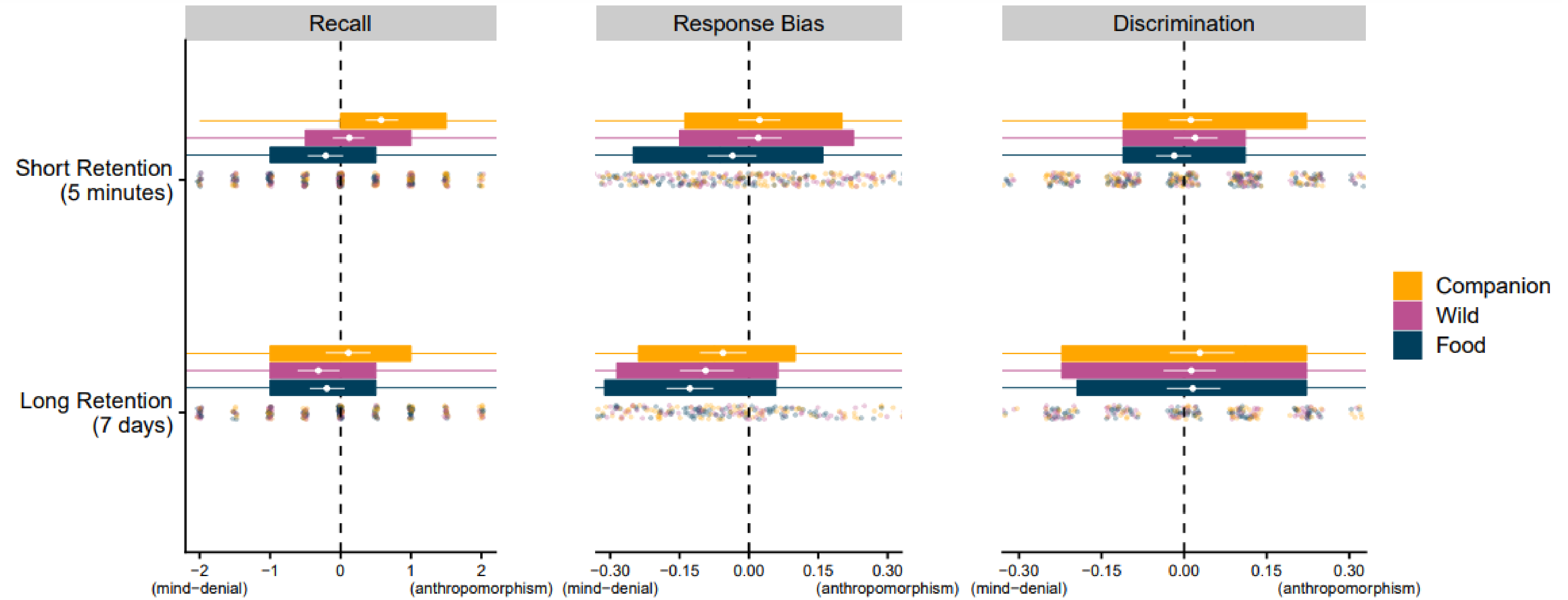
Next, we examined recall in relation to wild animals, which act as a sort of neutral baseline in this context. Recall was more anthropomorphic for companion animals than it was for wild animals, $t(248) = 2.79$, $p = .006$, $d = 0.35$, 95% CI [0.10, 0.60], suggesting that categorising an animal as one that is cared for and treated as a pet excites mind attribution. Whether categorising an animal as a source of food depresses mind attribution was less clear. We found no strong evidence to suggest that recall was more mind-denying for food animals than it was for wild animals, $t(248) = 1.92$, $p = .056$, $d = 0.24$, 95% CI [-0.01, 0.49]. Looking at wild animals in isolation, recall for this animal was neither anthropomorphic nor mind-denying, $t(120) = 1.14$, $p = .256$, $d = 0.10$, 95% CI [-0.08, 0.28].

We tested the longevity and stability of recall biases over time. The biases in recall were detectable across both time points, $F(2, 290) = 5.17$, $p = .006$, $\eta_p^2 = .03$, and there was no strong evidence to suggest that they became any weaker over time, $F(2, 290) = 2.53$, $p = .081$, $\eta_p^2 = .02$. As suggested by our prior data though, there was a tendency for recall to grossly shift towards mind-denial over time, irrespective of the animal in question, $F(1, 290) = 9.32$, $p = .002$, $\eta_p^2 = .03$. Recall was anthropomorphic when tested five minutes after encoding, $t(378) = 2.28$, $p = .023$, $d = 0.12$, 95% CI [0.02, 0.22], but was largely unbiased when tested after seven days, $t(292) = -1.59$, $p = .113$, $d = -0.09$, 95% CI [-0.21, 0.02]. This finding supports our predictions and suggests that memory may tend to shift towards mind-denial as time goes on, irrespective of the animal in question.

Finally, we probed the cognitive mechanisms by examining if biases in recall were accompanied by complimentary biases in response bias and discrimination. We found no differences between animals on measures of response bias and discrimination, $F\text{s} < 2.71$, $ps > .068$, $\eta_p^2 < .02$. There was also no evidence to suggest that these null effects differed across time, $F\text{s} < 0.70$, $ps > .499$, $\eta_p^2 < .01$. However, there was evidence that response bias, just as recall, became significantly more mind-denying over time, $F(1, 290) = 35.67$, $p < .001$, $\eta_p^2 = .11$. Response bias was initial unbiased, $t(378) = 0.15$, $p = .878$, $d = 0.01$, 95% CI [-0.09, 0.11], but came to be mind-denying, $t(292) = -5.99$, $p < .001$, $d = -0.35$, 95% CI [-0.47, -0.23]. This suggests that the changes in recall over time reflect a bias in the decisional processes about which evidence was encountered, as opposed to a bias in the availability of evidence in memory.

Figure 3

Memory biases in meat-eaters for companion, wild, and food animals after varying retention times.



Note. Positive scores reflect an anthropomorphism bias (greater recall, response bias, and discrimination for evidence of minds compared to mindlessness). Negative scores reflect a mind-denial bias (greater recall, response bias, and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Additional analyses

We examined the relationship between individual differences and memory biases sampled after a short delay. We found some evidence to suggest that RWA moderated biases in recall and discrimination, *r*s < -.11, *p*s < .037. However, we found no similar evidence for SDO and speciesism, *r*s < .07, *ps* > .187. The more meat-eaters' response bias was anthropomorphic after a short delay, the more they believed animals possessed a sophisticated mind, *r*(377) = .21, 95% CI [.11, .30], *p* < .001. There was little that biases in recall or discrimination were related to perceptions of mind, *r*s > .14, *ps* < .031. We found no evidence to suggest that recall, response bias, or discrimination were related to moral concern for the animal, *r*s < .07, *ps* > .304. Companion animals were not attributed more mind than were food animals, *t*(256) = 0.94, *p* = .348, *d* = 0.12, 95% CI [-0.13, 0.36], but they were extended more moral concern, *t*(256) = 5.50, *p* < .001, *d* = 0.68, 95% CI [0.43, 0.94]. Companion animals were perceived to suffer more if harmed, *t*(256) = 2.52, *p* = .012, *d* = 0.31, 95% CI [0.07, 0.56], and as more deserving of moral treatment than were food animals, *t*(256) = 2.38, *p* = .018, *d* = 0.30, 95% CI [0.05, 0.54] (Bratanova et al., 2011).

Experiment 4

Some of the results we have reported thus far, notably the biases in recall, could be attributed to biased initial encoding rather than memory retrieval processes. Knowing that an animal is a loved companion versus destined to be killed and eaten may shape the way people attend to, reject, or accept evidence about its mind during encoding. To tease these possible encoding effects apart from subsequent memory processes, Experiment 4 manipulated whether participants were aware of the animal's status as a companion or food at the time of encoding. In addition, Experiment 4 sought to improve the generalizability of our research by providing a population estimate in a large and representative sample of meat-eaters from the United Kingdom.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 4's hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/6423p/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis. We sought to be able to consistently detect a substantially smaller effect compared to in our prior Experiments and as such aimed to recruit 1000 participants so as to afford 90% to detect: d = 0.21 (two-tailed, α = .050).

Sample. We met our pre-registered sample target. One thousand self-identified meat-eaters (n_{male} = 512, n_{female} = 486, n_{other} = 2; M_{age} = 45.07, SD_{age} = 17.40) from the United Kingdom participated via *Prolific* in exchange for £1.25. Demographics were collected in the same manner as in prior experiments, with the addition of education and political orientation. Participants were sampled so as to be representative along the lines of gender and age (as indicated by the Office for National Statistics 2011 Census; ONS, 2012). They were also pre-screened and their diets were confirmed via self-report: *I prefer to eat meat* (n = 143), *I prefer meat and vegetables* (n = 543), *I eat meat, but not very much* (n = 314). No data were analysed prior to reaching the target sample size.

Design. Experiment 4 followed a 2-between (animal: companion vs. food) x 2-between (encoding conditions: animal status known vs. animal status unknown) design.

Procedure and Materials

Experiment 4 examined memory for trablans that are treated as companions and hunted for food. For half of the participants, the procedure was identical to that of Experiment 3. They were introduced to the trablans as a species of animal from Papua New Guinea and informed that they were either treated as a pet or hunted for food. They then read the article and completed the filler task. The remaining half of the participants were introduced to the trablans as a species of animal from Papua New Guinea, but not given any information about their status until after they had read the article and completed the filler task. They were instead informed that the trablans were either treated as a pet or hunted for food just prior to the surprise recall and recognition task. Thus, half of the participants were aware of the trablans cultural status, as a companion or food animal, when encoding information about its mental capacities whilst the other half became aware only after they had encoded this information. After the recall and recognition task, all participants completed the same eight questions regarding the extent to which trablans had various mental capacities (α = .73) and four questions regarding the morality of eating and harming them (α = .82). They also completed the two additional measures of moral concern related to animals perceived suffering if harmed and as more deserving of moral treatment (Bratanova et al., 2011). Finally, participants completed measures of right-wing authoritarianism (α = .85; Duckitt et al., 2010), social dominance orientation (α = .83; Ho et al., 2015), and speciesism (α = .76; Caviola et al., 2018).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), *ltm* (1.2.0; Rizopoulos, 2006), and *afex* (1.1.1; Singmann et al., 2022).

Indices of memory

Recall, discrimination, and response bias were compiled in the same fashion as in Experiments 1-3 (Snodgrass & Corwin, 1988). Recall coders achieved a high level of agreement (*r*s > .95) and participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *d*s > 1.65, *t*s > 52.22, *p*s < .001. We again computed a relative index of memory (mind - mindlessness) for all indices of memory.

Main analyses

We began by testing whether being aware of the animal's cultural status at the time of encoding (vs. after encoding) affected memory. We found no significant main or interaction effects of this manipulation on recall, discrimination, or response bias, *F*s < 0.44, *p*s > .505, $\eta_p^2 < .01$. This suggests that memory biases about animal minds cannot be attributed to differences in how information is encoded and therefore are likely to instead be attributable to differences in how information is stored or retrieved from memory. Moving forward, we consider the effects across both encoding conditions.

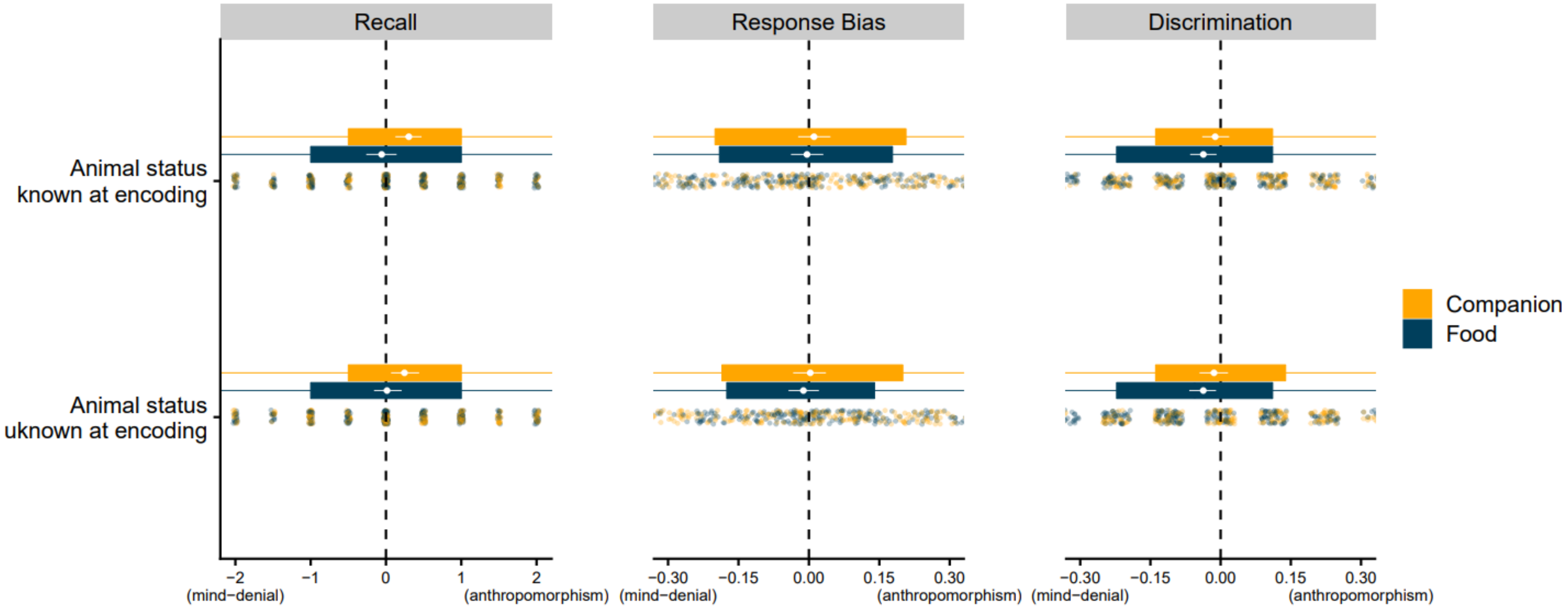
We examined if the same recall biases arose between animals kept as companions compared to those used for food. Recall was significantly more anthropomorphic for companion animals than it was for food animals, $t(998) = 3.07$, $p = .002$, $d = 0.19$, 95% CI [0.07, 0.32]. This meant that participants recalled more information that suggested companion animals had a mind compared to the opposite, $t(503) = 4.08$, $p < .001$, $d = 0.18$, 95% CI [0.09, 0.27]; but were largely evenhanded in their recall for food animals, $t(495) = -0.30$, $p = .761$, $d = -0.01$, 95% CI [-0.10, 0.07].

As in prior experiments, we examined if recognition memory could provide any further insights into the cognitive mechanisms underlying recall biases. We found no evidence of greater, or lesser, biases for companion versus food animals on response bias, $t(998) = 0.86$, $p = .388$, $d = 0.05$, 95% CI [-0.07, 0.18], or discrimination, $t(998) = 1.61$, $p = .107$, $d = 0.10$, 95% CI [-0.02, 0.23].

This high-powered study, conducted on a representative sample of 1000 meat-eaters from the United Kingdom, contributed by not only replicating key effects, but also by showing that they held regardless of any biases at encoding elicited by knowing whether the animal concerned is kept as a companion or kept for food. Thus, memory maintenance or retrieval processes appear to underlie the central memory effects.

Figure 4

Memory biases in meat-eaters for companion and food animals under different encoding conditions.



Note. Positive scores reflect an anthropomorphism bias (greater recall, response bias, and discrimination for evidence of minds compared to mindlessness). Negative scores reflect a mind-denial bias (greater recall, response bias, and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Additional analyses

We found some evidence to suggest that RWA moderated biases in recall and response bias, *r*(998) = -.06, 95% CI [-.12, -.00], *p* = .046, *r*(998) = -.11, 95% CI [-.17, -.05], *p* < .001. However, we did not find similar effects for SDO and speciesism, *r*s < .04, *ps* > .202. The more meat-eaters' recall and response bias were anthropomorphic, the more they believed animals possessed a sophisticated mind, *r*s > .147, *ps* < .001. We found no evidence to suggest that recall, response bias, or discrimination were related to moral concern for animals, *r*s < .04, *ps* > .171. Companions animals were attributed more mind than those used for food, *t*(998) = 2.32, *p* = .020, *d* = 0.15, 95% CI [0.02, 0.27], and were extended more moral concern, *t*(998) = 10.10, *p* < .001, *d* = 0.64, 95% CI [0.51, 0.77]. Companion animals were also perceived to suffer more if harmed, *t*(998) = 3.24, *p* = .001, *d* = 0.20, 95% CI [0.08, 0.33], and as more deserving of moral treatment than were food animals, *t*(998) = 5.16, *p* < .001, *d* = 0.33, 95% CI [0.20, 0.45] (Bratanova et al., 2011).

Experiments 5 and 6: Memory in veg*ns

We have argued that how we think about animals, as worthy of compassion or objects to be consumed, dictates what we tend to remember about their minds. On the basis of this, we would expect a predictably different pattern of memory biases in those who do not eat meat. This is because vegetarians and vegans (veg*ns) differ in their moral beliefs about animals, especially those typically reared for food (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012). Comparing meat-eaters and veg*ns therefore effectively provides a quasi-experimental manipulation of how participants view animals, as worthy of compassion or as food objects, allowing us to target the same psychological construct as did Experiments 1-4, but in a novel way that captures important differences between relevant social groups (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012).

Experiment 5

Experiment 5 examined memory in those who do not eat meat in relation to a particularly salient moral exemplar: pigs living in slaughterhouses that are reared for food. Off the back of work showing that veg*ns are more likely to view animals reared for food as worthy of compassion (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012), we predicted that they would be more likely to anthropomorphize pigs living in slaughterhouses. We also predicted that this tendency would be significantly greater than the one observed in meat-eaters towards the same animal in Experiment 2.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 5's hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/f2kpr/).

Sample size justification. We set our sample targets on the basis of an a priori pre-registered sequential-sampling approach (Lakens, 2017). We planned to examine the strength of the evidence and, if sufficiently convincing, halt data collection at three sample targets (n_1 = 125, n_2 = 250, n_3 = 375). We lowered the alpha threshold to account for the additional planned analyses by applying a linear spending function which maintained the cumulative nominal error rate (α_1 = .017, α_2 = .022, α_3 = .028; two-tailed). Given the alpha thresholds outlined above, the samples afforded adequate power (1-β_1 = 68%, 1-β_2 = 96%, 1-β_3 = 99%) to test for: d = 0.26.

Sample. The evidence was sufficiently strong when examining the data at the first sampling target and data collection was therefore halted. One-hundred and twenty-five veg*ns (n_{male} = 24, n_{female} = 101; M_{age} = 35.66, SD_{age} = 12.21) from the United Kingdom participated via Prolific in exchange for £1.25. Demographics were collected in the same way as in prior experiments. Participants were pre-screened and their diets were confirmed via self-report: *I do not eat meat* (n = 93), *I do not eat meat or animal products* (n = 32). No data were analysed prior to reaching the target sample size.

Design. Experiment 5 had a single condition.

Procedure and Materials

We employed a paradigm that was identical to that of Experiment 2, but only included a single target animal: pigs that were reared for food and destined to be sent to an abattoir and slaughtered for meat. As in Experiment 2, participants read the article, completed the same image-matching filler task and were prompted with the same surprise recall and recognition task. Participants then completed the same eight questions regarding the extent to which pigs had various mental capacities ($a = .84$) and four questions regarding the morality of eating and harming them ($a = .73$).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), and *ltm* (1.2.0; Rizopoulos, 2006)

Indices of memory

Recall, response bias, and discrimination were compiled in the same way as in prior experiments (Snodgrass & Corwin, 1988). Recall coders achieved a high level of agreement for statements suggesting the animal had and lacked a mind (rs > .94). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), ds > 1.45, ts > 16.22, ps < .001.

Main analyses

Beginning with recall, veg*ns were anthropomorphic towards pigs in slaughterhouses, $t(124) = 5.65$, $p < .001$, $d = 0.51$, 95% CI [0.32, 0.69]. Examining recognition showed that this was accompanied by a bias towards thinking that evidence of mind was previously encountered (response bias), $t(124) = 4.38$, $p < .001$, $d = 0.39$, 95% CI [0.21, 0.57], but not with any biases in the ability to differentiate between evidence that was present and absent (discrimination), $t(124) = 0.58$, $p = .566$, $d = 0.05$, 95% CI [-0.12, 0.23].

These findings stand in contrast to those of meat-eaters. Meat-eaters' recall for pigs in slaughterhouses was significantly more mind-denying than veg*ns, *t*(246) = -4.83, *p* < .001, *d* = -0.61, 95% CI [-0.87, -0.36]. A similar difference was evident on measures of response bias, *t*(246) = -3.16, *p* = .002, *d* = -0.40, 95% CI [-0.65, -0.15], but not discrimination, *t*(246) = 0.87, *p* = .387, *d* = 0.11, 95% CI [-0.14, 0.36]. These results support the predictions and again show that how we think about animals, as worthy of compassion or objects to be consumed, can affect what we tend to remember about their minds.

Additional analyses

The more veg*ns' response bias and discrimination were anthropomorphic, the more they believed pigs in slaughterhouses possessed a sophisticated mind, *r*s > .22, *ps* < .013. Recall showed a similar effect, but was not statistically significant, *r*(123) = .15, 95% CI [-.02, .32], *p* = .086. We found no evidence to suggest that recall, response bias, or discrimination were related to judgements of moral concern, *r*s < .09, *ps* > .294. Veg*ns (Experiment 5) attributed pigs in slaughterhouses more mind than did meat-eaters (Experiment 2), *t*(246) = 5.93, *p* < .001, *d* = 0.75, 95% CI [0.49, 1.01], and also extended them more moral concern, *t*(246) = 14.84, *p* < .001, *d* = 1.88, 95% CI [1.58, 2.18].

Experiment 6

Experiment 6 examined memory in those who do not eat meat in relation to a wider set of animals, comprising ones that are typically reared for food (pigs) and kept as companions (dogs). This allowed us to test if veg*ns consider food animals in the same way as they do companion animals, and also if this is similar to how meat-eaters do. In addition, Experiment 6 captured how veg*ns' memory changes over time by inviting them to return and complete the same memory tasks seven-days post encoding. This allowed us to test whether veg*ns have a tendency to become more mind-denying over time, just as meat-eaters do.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 6’s hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/6bxtr/, https://osf.io/kvx2y/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis, informed by our prior work about the likely magnitudes of the memory biases between different animals and over time: $d = 0.36$. Given these expectations, we aimed to recruit 250 participants so as to afford 80% to detect the expected effects (two-tailed, $a = .050$).

Sample. We met our pre-registered sample target. Two hundred and fifty-one self-identified veg*ns ($n_{\text{male}} = 50$, $n_{\text{female}} = 196$, $n_{\text{non-binary}} = 3$, $n_{\text{agender}} = 1$, $n_{\text{other}} = 1$; $M_{\text{age}} = 34.59$, $SD_{\text{age}} = 12.65$) from the United Kingdom participated via *Prolific* in exchange for £1.25. Demographics were collected in the same way as in prior experiments. Participants were pre-screened and their diets were confirmed via self-report: *I do not eat meat* ($n = 171$), *I do not eat meat or animal products* ($n = 80$). No data were analysed prior to reaching the target sample size. Two-hundred and six ($n_{\text{male}} = 42$, $n_{\text{female}} = 160$, $n_{\text{non-binary}} = 2$, $n_{\text{agender}} = 1$, $n_{\text{other}} = 1$; $M_{\text{age}} = 35.06$, $SD_{\text{age}} = 12.77$) returned seven days later to participate in the follow-up memory test via *Prolific* in exchange for £1.00.

Design. Experiment 6 followed a 2-between (animal: dog vs. pig) x 2-within (retention time: short vs. long) design.

Procedure and Materials

We employed a paradigm that was identical to that of Experiment 1 in which the target animal was either a dog or pig. As in Experiment 1, participants read the article, completed the same image-matching filler task and were prompted with the same surprise recall and recognition task. Participants then completed the same eight questions regarding the extent to which the target animal had various mental capacities ($a = .84$) and four questions regarding the morality of eating and harming the target animal ($a = .73$). Participants were invited to return via *Prolific* seven days (+/- 6 hours) after the initial experiment. They completed the same recall and recognition task, and then the same questions about the target animal's mental capacities (α = .82) and the morality of eating and harming the target animal (α = .84).

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), *ltm* (1.2.0; Rizopoulos, 2006), and *afex* (1.1.1; Singmann et al., 2022).

Indices of memory

Recall, response bias, and discrimination were compiled in the same way as in prior experiments (Snodgrass & Corwin, 1988). Recall coders achieved a high level of agreement for statements suggesting the animal had and lacked a mind (*r*s > .91). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *d*s > 1.31, *t*s > 27.59, *p*s < .001.

Main analyses

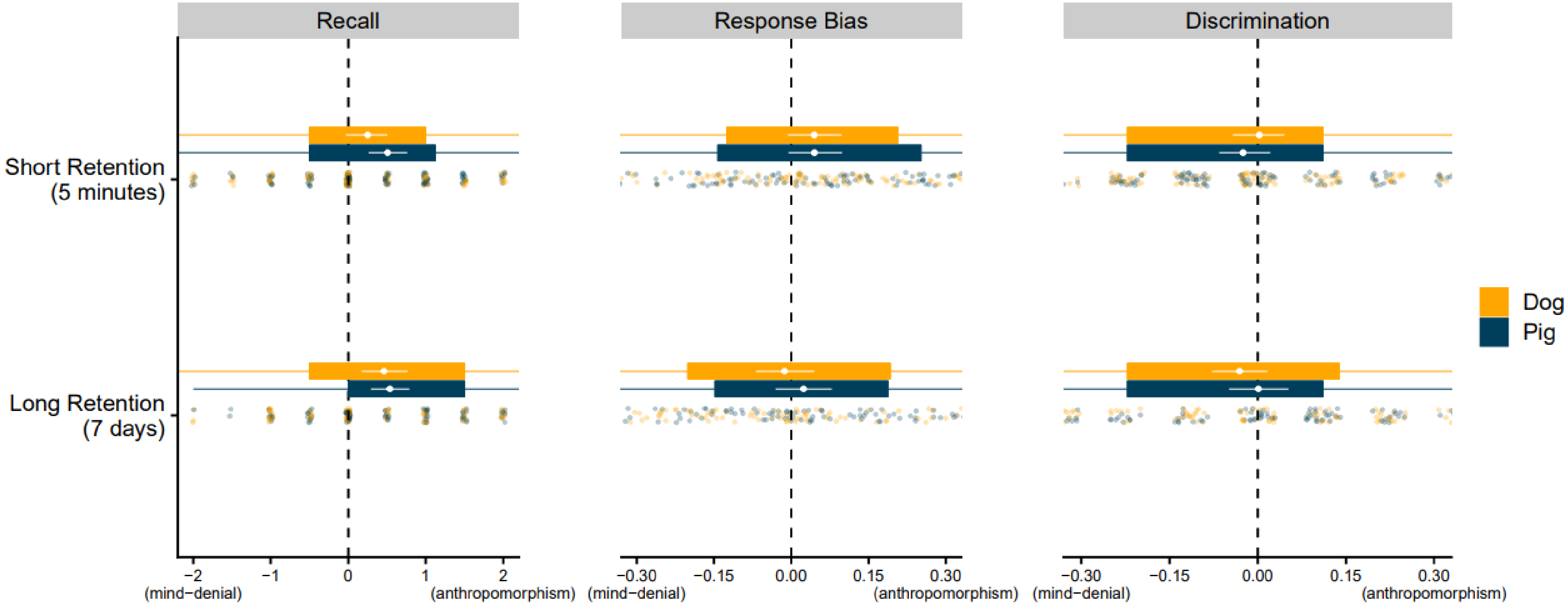
We began by testing how veg*ns remember evidence about different animals shortly after encoding. As can be seen in Figure 5, veg*ns' recall appeared equally anthropomorphic across the board. They made no strong distinction between dogs and pigs, *t*(249) = -1.37, *p* = .172, *d* = -0.17, 95% CI [-0.42, 0.08], and showed an anthropomorphic bias for both animals, *t*(250) = 4.04, *p* < .001, *d* = 0.26, 95% CI [0.13, 0.38]. Recognition judgements revealed that response bias showed a similar anthropomorphic pattern, *t*(250) = 2.48, *p* = .014, *d* = 0.16, 95% CI [0.03, 0.28], which did not differentiate dogs from pigs, *t*(249) = -0.01, *p* = .994, *d* = -0.00, 95% CI [-0.25, 0.25]. There were no noteworthy effects on discrimination, *t*s < 0.71, *p*s > .371, *d*s < 0.11.

Moving on, we tested if veg*ns differed from meat-eaters who judged the same animals in Experiment 1. As predicted, meat-eaters' recall for dogs versus pigs differed more than veg*ns, *F*(1, 501) = 6.54, *p* = .011, η_p^2 = .01. Veg*ns' recall was significantly more anthropomorphic than meat-eaters for pigs, *t*(238) = 3.07, *p* = .002, *d* = 0.40, 95% CI [0.14, 0.65], but was largely the same as meat-eaters were for dogs, *t*(263) = -0.70, *p* = .482, *d* = -0.09, 95% CI [-0.33, 0.15]. There was no evidence that meat-eaters' and veg*ns' response bias or discrimination differed for pigs or dogs, *Fs* < 0.46, *ps* > .498, η_p^2 < .01. These findings highlight differences between meat-eaters and veg*ns in exactly the case, that of food animals, one would expect if they are driven by whether animals are considered with compassion or as objects to be consumed.

Finally, we examined how veg*ns memory shifted over time. As shown in Figure 5, we found no differences in measures of recall or discrimination across time, *Fs* < 0.73, *ps* > .394, η_p^2 < .01. Their anthropomorphic bias in recall for both animals was clearly present here as well, *t*(205) = 5.01, *p* < .001, *d* = 0.35, 95% CI [0.21, 0.49]. We did, however, find that veg*ns were *less* likely to believe they had encountered evidence of animal minds (vs. mindlessness) after seven days compared to after five minutes, as indicated by shifts in their response bias, *F*(1, 204) = 4.53, *p* = .035, η_p^2 = .02. This meant that they became largely unbiased on this measure after seven days, *t*(205) = 0.26, *p* = .794, *d* = 0.02, 95% CI [-0.12, 0.15]. This finding is somewhat surprising and suggests that veg*ns memory may also tend to shift towards mind-denial with time.

Figure 5

*Memory biases in veg*ns for dogs and pigs after varying retention times.*



Note. Positive scores reflect an anthropomorphism bias (greater recall, response bias, and discrimination for evidence of minds compared to mindlessness). Negative scores reflect a mind-denial bias (greater recall, response bias, and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Additional analyses

We considered the relationships between perceptions of animals and memory biases measured shortly after encoding. Veg*ns' response bias was related to their explicit beliefs about pigs' and dogs' minds, *r*(249) = .17, 95% CI [.05, .29], *p* = .006, although their recall and discrimination were not, *r*s < .04, *ps* > .501. We found no strong evidence to suggest that recall, response bias, or discrimination were related to moral concern for pigs and dogs, *r*s < .09, *ps* > .064. Veg*ns attributed pigs and dogs more mind than did meat-eaters (Experiment 1), *t*(503) = 5.69, *p* < .001, *d* = 0.51, 95% CI [0.33, 0.68], and also extended them more moral concern, *t*(503) = 10.46, *p* < .001, *d* = 0.93, 95% CI [0.75, 1.11].

Experiments 7-9: Downstream effects of memory on perceptions of animal minds

The primary theoretical importance of the memory results observed here lies in their being an objective indication of the accuracy of people's judgements about animal minds. In addition, however, memory may serve as a process through which global judgements about animal minds are formed. Indeed, Experiments 1-6 have shown that memory biases correlate with subsequent measures of mind perception. Experiments 7-9 test this idea more comprehensively by experimentally manipulating memory biases and examining how this affects beliefs about animal minds.

Experiment 7

Experiment 7 exposed participants to an established directed forgetting procedure which instructed them, on a trial-by-trial basis, to either remember or forget evidence of animal minds (MacLeod, 1998). By prompting half of participants to remember more evidence suggestive of minds (and forget more evidence of mindlessness) and half to remember more evidence of mindlessness (and forget more evidence of minds), this paradigm allowed us to manipulate memory biases to be either anthropomorphic or mind-denying and to examine the downstream consequences for perceptions of mind.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 7 was not pre-registered.

Sample size justification. We set our sample target on the basis of an a priori power analysis, informed by some general expectations about the likely magnitudes of the directed-forgetting instructions on subsequent beliefs about animal minds: $d = 0.36$. Given these expectations, we aimed to recruit 350 participants so as to afford 80% to detect the expected effects (two-tailed, $a = .050$).

Sample. We met our pre-registered sample target. Two hundred and fifty-five students ($n_{\text{male}} = 42$, $n_{\text{female}} = 213$; $M_{\text{age}} = 19.60$, $SD_{\text{age}} = 4.07$) from a university in the United Kingdom participated via online in exchange for course credit. Demographics were collected in the same way as in prior experiments. Participants' diets were recorded via self-report: *I prefer to eat meat* ($n = 39$), *I prefer meat and vegetables* ($n = 126$), *I eat meat, but not very much* ($n = 55$), *I eat fish, but not other meat* ($n = 10$), *I do not eat meat* ($n = 18$), *I do not eat any meat or animal products* ($n = 7$). No data were analysed prior to reaching the target sample size.

Design. Experiment 7 followed a 2-between (induced memory bias: anthropomorphic vs. mind-denying) design.

Procedure and materials

As in Experiments 3 and 4, participants were introduced to a fictitious but allegedly real animal, the trablan (Piazza & Loughnan, 2014; Sytsma & Machery, 2012), as a species from Papua New Guinea with a large and steady population that has never been threatened by extinction. They were given no information about the animals’ relationship to humans. We then adapted an established item-method directed forgetting paradigm to induce memory biases (Basden et al., 1993; Basden & Basden, 1996; Bjork & Woodward, 1973; MacLeod, 1975, 1998). We utilised the same statements about animal minds as we did Experiments 1-6: eight statements that were suggestive of minds and eight that were suggestive of mindlessness, randomly selected from a larger pool of statements. In these experiments, participants were presented with each statement in isolation for three seconds, afterwhich an instruction was presented alongside the statement, either "REMEMBER" or "FORGET", for eight seconds. We manipulated the instructions such that half of the participants were directed towards an anthropocentric memory bias, receiving the following instructions: "REMEMBER" for 6/8 and "FORGET" for 2/8 statements suggestive of minds, and "REMEMBER" for 2/8 and "FORGET" for 6/8 statements suggestive of mindlessness. The other half of the participants were directed towards a mind-denying memory bias, receiving the following instructions: "REMEMBER" for 6/8 and "FORGET" for 2/8 suggestive of mindlessness, and "REMEMBER" for 2/8 and "FORGET" for 6/8 statements suggestive of mind. The order of the statements and instructions was randomised for each participant. Immediately after the directed forgetting task, participants completed a recognition memory test. This test was identical to the recognition test in Experiments 1-6. Participants indicated if they had previously encountered 32 statements (16 targets included in the directed forgetting task and 16 matched foils not included in the task; yes vs. no). The order of these statements, and which served as targets and foils, was randomised for each participant. Participants then completed the same eight questions regarding the extent to which trablans had various mental capacities (*α* = .81) and four questions regarding the morality of eating and harming them (*α* = .83). These were identical to those used in Experiments 3 and 4.

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), and *ltm* (1.2.0; Rizopoulos, 2006).

Indices of memory

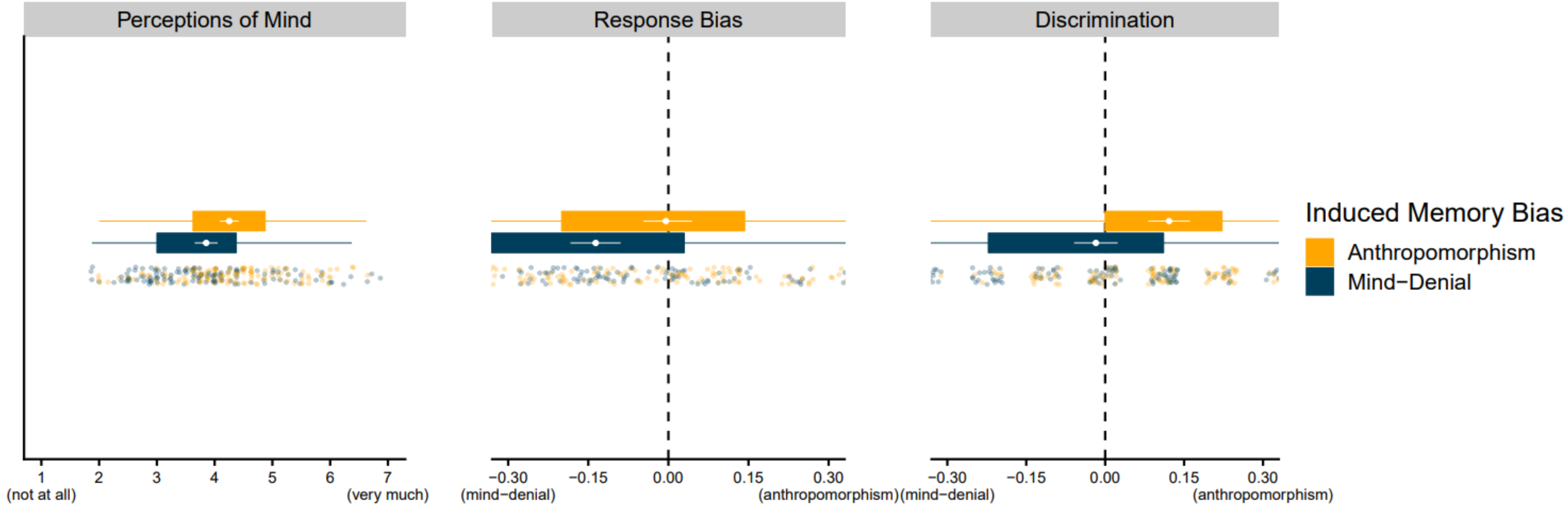
Response bias and discrimination were compiled in the same way as in prior experiments (Snodgrass & Corwin, 1988). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *t*s > 29.72, *p*s < .001, *d*s > 1.86.

Main analyses

As can be seen in Figure 6, inducing an anthropomorphic (vs. mind-denying) memory bias led participants to judge animals as being more capable of cognitive and emotional capacities, $t(253) = 2.99$, $p = .003$, $d = 0.37$, 95% CI [0.13, 0.62]. However, it did not lead to any changes in moral concern for animals, $t(253) = 0.03$, $p = .974$, $d = 0.00$, 95% CI [-0.24, 0.25]. We verified the effectiveness of the manipulation by testing recognition memory. Participants who were manipulated to have an anthropomorphic bias showed a greater bias in favour of minds (vs. mindlessness) on measures of response bias, $t(253) = 4.00$, $p < .001$, $d = 0.50$, 95% CI [0.25, 0.75], and discrimination, $t(253) = 4.61$, $p < .001$, $d = 0.58$, 95% CI [0.33, 0.83], compared to participants who were manipulated to have a mind-denying bias.

Figure 6

Perceptions of, and memory for, animal minds by induced memory bias.



Note. Positive scores reflect elevated perceptions of mind and anthropomorphism bias (greater response bias and discrimination for evidence of minds compared to mindlessness). Negative scores reflect suppressed perceptions of mind and mind-denial bias (greater response bias and discrimination for evidence of mindlessness compared to minds). Figure depicts first to third quartiles (boxes), means (white circles), 95% CIs (white whiskers), and individual jittered data points (coloured points).

Experiment 8

Experiment 8 extended the work by testing if inducing memory biases can also shape beliefs about real animals' minds. It did so by applying the directed-forgetting paradigm to a real and morally-relevant animal: pigs.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 8's hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/dhm85/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis, informed by our prior work about the likely effects of inducing memory biases on beliefs about animal's minds: $d = 0.35$. Given these expectations, we aimed to recruit 350 participants so as to afford 90% to detect the expected effects (two-tailed, $a = .050$).

Sample. We met our pre-registered sample target. Three-hundred and fifty adults ($n_{\text{male}} = 151$, $n_{\text{female}} = 193$, $n_{\text{non-binary}} = 4$, $n_{\text{agender}} = 1$, $n_{\text{trans-female}} = 1$; $M_{\text{age}} = 26.12$, $SD_{\text{age}} = 8.41$) from the United Kingdom participated via *Prolific* in exchange for £1.25. Demographics were collected in the same way as in prior experiments. Participants' diets were recorded via self-report: *I prefer to eat meat* ($n = 49$), *I prefer meat and vegetables* ($n = 204$), *I eat meat, but not very much* ($n = 91$), *I eat fish, but not other meat* ($n = 3$), *I do not eat meat* ($n = 1$), *I do not eat any meat or animal products* ($n = 2$). No data were analysed prior to reaching the target sample size.

Design. Experiment 8 followed a 2-between (induced memory bias: anthropomorphic vs. mind-denying) design.

Procedure and Materials

The paradigm was identical to that of Experiment 7, with the singular change that the evidence referred to a real animal: pigs. Participants completed the same established item-method directed forgetting paradigm to induce either an anthropomorphic or mind-denying memory bias

(Basden et al., 1993; Basden & Basden, 1996; Bjork & Woodward, 1973; MacLeod, 1975, 1998). They then answered eight questions regarding the extent to which pigs had various mental capacities (α = .83) and four questions regarding the morality of eating and harming them (α = .80). These were identical to those used in prior experiments.

Results and Discussion

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), and *ltm* (1.2.0; Rizopoulos, 2006).

Indices of memory

Response bias and discrimination were compiled in the same way as in prior experiments (Snodgrass & Corwin, 1988). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *t*s > 44.08, *p*s < .001, *d*s > 2.36.

Main analyses

Replicating the findings of Experiment 7, we found that inducing an anthropomorphic memory bias led participants to judge pigs as having more sophisticated minds, $t(348) = 4.98$, $p < .001$, $d = 0.53$, 95% CI [0.32, 0.74]. Again, the memory induction did not lead to any changes in moral concern for pigs, $t(348) = 1.51$, $p = .132$, $d = 0.16$, 95% CI [-0.05, 0.37]. There was strong evidence to suggest that the manipulation induced the expected memory biases. Participants who were manipulated to have an anthropomorphic bias showed a greater bias in favour of minds (vs. mindlessness) on measures of response bias, $t(348) = 5.23$, p < .001, $d = 0.56$, 95% CI [0.35, 0.77], and discrimination, $t(348) = 8.75$, $p < .001$, $d = 0.94$, 95% CI [0.71, 1.16], compared to participants who were manipulated to have a mind-denying bias.

Experiment 9

Experiment 9 replicated the directed-forgetting phenomena and tested a trivialising explanation of it. It is possible that participants cottoned on to the experimental aims. A keen participant may have noticed that they were, for example, more likely to be told to remember evidence that presented pigs in a generous light and forget evidence of the opposite. To rule out demand characteristics, we conducted a direct replication of Experiment 8 with the addition of a standardised funnel debriefing which allowed us to exclude any participant who reported awareness of the directed-forgetting induction.

Methods

Participants and design

Open science. We report all measures and exclusions. Experiment 9's hypotheses, sample targets, exclusion criteria, and statistical models were pre-registered (https://osf.io/3pjwb/).

Sample size justification. We set our sample target on the basis of an a priori pre-registered power analysis, informed by our prior work about the likely effects of inducing memory biases on beliefs about animal's minds: $d = 0.42$. Given these expectations, we aimed to recruit 300 participants so as to afford 95% power to detect the expected effects (two-tailed, $a = .050$).

Sample. We met our pre-registered sample target. Three hundred adults ($n_{\text{male}} = 149$, $n_{\text{female}} = 148$, $n_{\text{agender}} = 1$, $n_{\text{other}} = 2$; $M_{\text{age}} = 36.89$, $SD_{\text{age}} = 12.12$) from the United Kingdom participated via *Prolific* in exchange for £1.25. Participants' diets were recorded via self-report: *I prefer to eat meat* ($n = 49$), *I prefer meat and vegetables* ($n = 157$), *I eat meat, but not very much* ($n = 80$), *I eat fish, but not other meat* ($n = 5$), *I do not eat meat* ($n = 5$), *I do not eat any meat or animal products* ($n = 4$). No data were analysed prior to reaching the target sample size.

Design. Experiment 9 followed a 2-between (induced memory bias: anthropomorphic vs. mind-denying) design.

Procedure and Materials

The paradigm was identical to that of Experiment 8, with the singular change that after completing the memory induction, recognition task, and reporting their beliefs about pigs (as > .76), they were presented with an established funnel debrief probing their understanding of the task (Bargh & Chartrand, 2014). The funnel debrief comprised six questions, beginning with an open-ended prompt about the purpose of the experiment (“What do you think the purpose of the experiment was?”), followed by two forced-choice (yes vs. no) questions about the relationship between the tasks (“Do you think that any of the tasks were related in any way?”, “Did anything you did on one task affect what you did on the other task?”). If participants answered ‘yes’ to either of these they were prompted to elaborate in an open-ended fashion (“In what way were the tasks related?”, “How exactly did it affect you?”). Finally, they were presented with an open-ended prompt about potential patterns in the directed-memory task (“When you were studying the information and being asked to remember and forget it, did you notice any patterns?”).

Results and Discussion

Exclusions

Following our pre-registered approach, we excluded participants who indicated an awareness of the central hypotheses or a pattern between the memory prompts and the different types of evidence they were applied to. Thirty-five participants (12%) were excluded on this basis.

Computational reproducibility

Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *apa* (0.3.3; Gromer, 2020), *psych* (2.2.5; Revelle, 2022), and *ltm* (1.2.0; Rizopoulos, 2006).

Indices of memory

Response bias and discrimination were compiled in the same way as in prior experiments (Snodgrass & Corwin, 1988). Participants were able to discriminate at above-chance levels between evidence they had seen (targets) and evidence they had not (foils), *t*s > 36.53, *p*s < .001, *d*s > 2.24.

Main analyses

Considering only those participants who showed no awareness of the experimental aims or any patterns the directed forgetting instruction, we again found that inducing an anthropomorphic (vs. mind-denying) memory bias led participants to judge pigs as being more capable of cognitive and emotional capacities, *t*(263) = 3.47, *p* < .001, *d* = 0.43, 95% CI [0.18, 0.67]. We found no evidence that inducing memory biases shifted moral concern for pigs, *t*(263) = -1.25, *p* = .213, *d* = -0.15, 95% CI

[-0.39, 0.09]. As in Experiments 7 and 8, measures of response bias, *t*(263) = 5.19, *p* < .001, *d* = 0.64, 95% CI [0.39, 0.88], and discrimination, *t*(263) = 6.47, *p* < .001, *d* = 0.80, 95% CI [0.54, 1.05], both indicated that the memory induction procedure was successful.

Meta-Analysis

To conclude, we present a set of meta-analytic estimates derived from all available data. Effect sizes were estimated from fixed-effects analyses when derived from pairs of experiments and random-effects analyses when derived from larger sets of experiments. Effect sizes for simple between-participant comparisons were estimated from standardised mean differences (Cohen's *d*) and weighted via an inverse-variance method (Schwarzer et al., 2015). Interactions and within-participant comparisons were estimated by fitting Linear Mixed Models. All variables were standardised prior to model fitting, such that coefficients (β) can be interpreted in terms of standardised units, akin to an effect size (Bryk & Raudenbush, 1992; Nezlek, 2012). Statistical analyses were conducted in R (4.2.1; R Core Team, 2022) with the packages *meta* (5.5.0; Balduzzi et al., 2019), *lme4* (1.1.30; Bates et al., 2015), and *lmerTest* (3.1.3; Kuznetsova et al., 2017).

Main estimates

We focused primarily on the effects within meat-eaters and veg*ns, for different animals, and over time. This allowed us to provide the most accurate estimates and to draw the most definitive conclusions with regards to whether recall biases are accompanied by biases in recognition, and therefore whether memory biases about the minds of animals are likely driven by differences in the decisional processes associated with how evidence is reported (response bias) or in the availability of evidence in memory (discrimination).

Memory in meat-eaters. Across Experiments 1-4, meat-eaters showed a clear memory bias after a short delay in the recall of information about animal minds. They recalled more evidence of companion animal minds compared to mindlessness, *d* = 0.31, 95% CI [0.18, 0.45], *Z* = 4.49, *p* < .001. This anthropomorphic bias was not shown for food animals, about which evidence was recalled equally well, *d* = -0.04, 95% CI [-0.11, 0.02], *Z* = -1.35, *p* = .176. This difference in recall about companion and food animals was significant, *d* = 0.38, 95% CI [0.19, 0.57], *Z* = 3.85, *p* < .001. Expressed as raw unweighted proportions, the results indicated that meat-eaters recalled 15% more evidence of minds than of mindlessness for companion animals. On the other hand, for food animals, their recall for different types of evidence differed only by 2%.

Examining recognition illuminated the underlying psychological mechanisms responsible for these errors. After a short delay, meat-eaters tended to indicate they had seen more evidence of minds than mindlessness for compassion animals, *d* = 0.11, 95% CI [0.01, 0.22], *Z* = 2.16, *p* = .030, but not for food animals, *d* = -0.01, 95% CI [-0.10, 0.07], *Z* = -0.28, *p* = .778. As with recall, the response biases regarding companion and food animals were significantly different, *d* = 0.10, 95% CI [0.01, 0.20], *Z* = 2.18, *p* = .030. There was no evidence that participants' ability to discriminate was skewed towards either type of evidence, nor was it moderated by the target animal (companion vs. food), *ds* < 0.03, *Zs* < 1.09, *ps* > .276. These effects suggest that errors in recall are likely to be caused by biases in the decision-making processes associated with how evidence is reported from memory rather than biases in how evidence is made available in memory.

Memory in veg*ns. In Experiments 5 and 6, veg*ns' recall was anthropomorphic across the board, irrespective of the animal in question, *d* = 0.37, 95% CI [0.13, 0.62], *Z* = 2.98, *p* = .003. This meant that veg*ns were substantially more generous in their recall of animals reared for food than were meat-eaters, *d* = 0.51, 95% CI [0.29, 0.72], *Z* = 4.64, *p* < .001. In terms of raw unweighted proportions, veg*ns recalled 19% more evidence of minds compared to mindlessness (irrespective of the animal in question). This contrasts with the results obtained in meat-eaters and is particularly striking when juxtaposed with the fact that their recall only varied by 2% in either direction for animals that were eaten.

Analyses of recognition responses provided additional context to interpret these results. Veg*ns' response bias was similarly anthropomorphic as their recall, *d* = 0.27, 95% CI [0.04, 0.50], Z = 2.26, *p* = .024. Whilst, there was no evidence that their ability to discriminate was biased in either direction, *d* = -0.01, 95% CI [-0.11, 0.09], *Z* = -0.24, *p* = .807. These results suggested that, as they did for meat-eaters, veg*ns errors reflect biases in the decision-making processes associated with the reporting of evidence from memory rather than biases in how available evidence is in memory.

Temporal shifts in memory biases. We analysed all experiments which sampled memory after varying durations, including Experiments 2 and 3 (meat-eaters) and Experiment 6 (veg*ns). We found that meat-eaters' recall drifted towards mind-denial over time, β = -0.15, SE = 0.05, 95% CI [-0.24, -0.06], *p* = .002, more than did veg*ns, β = 0.23, SE = 0.09, 95% CI [0.05, 0.40], *p* = .011. These effects were accompanied by shifts towards mind-denial on response bias, β = -0.23, SE = 0.04, 95% CI [-0.31, -0.15], *p* < .001, which were similar in meat-eaters and veg*ns, β = 0.07, SE = 0.04, 95% CI [-0.01, 0.15], p = .079. There was no evidence to suggest that biases in discrimination varied across time, β = 0.03, SE = 0.05, 95% CI [-0.07, 0.12], *p* = .605, and this was equally true of meat-eaters as it was of veg*ns, β = -0.05, SE = 0.05, 95% CI [-0.14, 0.05], *p* = .360. These results suggest that over time, both meat-eaters and veg*ns may be prone to 'defaulting' to an assumption that animals are mindless.

Additional estimates

For completeness, we also provide meta-analytic estimates of the directed forgetting procedure on subsequent beliefs about animal minds, the relationship between ideological beliefs and memory biases, and some more general effects replicating prior work.

Down-stream effects on perceptions of animal minds. Experiments 7-9 showed that inducing an anthropomorphic (vs. mind-denying) memory in bias led participants to judge animals as being more capable of cognitive and emotional capacities, *d* = 0.48, 95% CI [0.30, 0.63], *Z* = 5.64, *p* < .001. We found no evidence to suggest that inducing anthropomorphic (vs. mind-denying) memory biases led participants to judge animals as more worthy of moral concern, *d* = 0.03, 95% CI [-0.14, 0.19], Z = 0.31, *p* = .758. Experiments 1-6 corroborate these findings by showing that recall and response memory biases sampled after a short delay were predictive of perceptions of animal minds, *r* = .13, 95% CI [.08, .19], *Z* = 4.73, *p* < .001; *r* = .26, 95% CI [.21, .30], *Z* = 11.01, *p* < .001. There was again no evidence that memory biases were related to moral concern for animals, *r*s > .02, *p*s > .473.

Ideological moderators. We examined the relationships between individual differences and memory biases sampled after a short delay across Experiments 1-4. Those high in RWA were less likely to show an anthropomorphic recall bias compared to those low in RWA, *r* = -.07, 95% CI [-.11, -.02], *Z* = -2.85, *p* = .004. Similarly, those high in RWA were less likely to assume that evidence of minds (vs. mindlessness) was present in the text, *r* = -.10, 95% CI [-.13, -.04], *Z* = -4.18, *p* < .001, and were less likely to be able to discriminate new from old evidence of minds (vs. mindlessness), *r* = -.05, 95% CI [-.10, -.00], *Z* = -2.16, *p* = .031. We found no consistent evidence that SDO or speciesism predicted recall, discrimination, or response bias for animal minds, *rs* < .04, *ps* > .132. Nor did we find any evidence that these effects differed across animals or time, βs < 0.05, *ps* > .051. Overall, the findings provide only weak evidence for the role of ideological processes in memory errors.

Replications of previous findings about judgements of mind and moral concern. Replicating earlier results, meat-eaters thought it was more wrong to eat and harm companion animals than food animals, *d* = 0.85, 95% CI [0.43, 0.1.27], *Z* = 3.93, p < .001. Similarly, they held that companion animals had more sophisticated minds than did food animals, *d* = 0.16, 95% CI [0.07, 0.26], Z = 3.39, *p* < .001 (Bastian et al., 2012). Meat-eaters, compared to veg*ns, attributed less mind to animals, *d* = -0.69, 95% CI [-1.05, -0.32], *Z* = -3.69, *p* < .001, and also less moral concern, *d* = -1.15, 95% CI [-1.60, -0.71], *Z* = -5.05, *p* < .001 (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012). We also found the expected relationships between beliefs about animals' minds, moral concern, and individual differences. For example, those high in RWA and SDO saw animals as possessing less sophisticated minds, *r* = -.20, 95% CI [-.24, -.15], *Z* = -8.63, *p* < .001; *r* = -.12, 95% CI [-.17, -.08], *Z* = -5.29, *p* < .001, whilst those who endorsed speciesism were less concerned with animal welfare, *r* = -.47, 95% CI [-.51, -.44], *Z* = -22.15, *p* < .001 (Bilewicz et al., 2011; Caviola et al., 2018; Dhont & Hodson, 2014; Dhont et al 2016; Monteiro et al., 2017; Piazza et al., 2015). Together, these results lend confidence to our interpretation of memory effects because they have occured in the context of experiments that have replicated earlier findings.

General Discussion

Building on previous investigations using memory paradigms to examine error in topics such as self-perception, climate change, just-world beliefs, and rape myth acceptance (Callan et al., 2009; Dawtry et al., 2019; Hennes et al., 2016; Kouchaki & Gino, 2016; Sedikides & Green, 2000), the present studies used memory paradigms to study human judgments about the minds of animals. Memory paradigms assess objective performance, which enables the study of anthropomorphism and mind-denial not only as tendencies but also as fallacies. By approaching anthropomorphism and mind-denial as fallacies, the studies are able to speak to whether we are, in an objective sense, 'smart enough to know how smart animals are' (de Waal, 2016).

Systematic biases in memory for animal minds and their implications

Neither type of memory bias, anthropomorphic or mind-denial, prevailed in a gross or unqualified way. Rather, memory errors arose under theoretically-predictable conditions. Just minutes after a learning phase, meat-eaters' and veg*ns' memory was reliably anthropomorphic towards companion animals. This finding corroborated evidence that people, in general, are widely prone to anthropomorphic biases (Douglas et al., 2016; Heider & Simmel, 1944; Waytz et al., 2010). However, when the animal in question was reared for food, meat-eaters were consistently less generous, whilst veg*ns' anthropomorphic tendencies remained. This confirms previous findings that human judgments about animals' mental capacities depend solipsistically on what purpose the animal serves (Bastian et al., 2012; Bratanova et al., 2011; Loughnan et al., 2010; Rothgerber, 2020; Rothgerber & Rosenfeld, 2021) and that veg*ns are more inclined to appreciate animal minds than are meat-eaters (Rothgerber, 2014b).

By iteratively honing in on the role that animals' cultural status plays in shaping memory, the work suggests that biases are distinctly moral in flavour. Some of the patterns we observed were consistent with an unmotivated reconstruction of what is already believed (Eagly et al., 1999). For example, meat-eaters may have been more prone to anthropomorphize dogs in memory more than pigs simply because evidence of their intelligence is more congruent with their prior beliefs about dogs than it is about pigs (Possidónio et al., 2019). However, the same biases remained even when prior knowledge about the animal was held constant or entirely absent. In these cases, participants were only aware of the animal's cultural status as an entity worthy of compassion or used for food. This suggests that memory errors do not just reflect an unmotivated process of reconstructing what is already known about animals, but a morally-motivated one that is driven by the tension associated with animals' status as a food object (Bastian & Loughnan, 2017; Loughnan & Davies, 2020).

After a week, memory biases, irrespective of participants' diet or the type of animal in question, shifted away from anthropomorphism. Meat-eaters displayed a mind-denying bias after a week in how they approached the recognition task--indexed by the measure of response bias. This result provides the first evidence that as memories age and fade, they may drift toward representing animals as having less sophisticated minds. This could reflect a difficulty to maintain an anthropomorphic orientation in the face of our wider cultural commitments–as evidenced by how we collectively exploit animals for food, medical research, and entertainment; and in how we portray them as being less worthy of moral concern (Leach et al., 2021; Sealey & Oakley, 2013). Future research could test this explanation by examining if memories of humans fade in the way as they do for animals.

Memory biases were clearest in how participants spontaneously recalled evidence in their own words. Errors of this sort can be driven by multiple mechanisms. Impaired recall can reflect differences in how information is encoded, for example, because certain evidence might garner more attention than others during the initial encounter. It could also reflect differences in the fidelity with which memories are stored, or the ease with which information can be retrieved. Certain evidence may be more readily recalled than others because it is more accessible during retrieval attempts, or because it is less vulnerable to processes causing forgetting. Alternatively, impaired recall can reflect differences in the decisions made about whether to report certain evidence compared to others (Tulving & Pearlstone, 1966). By manipulating the conditions under which information was encountered, we were able to demonstrate that the encoding of evidence cannot account for the errors participants made about animal minds. Furthermore, the inclusion of measures of recognition memory allowed us to better understand if errors were due to differences in the availability or reporting of evidence. Recall biases were mirrored in recognition response biases but not discrimination differences. This pattern suggests that biased memory for evidence of animal minds is not due to certain memories being more available than others, but that certain memories are considered differently than others when it comes to how they are reported. This is consistent with viewing the phenomena as a morally-motivated one, because response bias is typically more influenced by the motivation to believe evidence than is discrimination (Heit, 1993; Rhodes & Jacoby, 2007). It also suggests that perceptions of animals' minds may be, at least in part, the product of biased reproductions transmitted from person to person (Bartlett, 1932; Kashima, 2008, 2016; Mesoudi, Whiten, & Laland, 2006).

As well as providing a reality-test for participants' judgments, memory was shown to play a causal role in perceptions of animal minds. Inducing mind-denying (vs. anthropomorphic) memory biases caused participants to see animals as possessing less sophisticated minds. This is important because it suggests that the systematic departures from reality, induced by memory biases, translate into summary beliefs about animals' mental capacities. This has implications for the present work and also helps explain, in a more general way, how morally-significant beliefs are perpetuated by memory distortions (Callan et al., 2009; Dawtry et al., 2019; Hennes et al., 2016; O'Sullivan & Durso, 1984).

Concluding remarks

It is important to consider whether our findings can be applied to other situations and populations. We believe that our results can be generalised to most situations where people encounter information about animal minds because we used a diverse set of evidence from genuine studies on animal cognition that feature in popular media (e.g., de Waal, 2016; Shettleworth, 2001). We also expect our findings to generalise well to populations that are similar to the United Kingdom, such as the United States and Australia (Henrich et al., 2010). This is because of our representative sampling approach (see Experiment 4) and the commonalities in these populations with regards to their cultural orientation to animals and meat consumption (Rosenfeld, 2018; Ruby, 2012). One potential exception may be cultures with substantially different views on animals and meat consumption, such as India where some animals are considered sacred and meat avoidance for religious reasons is more common (Ruby et al., 2013).

We approached questions of accuracy and bias about animal minds by examining the correspondence between what participants reported and what they actually encountered (Winograd 1994; Payne & Blackwell 1998). This allowed us to side-step the inherent limitations imposed by the scientific study of animal consciousness (Dawkins, 2015; de Waal, 2016) and provide some of the first empirical data that can speak to whether people over- or underestimate animal minds. This approach warrants strong claims about how people get it wrong in relation to the evidence available to them, but may not warrant equally strong ones about whether they get it wrong in relation to some ultimate real-world truth about animal minds. It is possible that, for example, the anthropomorphic biases we see towards companion animals could, in principle, lead to beliefs that align with some real-world truth about the sophistication of their minds (see Funder, 1987). This does not detract from the validity and informativeness of the present work. Identifying the nature and consequences of errors in how information is processed and reproduced is arguably one of the central goals of psychological science (Funder, 1987; Kruglanski, 1989).

As well as confirming and extending previous results, the present findings offer some important qualifications. We found the expected relationships between speciesism, SDO, and RWA and attitudes to animals (Caviola et al., 2018; Dhont et al., 2014, 2016; Dhont & Hodson, 2014; Krings et al., 2021). Despite this, memory errors were not much affected by individual differences. Further, the observed moral memory biases in meat-eaters and veg*ns likely serve different purposes. Meat eaters' seemed to 'switch off' their default anthropomorphic biases when confronted with food animals. This likely serves to defend and excuse animal exploitation, much in the same way as common psychological justifications for meat eating do (Piazza et al., 2015). Veg*ns, on the other hand, let their anthropomorphic biases reign when considering food animals. This could reflect a sense of duty to represent exploited animals as worthy of moral consideration, which is consistent with their greater objection to their exploitation (Rothgerber, 2014b; Rosenfeld, 2014; Ruby, 2012).

Mind-denial, or its reverse, may yet be found in studies of communication of evidence (Ekstrom & Lai, 2020; Kashima, 2000; Lyons & Kashima, 2003; Mesoudi, Whiten, & Dunbar, 2006). It would be interesting, for example, to examine if veg*ns are motivated to share evidence that animals are intelligent, and to avoid sharing evidence to the contrary. Social communication motives have been shown to influence memory performance (Echterhoff et al., 2008). For veg*ns, their specific motivation might be to condemn the practice of killing and eating animals. Systematic biases have been identified in the choices people make about whether to expose themselves to information about animals' minds (Leach et al., 2022) and in how they update their beliefs about their minds (Leach et al., 2023). They may also extend to how they reason about them (Gampa et al., 2019; Janis & Frick, 1943; Morgan & Morton, 1944). These tasks promise to further advance our understanding of judgments about animals, and in turn some of the most important existential and ethical questions confronting our species.

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