1 **Opinion**
2 **Theory of Animal Mind: Human Nature or**
3 **Experimental Artefact?**

4

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10

11 **Abstract**

12 Are animals capable of empathy, problem-solving or even self-recognition?
13 Much research is dedicated to these questions and yet few have considered
14 how people form beliefs about animal minds. Evidence suggests our
15 mentalising of animals may be a natural consequence of Theory of Mind
16 capabilities. However, where beliefs regarding animal mind have been
17 investigated, this review reveals slow progress in establishing the mechanism
18 underpinning how this is achieved. Here, we consider what conclusions can
19 be drawn regarding how people theorise about animal minds and the different
20 conceptual and particularly methodological issues that might limit the
21 accuracy of conclusions currently drawn from this work. We suggest a new
22 empirical framework for better capturing people's theory of animal mind, which
23 in turn has significant political and social impacts.

24

25 *“The difference in mind between man and the higher animals,*
26 *great as it is, is certainly one of degree and not of kind.” [1]*

27

28 **Thoughts on Animal Thinking**

29

30 Scientific debate regarding the existence and nature of mental states in
31 animals has a longstanding history [2,3] and covers an extensive range of
32 topics from mirror recognition to numerosity (Box 1). Yet the majority of
33 people form beliefs about animal minds based on everyday occurrences, such
34 as when caring for pets [4] or consuming animal products. Understanding how
35 people construct this “Theory of Animal Mind” (TAM) is therefore likely to
36 reveal important insights, based on their experience and influence in relation
37 to animals. Additionally, as a form of internal construal of other minds,
38 examination of the psychological mechanisms generating TAM will likely have
39 broad implications on account of behavior interpretation not being limited to
40 human-animal relationships [5]. However, little research has been dedicated
41 to exploring the basis on which mental abilities are attributed to nonhuman
42 animals, despite few doubting the existence of animal mind [6,7].
43 Furthermore, when directly questioned, people often substantiate their beliefs
44 with explanations from personal experience or media sources [7]. As a result,
45 it is highly unlikely that the psychological mechanisms that contribute to TAM
46 are analogous to the reasoning used by scientific experts to support
47 judgements on animal cognition [8]. This mismatch gives rise to several
48 ethical, scientific and societal issues. Ethical issues arise because views on

49 the sentience of different species are correlated with attitudes towards their
50 use and treatment by humans [9,10]. Therefore, not only is TAM a potential
51 driver of positive human-animal interactions [11], but also welfare-related
52 decisions for millions of animals that are currently based upon psychological
53 mechanisms we know little about. Scientific issues emanate from empirical
54 approaches to animal cognition, which likely contaminate research design and
55 produce a biased or inaccurate snapshot of the overall picture of TAM. Social
56 issues are associated with decision-making in related policy areas such as
57 animal welfare, food security and climate change that are, understandably,
58 driven by current scientific opinion. The behavior change envisaged by policy
59 makers is unlikely to be realised if supporting evidence does not accurately
60 capture peoples actual thought processes [12,13].

61 As such, this article is important and timely, and designed to expose
62 some of the core issues regarding the evidence available in relation to TAM
63 as well as the research methods commonly used to investigate the
64 phenomenon. Therefore, we start by identifying, and later proposing, a
65 candidate mechanism underlying the development of TAM that generates
66 judgements on the mindedness of non-human animals. Because TAM
67 involves animal ‘agents’, several theories of relevance from social psychology
68 are also discussed. Following on from this, we discuss ways in which
69 research methods might be affecting the results gained from previous TAM
70 research, and thus pose **validity** (see glossary) and **reliability** issues. We
71 propose a model that allows both conceptualisation and empirical
72 investigation of the initial stages of TAM using a measurement scale model
73 (specifically **Churchill’s Scale Development Paradigm** [14]), which in turn,

allows mechanisms contributing to TAM to be determined. We conclude by discussing the importance of reframing TAM in terms of wider relevance to ethical and policy issues than just animal welfare.

TAM as a Mechanism of Belief Formation

Often, people's views on animal mind have been speculated to reflect a simple accumulation of various disparate attitudes and beliefs that are often informed by general society. In essence, we suggest that TAM is more nuanced. It is based on a belief-generating cognitive mechanism that begins by drawing on multiple sources of experience and knowledge that are integrated in order to formulate a judgement (e.g., to what extent is this animal intelligent?) or belief (e.g., I'm of the view that most animals are intelligent); the belief/judgement is thresholded, requiring the establishment of criteria on which to assign mindedness to some species over others. The mechanism underpinning TAM consists of multiple components (Figure 1), similar to general models of belief formation [15]. For example, relevant information is **encoded** for later use in generating beliefs about TAM. Encoded information may be descriptive, e.g. chimpanzees can use tools to harvest food, or inferential, e.g. my dog wags his tail when we play ball, playing ball makes my dog happy, ergo my dog experiences emotions. These different types of information become integrated to produce stored schemas or **constructs** regarding TAM. People may actively retrieve, or through associative memory processes are prompted to draw, information from this store as a way of establishing the certitude of their beliefs regarding TAM [16]. In other words,

cumulative perceived knowledge/experience from multiple sources allows an individual to make an estimate that a specified animal possesses a particular mental attribute that is indicative of TAM. If the estimate reaches a threshold limit as determined by that individual, the concept of mind is bestowed upon the animal. This process of belief formation is similar to many models attributed to other domains [16,17]. Below we consider evidence that supports speculation on several psychological theories in this mechanism and later, we outline a framework that helps clarify conceptual and empirical issues when investigating some of the key components of TAM.

TAM: Evidence of Influencing Psychological Theories

Because views on the existence of animal mind are influenced by the idea of animals as social agents [7], we consider four theories, with origins in social psychology, and their supporting evidence: **Simulation Theory**, **Cognitive Dissonance** Theory, **Terror Management** Theory and **Social Dominance** Theory.

Simulation Theory (ST)

In interacting with social 'others', we attempt to make sense of behavior and predict future actions. Therefore, TAM, as the capacity to attribute mental states to non-humans, is likely to be influenced by Theory of Mind capabilities. This is supported by evidence suggesting that, similar to human-human attributions [18], we confer greater mind to animals as we age [19][11]; most

likely because we generate more experiences on which to form the beliefs/judgements, and to specify the details of the criteria on which they are evaluated. The influence of ToM (specifically as Simulation Theory) is also supported by people's use of context and behavioral similarity between animals and humans as a central factor in the psychological interpretations of an animal's actions [20]. Notably, people consider species an important determinant of animal mind: 72% of survey participants believe chimpanzees have human-like capacities to feel pain, while only 30% believe worms can feel pain to a moderate degree [21]. Previously, this has been interpreted as a cognitive ability being derived from **phylogenetic** similarity [20], with evolutionarily more recent animals being seen as in possession of greater mental abilities [9,22,23]. We suggest this finding is more likely due to the influence of mental simulation within a TAM mechanism based on the following evidence: 1) where differences in perceptions of species were found, results varied in degree rather than kind [20], suggesting we are extrapolating or 'simulating' from a human model, and 2) mirror neuron activation occurs when people observe both human and non-human animals performing similar actions [24].

The idea that people view specific behaviors and then attribute mind based on this is a common description of how we achieve TAM, and is also supported by findings that when viewing animal behavior videos, participants broke down scenarios into specific behavioral 'event units' [5]. Despite not using every event unit to describe the behaviors seen, there was near perfect agreement on the event unit nature/meaning and the total number present per video. This evidence suggests that judgements were made based on

recognition of agent's discrete actions rather than on their similarity to humans.

A note on Simulation Theory as anthropomorphism

Skilled mind reading of a human target (in relation to ST) requires an accurate replication of their mental states, but a simulator's own mental states may contaminate this process [25]. Because our interactions with animals naturally preclude verbal confirmation of inaccurate mental states, it is unlikely that over time, with more feedback from our interactions, we will develop improvements in our mindreading. This, combined with the necessity of simulating within a human mind, means attribution of **anthropomorphic** mental abilities to animals is unavoidable (e.g. deception, self-recognition). However, labelling these errors as anthropomorphic is unhelpful when investigating TAM. In describing animal minds, people assign psychological terms to specific shared behaviors, regardless of species [20] suggesting 'interpretative' anthropomorphism rather than 'imaginative' [26]. Along with accumulated knowledge and experience, this work shows that we look to simulate the mind of animals, by assuming that similar actions to our own reflect similar cognitions.

Cognitive Dissonance Theory (CD)

Empirical evidence suggests predominant societal attitudes to meat eating underpin production animals being ascribed lower mental capacities;

an attempt to reduce the cognitive dissonance arising from this ethically contentious yet widely adopted societal custom [27,28]. As such, these mechanisms of dissonance reduction are likely to impact upon TAM and manifest as opposing correlations between TAM and support for i) animal use (negative) [19] and ii) animal welfare (positive) [10]. Because criteria upon which this dissonance reduction is achieved may vary, we consider CD in relation to TAM as two forms, terror management (TM) and social dominance (SD).

In individuals with a preference for social hierarchies, dehumanisation by ridding animals of mind and therefore moral worth [29], allows their conception as an out-group and subsequent exploitation [6]. For example, those who support animal experimentation endorse a greater mental divide between humans and other species [9,30]. Conversely, experimental framing of human-animal similarity has been shown to increase moral concern for animals and human outgroups simultaneously [31]. This concept of out-group dementalization can also be seen in our reduced attributions of mind to pest species in comparison to other animals [32].

In contrast to our social dominance orientation, which acts to reduce animals perceived cognitive abilities, mechanisms of terror management aids dissonance reduction by elevating humans in comparison to other animals. In order to avoid the cognitive and emotional experiences inherent in awareness of human or animal death (mortality salience), particularly as a result of human activity (e.g., farming), we advocate the anthropocentric view that humans rights be prioritised on the basis of sophisticated cognitive abilities [6,31,33]. This elevation of own cognitive capacities can be seen in our

consistent segregation of humans at the top of mental ability scales [22,30]
(for a notable exception see [34]).

However, despite employing different criteria to create distinctions
between human and animal mentality, SD and TM show similarities in that
they likely depend upon the same belief formation processes. In contrast,
simulation theory, and anthropomorphism, are designed to develop criteria for
detecting similarities between humans and animals.

Theory of Animal Mind: Innate or Acquired?

Having set out what we propose as a candidate mechanism that
underpins TAM, as well as current theoretical proposals regarding TAM, we
now consider a key question that all theories need to address, namely that
TAM is innate or acquired. In other words, should a special status be
attributed to the formation of TAM? From the theories reviewed, the basic
mechanism of TAM is much like other processes/theories of belief formation.
However, the bank of perceived knowledge the mechanism employs is
subject to several influences that would likely predict individual differences in
the types of beliefs formed. For example, factors such as education [9],
exposure to media [7] and political orientation [35] are likely to cause variation
in TAM. Therefore, despite evidence of similarities across cultures when
ascribing mental states [36], individual and cultural context are likely to affect
the mechanism, as seen in Japanese students who ascribe greater
intelligence to crows compared to other nationalities [10]. However, while
observed variations may be considered the result of social traditions and

practices, the contribution of specific societal influences on TAM is unsubstantiated as previous research has predominantly sampled WEIRD (Western, educated, industrialised, rich and democratic) populations [37].

Are there limitations to conclusions drawn from empirical research on TAM?

To summarise, the effects of individual and social factors on the mechanism of TAM is clearly interactive, fluid and warrant investigation. Yet despite several variables such as age, species of animal and cultural background being of consequence, based on the evidence we have at present, the direction and magnitude of effects is often disputed e.g. meat consumption based on gender. Additionally, even for those factors considered influential, the variance in TAM they account for is typically small [11,19]. These issues suggest that research methods may be a potential barrier to not only understanding the underlying mechanics of TAM but also in clearly identifying predictive factors. As discussed above, human tendency to anthropomorphise has received much academic attention, predominantly as a methodological and individual weakness [38]. TAM research often proposes avoidance of the former by claiming to purely substantiate beliefs, rather than test accuracy of knowledge. While valid, this perspective is problematic, primarily because variation in experience and encoded knowledge is likely a determinant of beliefs formed [29,39], (as evidenced by the demonstrated effect of psychology-focused education on TAM [40]).

248 In conjunction with this issue, heavy reliance on scale-based methods
249 may exaggerate the influence of cognitive dissonance on judgements. TAM
250 research typically presents animals as phylogenetic bands on the basis of
251 mapping onto confirmed, yet incorrect, evolutionarily linear beliefs held by
252 non-scientists [30,32,41]. This runs the risk of reducing TAM to a simple
253 ranking exercise against 'advanced' humans.

254 These methodological problems combine to perpetuate the idea that
255 TAM is easily explained, prompting a 'dumbing-down' of the parameters
256 investigated. Much research has focused on a single attribute or dimension of
257 TAM [42,43], perhaps because evidence suggests that there are
258 commonalities in assigning TAM across the board [44]. This approach
259 promotes a narrow and unsophisticated demonstration of TAM and distorts
260 the manner in which variation in knowledge/information is used to consider
261 the multiple attributes/dimensions on which to assign TAM. If the devil is in the
262 detail, understanding specific and unexpected results (e.g. 25% of Finnish
263 people surveyed believe shrimp can remember **conspecifics**) is surely
264 imperative [45]. Furthermore, restricting the TAM constructs considered
265 worthy of investigation not only limits opportunities for understanding but also
266 assumes an even weighting in the importance of mental attributes.

267 The consequences of this inflexibility and lack of precision when
268 employing rating scales is highlighted by use of the 'belief in animal mind'
269 scale [41]. When originally devised, the four-part scale showed high internal
270 consistency. No subsequent study has managed to reproduce this level of
271 reliability. This issue could be attributed to views on animal mind having
272 undergone temporal changes, a credible theory since i) the amount of

research on animal cognition has increased over time [11] and ii) exposure to animals via influential media e.g. TV [46] has increased. However, minor changes to the scale may well be affecting the reliability of findings on the basis that TAM is more nuanced than previously claimed (for instance, inclusion of the term “human-like” in surveys appears to reduce participants willingness to ascribe emotions to animals [40]). Additionally, in its original use, specific categories of animals were provided (mammals excluding humans, birds, fish and insects) on a 5-point scale. Much subsequent work condensed the four groups into “most animals” (a term typically construed as a mammal [47]) alongside a variety of scale measurements [19,32,47,48] and subtle changes in wording. This highlights the crucial issues of scale construction and vague or dual meanings for cognitive terms.

Much research on TAM has hinged on the generalised concept of intelligence. While this widely used term allows rapid entry into our frameworks of mind [49], there is often little confirmation of what constitutes intelligence to sample populations despite evidence that it comprises varying constructs to different individuals [50]. Intelligence also involves associations alien to the natural world (e.g. IQ tests). With no specifics to work from, people may simply execute cognitively accessible judgements of ‘advanced’ mammals, generating repeated correlations between intelligence and phylogeny [43].

We suggest this inconsistency in methods accumulates to produce the varied reported findings detailed previously. Hence, while regression and correlation analysis has provided evidence for relationships between TAM and several other factors, findings have rarely been repeatedly substantiated.

298 These discrepancies are understandable on the basis that TAM comprises
299 different constructs within a study, as well as variation for the different species
300 on which TAM is being investigated [48].

301 Taken together, these concerns reassert the need to have precise
302 scale items for establishing factors that truly influence TAM formation as well
303 guarding against experimenter bias when designing such scales. As noted,
304 'respondents are constrained by the categories provided' [44], which are often
305 transferred directly from animal cognition literature to social science studies
306 [51]. This is acceptable if testing transmission of scientific knowledge is our
307 aim, but precludes accurate understanding of how we construct TAM. Despite
308 suggestions that our attributions of emotion to animals aligns with scientific
309 views of a basic/higher emotional divide, only a minority of participants believe
310 that animals experience disgust [32]. This demonstrates the importance of
311 ascertaining specific meanings of participant-generated constructs before
312 overlaying scientific theory.

314 **Targeting Issues and Improving Tools of Assessment**

316 In order to align scale use with meaningful comparisons between
317 findings investigating TAM, we propose a more focused research programme
318 examining the construct formation in TAM. To achieve this, we propose a
319 **Reflective Measurement Model** [52] (Figure 2). This model would allow
320 movement away from considering TAM as a single dimension (supported by
321 the results of [21,35]), allowing greater analysis of the role of specific mental
322 capacities within an overarching belief in animal mentality.

We suggest the use of Churchill's measurement model [14] in order to generate a valid and reliable model. While full discussion of the model is beyond the scope of this article, in figure 3 we detail the way in which this 8-step approach to measurement will aid the development of reliable tools for generating theoretical predictions as well as empirically testing a critical but often neglected component of the TAM mechanism, namely construct formation; the way in which knowledge and experience is integrated in order to formulate constructs that are used to make decisions/judgements, and form beliefs.

The benefits of this model are that, it would more likely reveal the types of dependencies that have been speculated over, such as the association between TAM and empathy. Furthermore, a reliable scale would support empirical work that continues to employ innovative methods to assess animal behavior through videos [5,20]. People's beliefs, judgements and decisions of animals is context sensitive [23], and so using techniques like this can allow comparison of how animal mentality may be viewed in both imagined and real terms. Having a measurement framework that comes with the theoretical apparatus to generate testable predictions around construct formation that underpins beliefs, judgements and decision-making behavior, will elucidate a richer understanding of how we come to our TAM.

Concluding Remarks and Future Perspectives

People's views of the mental abilities of animals, and the resulting moral duty for their welfare, have considerable economic, social and political

consequences. Despite this, TAM has received relatively little scientific attention and the ambiguity in the findings generated from work in this area may be attributable to methods and tools. More to the point, we propose that construct formation, a core component of the mechanism of TAM, has been particularly underexplored. Future progress on the subject will likely be mediated by the convergence of scientific approaches to determine a wider range of cognitive constructs (see 'Outstanding Questions'), a process that application and examination of the proposed model should aid. Certainly, the use of validated scale measurements in combination with other methods would shift focus away from confirming unwarranted assumptions around TAM. In addition, a richer conceptual framework for generating hypotheses would improve ways of uncovering people's assumptions of animal's mental capacity. Moreover, focusing TAM research away from seeking correlation with diverse attitude measures in an attempt to predict human treatment of animals, would allow exploration of other potentially substantial influences such as an individual's history of interaction with specific species. This redirection is important because TAM is supported by work from many areas of psychology (e.g. attribution theory, cultural norms, Theory of Mind). In reducing TAM to a single predictable component within a decision-making system focused only on humane animal use, we ignore its diverse implications by omission.

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References

- 1 Darwin, C.R. (1871) *The Descent Of Man, And Selection In Relation To Sex*, John Murray.
- 2 Gould, J.L. (2004) Animal cognition. *Curr. Biol.* 14, R372-375
- 3 Church, R.M. (2001) Animal cognition: 1900 – 2000. *Behav. Process.* 54, 53–63
- 4 Howell, T.J. *et al.* (2013) The Perceptions of Dog Intelligence and Cognitive Skills (PoDlaCS) Survey. *J. Vet. Behav.* 8, 418–424
- 5 Morris, P. *et al.* (2000) Beyond Anecdotes: An Empirical Study of “Anthropomorphism.” *Soc. Anim.* 8, 151–165
- 6 Knight, S. *et al.* (2003) Using Grounded Theory to Examine People’s Attitudes Toward How Animals are Used. *Soc. Anim.* 11, 307–327
- 7 Maust-Mohl, M. *et al.* (2012) Wild Minds: What People Think about Animal Thinking. *Anthrozoos* 25, 133–147
- 8 Reggia, J.A. *et al.* (2015) Beliefs Concerning the Nature of Consciousness. *J. Conscious. Stud.* 22, 146–171
- 9 Davis, S.L. and Cheeke, P.R. (1998) Do Domestic Animals Have Minds and the Ability to Think? A Provisional Sample of Opinions on the Question. *J. Anim. Sci.* 76, 2072–2079
- 10 Phillips, C.J.C. and McCulloch, S. (2005) Student attitudes on animal

396 sentience and use of animals in society. *J. Biol. Educ.* 40, 17–24

397 11 Hawkins, R.D. and Williams, J.M. (2016) Children’s Beliefs about
398 Animal Minds (Child-BAM): Associations with Positive and Negative
399 Child–Animal Interactions. *Anthrozoos* 29, 503–519

400 12 Sok, J. *et al.* (2015) Farmers’ beliefs and voluntary vaccination
401 schemes: Bluetongue in Dutch dairy cattle. *Food Policy* 57, 40–49

402 13 Wald, D.M. *et al.* (2013) Outdoor cats: Identifying differences between
403 stakeholder beliefs, perceived impacts, risk and management. *Biol.*
404 *Conserv.* 167, 414–424

405 14 Churchill Jr., G.A. (1979) A Paradigm for Developing Better Measures
406 of Marketing Constructs. *J. Mark. Res.* 16, 64–73

407 15 Wyer Jr, R.S. (2005) Belief Formation, Organization, and Change:
408 Cognitive and Motivational Influences. In *The Handbook of Attitudes*
409 (Albarracin, D. *et al.*, eds), pp. 273–322, Psychology Press

410 16 Connors, M.H. and Halligan, P.W. (2015) A cognitive account of belief:
411 A tentative road map. *Front. Psychol.* 5, 1–14

412 17 Boden, M.T. *et al.* (2016) Why do people believe what they do? A
413 functionalist perspective. *Rev. Gen. Psychol.* 20, 399–411

414 18 Happe, F.G.E. *et al.* (1998) The getting of wisdom: Theory of mind in
415 old age. *Dev. Psychol.* 34, 358–362

416 19 Knight, S. *et al.* (2004) Attitudes towards animal use and belief in animal
417 mind. *Anthrozoos* 17, 43–62

418 20 Mitchell, R.W. and Hamm, M. (1997) The interpretation of Animal
419 Psychology: Anthropomorphism or Behavior Reading? *Behaviour* 134,
420 173–204

- 421 21 Herzog, H.A. and Galvin, S. (1997) Common Sense and the Mental
 422 Lives of Animals: An Empirical Approach. In *Anthropomorphism,*
 423 *Anecdotes and Animals* (Mitchell, R. W. et al., eds), pp. 237–253, State
 424 University of New York Press
- 425 22 Eddy, T.J. *et al.* (1993) Attribution of Cognitive States to Animals:
 426 Anthropomorphism in Comparative Perspective. *J. Soc. Issues* 49, 87–
 427 101
- 428 23 Knight, S. *et al.* (2009) Science versus Human Welfare? Understanding
 429 Attitudes toward Animal Use. *J. Soc. Issues* 65, 463–483
- 430 24 White, N.C. *et al.* (2014) Responses of the human motor system to
 431 observing actions across species: A transcranial magnetic stimulation
 432 study. *Brain Cogn.* 92, 11–18
- 433 25 Goldman, A.I. (2012) Theory of Mind. In *The Oxford Handbook of*
 434 *Philosophy of Cognitive Science* (Margolis, E. et al., eds), pp. 402–424,
 435 Oxford University Press
- 436 26 Fisher, J.A. (1991) Disambiguating anthropomorphism: An
 437 interdisciplinary review. *Perspect. Ethol.* 9, 49–85
- 438 27 Bastian, B. *et al.* (2012) Don't Mind Meat? The Denial of Mind to
 439 Animals Used for Human Consumption. *Personal. Soc. Psychol. Bull.*
 440 38, 247–256
- 441 28 Ruby, M.B. and Heine, S.J. (2012) Too close to home. Factors
 442 predicting meat avoidance. *Appetite* 59, 47–52
- 443 29 Costello, K. and Hodson, G. (2014) Explaining dehumanization among
 444 children: The interspecies model of prejudice. *Br. J. Soc. Psychol.* 53,
 445 175–197

- 446 30 Rasmussen, J.L. *et al.* (1993) Humans' perceptions of animal mentality:
447 ascriptions of thinking. *J. Comp. Psychol.* 107, 283–90
- 448 31 Bastian, B. *et al.* (2011) When Closing the Human-Animal Divide
449 Expands Moral Concern: The Importance of Framing. *Soc. Psychol.*
450 *Personal. Sci.* 3, 421–429
- 451 32 Wilkins, A.M. *et al.* (2015) Factors affecting the Human Attribution of
452 Emotions toward Animals. *Anthrozoos* 28, 357–369
- 453 33 Mitchell, R.W. and Smith, J.A. (2012) *Experiencing animal minds: an*
454 *anthology of animal-human encounters*, Columbia University Press.
- 455 34 Driscoll, J.W. (1995) Attitudes toward Animals: Species Ratings. *Soc.*
456 *Anim.* 3, 139–150
- 457 35 Gray, H.M. *et al.* (2007) Dimensions of Mind Perception. *Science.* 315,
458 619–619
- 459 36 Haslam, N. *et al.* (2008) Subhuman, Inhuman, and Superhuman:
460 Contrasting Humans with Nonhumans in Three Cultures. *Soc. Cogn.*
461 26, 248–258
- 462 37 Henrich, J. *et al.* (2010) The weirdest people in the world? *Behav. Brain*
463 *Sci.* 33, 61–135
- 464 38 Andrews, K. and Huss, B. (2014) Anthropomorphism, anthropectomy,
465 and the null hypothesis. *Biol. Philos.* 29, 711–729
- 466 39 Hazel, S. *et al.* (2015) “Chickens Are a Lot Smarter than I Originally
467 Thought”: Changes in Student Attitudes to Chickens Following a
468 Chicken Training Class. *animals* 5, 821–837
- 469 40 Helton, W.S. and Helton, N.D. (2005) Changing Animal and
470 Environmental Attitudes with Evidence of Animal Minds. *Appl. Environ.*

471 *Educ. Commun.* 4, 317–323

472 41 Hills, A.M. (1995) Empathy and Belief in the Mental Experience of

473 Animals. *Anthrozoos* 8, 132–142

474 42 Nakajima, S. *et al.* (2002) Estimation of animal intelligence by university

475 students in Japan and the United States. *Anthrozoos* 15, 194–205

476 43 Banks, W.P. and Flora, J. (1977) Semantic and Perceptual Processes

477 in Symbolic Comparisons. *J. Exp. Psychol. Hum. Percept. Perform.* 3,

478 278–290

479 44 Rasmussen, J.L. and Rajecki, D.W. (1995) Differences and Similarities

480 in Humans' Perceptions of the Thinking and Feeling of a Dog and a

481 Boy. *Soc. Anim.* 3, 117–137

482 45 Kupsala, S. *et al.* (2016) Public Perceptions of Mental Capacities of

483 Nonhuman Animals: Finnish Population Survey. *Soc. Anim.* 24, 445–

484 466

485 46 Fraser, J. *et al.* (2006) Dolphins in Popular Literature and Media. *Soc.*

486 *Anim.* 14, 1063–1119

487 47 Apostol, L. *et al.* (2013) Psychological and Socio-demographic

488 Predictors of Attitudes toward Animals. *Procedia - Soc. Behav. Sci.* 78,

489 521–525

490 48 Morris, P. *et al.* (2012) Belief in Animal Mind: Does Familiarity with

491 Animals Influence Beliefs about Animal Emotions? *Soc. Anim.* 20, 211–

492 224

493 49 Sickler, J. *et al.* (2006) Social Narratives Surrounding Dolphins: Q

494 Method Study. *Soc. Anim.* 14, 351–382

495 50 Sternberg, R.J. *et al.* (1981) People's Conceptions of Intelligence. *J.*

496 *Pers. Soc. Psychol.* 41, 37–55

497 51 Fraser, J. *et al.* (2013) *A Proposed Transdisciplinary Framework to*

498 *Align Comparative Psychology and Social Science Research on Animal*

499 *Minds,*

500 52 Hansson, H. and Lagerkvist, C.J. (2014) Defining and measuring

501 farmers' attitudes to farm animal welfare. *Anim. Welf.* 23, 47–56

502 53 McGrath, N. *et al.* (2013) Public attitudes towards grief in animals.

503 *Anim. Welf.* 22, 33–47

504 54 Walker, J.K. *et al.* (2014) Does owning a companion animal influence

505 the belief that animals experience emotions such as grief? *Anim. Welf.*

506 23, 71–79

507 55 Rossiter, J.R. (2002) The C-OAR-SE procedure for scale development

508 in marketing. *Int. J. Res. Mark.* 19, 305–335

509 56 Dolnicar, S. (2013) Asking Good Survey Questions. *J. Travel Res.* 52,

510 551–574

511 57 Demertzi, A. *et al.* (2009) Dualism Persists in the Science of Mind. *Ann.*

512 *N. Y. Acad. Sci.* 1157, 1–9

513 58 Anglin, S.M. (2014) I think, therefore I am? Examining conceptions of

514 the self, soul, and mind. *Conscious. Cogn.* 29, 105–116

515 59 Dawkins, M. (2015) Animal Welfare and the Paradox of Animal

516 Consciousness. *Adv. Study Behav.* 47, 5–38

517 60 Schurger, A. *et al.* (2010) Reproducibility Distinguishes Conscious from

518 Nonconscious Neural Representations. *Science.* 327, 97–99

519 61 Andics, A. *et al.* (2016) Neural mechanisms for lexical processing in

520 dogs. *Science* 353, 1030–1032

- 521 62 Bentley-Condit, V.K. and Smith, E.O. (2010) Animal tool use: current
522 definitions and an updated comprehensive catalog. *Behaviour* 147,
523 185–221
- 524 63 Taylor, A.H. (2014) Corvid cognition. *Wiley Interdiscip. Rev. Cogn. Sci.*
525 5, 361–372
- 526 64 Cantlon, J.F. *et al.* (2016) Monkeys display classic signatures of human
527 symbolic arithmetic. *Anim. Cogn.* 19, 405–415
- 528 65 Inoue, S. and Matsuzawa, T. (2007) Working memory of numerals in
529 chimpanzees. *Curr. Biol.* 17, R1004-1005
- 530 66 Kendrick, K.M. *et al.* (2001) Sheep don't forget a face. *Nature* 414, 165–
531 166
- 532 67 Jackson, R.R. and Cross, F.R. (2011) Spider cognition. *Adv. In Insect*
533 *Phys.* 41, 115–174
- 534 68 Mueller-Paul, J. *et al.* (2012) Radial-arm-maze behavior of the Red-
535 Footed tortoise (*Geochelone carbonaria*). *J. Comp. Psychol.* 126, 305–
536 317
- 537 69 Wada, M. *et al.* (2016) The Rubber Tail Illusion as Evidence of Body
538 Ownership in Mice. *J. Neurosci.* 36, 11133–11137
- 539 70 Bekoff, M. and Sherman, P.W. (2004) Reflections on animal selves.
540 *Trends Ecol. Evol.* 19, 176–180
- 541 71 Toda, K. and Platt, M.L. (2015) Animal cognition: Monkeys pass the
542 mirror test. *Curr. Biol.* 25, R64–R66
- 543 72 de Vere, A.J. and Kuczaj II, S.A. (2016) Where are we in the study of
544 animal emotions? *Wiley Interdiscip. Rev. Cogn. Sci.* 7, 354–362
- 545 73 Campbell, M.W. and de Waal, F.B.M. (2014) Chimpanzees empathize

546 with group mates and humans, but not with baboons or unfamiliar
547 chimpanzees. *Proc. R. Soc. B Biol. Sci.* 281, 20140013

548 74 Edgar, J.L. *et al.* (2012) Measuring empathic responses in animals.
549 *Appl. Anim. Behav. Sci.* 138, 182–193

550 75 Emery, N.J. and Clayton, N.S. (2009) Comparative social cognition.
551 *Annu. Rev. Psychol.* 60, 87–113

552 76 Penn, D.C. *et al.* (2008) Darwin’s mistake: Explaining the discontinuity
553 between human and nonhuman minds. *Behav. Brain Sci.* 31, 109–78

554 77 Heyes, C. (2017) Apes Submentalise. *Trends Cogn. Sci.* 21, 1–2

555 78 Miklosi, A. and Kubinyi, E. (2016) Current Trends in Canine Problem-
556 Solving and Cognition. *Curr. Dir. Psychol. Sci.* 25, 300–306

557 79 Shettleworth, S.J. (2009) The evolution of comparative cognition: Is the
558 snark still a boojum? *Behav. Processes* 80, 210–217

559 80 Tomasello, M. and Rakoczy, H. (2003) What Makes Human Cognition
560 Unique? From Individual to Shared to Collective Intentionality. *Mind*
561 *Lang.* 18, 121–147

Fig. 1 Proposed Mechanism of Belief Formation underpinning Theory of Animal Mind. The proposed mechanism is conceptualised as a series of connected components allowing relevant information to be perceived, encoded, integrated and subsequently utilised when forming judgements on the mindedness of non-human animals. Judgements are computed 'online' and represent confidence estimates of belief validity [15]. Formulated judgements may be integrated into an individual's bank of perceived knowledge to be reused in future estimates. Each component of the mechanism is susceptible to the influence of specified social theories (ST: Simulation Theory, TM: Terror Management Theory, SD: Social Dominance Theory, CD: Cognitive Dissonance Theory). For example, we propose that simulation affects perception and encoding of information relevant to TAM through recognition of cross-species behaviors/actions. Thus, Simulation

Theory, as a rule, acts to increase the likelihood of exceeding the judgement threshold required to attribute mind to animals purely as a result of observing non-human species. This mechanism is seen by the higher levels of TAM reported by owners towards their pets [53,54]. Conversely, CD, TM and SD all influence the judgement process by reducing the likelihood of exceeding this judgement threshold.

599

600 **Fig. 2 Reflective Measurement Model depicting Theory of Animal Mind**
 601 **as a multidimensional construct.** Within this model (indicated as blue),
 602 mechanism of TAM is conceptualised as a second order, latent construct that
 603 underlies multiple first order constructs (dimensions). Dimensions would be
 604 expected to consist of mental traits considered attributes of mind e.g. agency
 605 as seen in [35] (Note: this prediction, based on previous findings, would need
 606 confirming as part of the process). Several specific indicators are used to
 607 capture the constructs. The model acts to provide a way to both conceptualise
 608 and investigate (indicated as purple) the initial stages of TAM development
 609 i.e. construct formation.

Fig. 3 Use of Churchill's model to improve scale development (indicated

as blue). Definitions of TAM are numerous [19] and often overlap, resulting in

conceptual confusion. Step 1 is designed to address this by providing a

delineated definition, thereby improving scale validity and transferability. Use

of Rossiter's 5 definition rules may aid the definition process [55]. Employing a

multi-item scale would ensure capturing each dimension in its entirety i.e. for

all animals rather than overly broad groups e.g. mammals. Because TAM is a

perceptual attribute/implicit theory [50], it is unlikely that literature reviews and

researcher introspection will generate sufficient scale items [56]. Use of

developmental qualitative research proposed by Churchill would allow rater

consultation in Step 2 (namely the public), improving validity. This is

particularly important because a significant proportion of TAM research has

been based on student populations. Subsequent completion of steps 1-6 of

the paradigm avoids subjective 'cherry picking' of cognitive terms [51] and

assumes the generation of a measure that is content or face valid [14].

Construct validity could then be assessed by a) correlating similar measures

or b) confirmation of the scale behaving as predicted (e.g. can it predict an

associated measure?). Correlation with connected constructs such as

anthropomorphism should be assessed to ensure discriminant validity. The

final step of developing norms would ensure BAM research extends beyond

the Western demographics typically sampled, an important exercise since the

role of culture has not been thoroughly explored and is likely to influence the

development of TAM [10]. A scenario to illustrate the steps is detailed

(indicated as red). For methods of statistical analysis to support each stage,

refer to [14].

636

637 **Box 1. Scientific Theory of Animal Mind**

638

639 Peoples beliefs regarding the nature of mind are typically dualistic, with
640 mind and body being viewed as separate entities [57]. In contrast, scientists
641 working in areas relevant to animal cognition predominantly support theories
642 of materialism, in that all mental phenomena derive from the physical brain
643 [8]. Additionally, while most individuals consider mind as 'thoughts' or
644 'consciousness' [58], among academics, there is no universally agreed
645 definition of mind, animal-based or otherwise. In combination with the
646 currently limited understanding of neural correlates of cognitive traits, this
647 means empirical validation of mental states in animals is problematic [59],
648 although increasing use of modern techniques such as fMRI promises the
649 visualisation of neural states/activity such as consciousness [60,61].
650 Consequently, scientific views on animal mentality center on examination of
651 specific mental processes that are i) empirically measurable and ii)
652 considered meaningful components of human mind, thereby suggesting
653 comparable mental experiences when evidenced in nonhuman species. To
654 this end, a range of cognitive capacities have been investigated including tool
655 use (acknowledged in a range of species [62,63]), numeracy [64] and varying
656 forms of memory, with evidence of chimpanzees outperforming humans in
657 short term memory tasks [65] and facial recognition in sheep [66]. Indeed,
658 mounting evidence hints at unexpected abilities in long derided species such
659 as spiders, tortoises [67,68] and mice, which recent findings suggest might
660 experience ownership of their body parts (an aspect of self-consciousness)
661 [69]. Previously, notions of self-awareness among nonhumans have met with

resistance, particularly because only a few animals (e.g. chimpanzees, dolphins, elephants) pass the 'mirror test', a gold standard for self-recognition [70,71]. Similarly, when considering the emotional lives of animals, it is noted that while the 'nature and range' of emotional experiences is debated, the literature widely assumes their occurrence in animals [72]. And yet empathy, although acknowledged in terms of emotional contagion or sensitivity to conspecifics [73], is often disputed when defined at the level of perspective taking [74] or related to Theory of Mind [75]. As such, many capacities considered integral to human cognition are still contested in the literature e.g. language, mental time-travel, relational reasoning or mentalising [72,76,77]. These views may also be bolstered by the historical accumulation of experimental evidence (as a proxy for widely held scientific belief) favouring particular animals e.g. primates or dogs [78], despite modern scientists employing a range of models [79]. Hence, current scientific opinion remains that animal mentality lies on a varied spectrum with only humans possessing the combination of complex abilities and thoughts required to generate our unique minds [80].

Glossary:

Anthropocentrism: the belief that humans are the most important species in existence and source of all value, resulting in the interpretation of reality according to human values, needs and experience.

Anthropomorphism: the attribution of 'uniquely' human characteristics to

non-human entities. Originally viewed as a hindrance to scientific methods, increasing understanding of animal cognition has generated issues in delineating anthropomorphism as the unjustified attribution of mental states vs. interspecies behavior recognition.

Churchill's Scale Development Paradigm: an 8-step framework for the systematic development of multi-item measurement scales when measuring latent constructs.

Cognitive Dissonance: a state of tension arising from inconsistent thoughts, beliefs, attitudes and actions.

Conspecifics: individuals that belong to the same species.

Construct: an abstract, psychological concept or variable that cannot be directly observed (latent) and exists independently of any resulting measurable phenomenon e.g. intelligence. Since constructs such as TAM represent psychological attributes that vary between individuals, operationalization of constructs should allow for participant involvement (participant-generated).

Encoding: the processing and conversion of perceived information into a form suitable for storage in memory.

Phylogenetics: the study and taxonomical classification of organisms based

on evolutionary relatedness. Proposed relationships between groups of organisms, inferred from similarities in genetic or physical attributes, are presented as a **phylogeny** or phylogenetic tree. For simplicity when investigating beliefs, animals are often presented as '**phylogenetic bands**' or classes e.g. mammals, birds, etc.

Reflective Measurement Model: a type of structural equation model that depicts the relationship between a latent, unobserved construct (e.g. personality) and its corresponding indicators within a measure.

Reliability: the degree to which an instrument measures a specified construct both across time (repeatability) and across scale items (consistency) e.g. test-retest reliability.

Simulation Theory: psychological theory of mind in which individuals use their own mind to model a targets mental state, to make inferences about a target.

Social Dominance: an individual's preferences for inequality and hierarchy among social groups, typically measured using the Social Dominance Orientation Scale.

Terror Management: psychological theory that individuals are motivated to manage the anxiety caused by awareness of death through investment in belief systems or culture that provide value and meaning.

737

738 **Validity:** the degree to which differences in observed scores on an instrument
739 reflects true differences in the variable of interest. Validity may be confirmed
740 by assessing the ability of an instrument to i) effectively and specifically
741 measure the theorized latent construct (construct validity), ii) capture all facets
742 of the construct's theoretical domain (content validity) and iii) differentiate
743 between individuals in order to allow the predict future outcomes of a related
744 variable (criterion validity).

745

746

747

748 **Outstanding Questions**

749

750 • What are the critical constructs that form TAM and in what way are
751 these are odds with those held by the scientific community?

752

753 • Which mental attributes of animals are considered of greatest
754 importance when judgments are made about how ethical it is to
755 consume animals?

756

757 • How do specific cultural influences or practices affect the development
758 of TAM?

759

760 • To what extent can TAM be considered a distinct psychological
761 phenomenon rather than the byproduct of other processes such as
762 anthropomorphism or adherence to cultural norms?

763
764

- 765 • If high order mental faculties form the basis of moral worth, is
766 anthropocentrism the dominant mechanism in disqualifying objections
767 to the use of animals that are viewed as 'of mind'?

768

769

770 **Trends Box**

771

772

- 773 • Current evidence suggests widespread belief in the mental lives of
774 animals, which has serious consequences for human-animal
775 interactions.

- 776 • The scientific community has been slow to investigate the mechanism
777 underlying our Theory of Animal Mind (TAM), due to oversimplification
778 and limited objectivity.

- 779 • By expanding the study of TAM to encompass a richer multi-
780 dimensional approach, it is possible to more accurately theorise and
781 empirically validate investigations of TAM.

782