
A Proposed Transdisciplinary Framework to Align Comparative Psychology and Social Science Research on Animal Minds

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OVERVIEW

The following paper was prepared as part of an effort to advance public understanding of the science of animal cognition. The project, *Wild Minds! What Animals Really Think*, was developed by the New York Hall of Science (NYSci), in collaboration with Institute for Learning Innovation (ILI), ILI's successor on the project, New Knowledge Organization Ltd. and Hunter College through funding from the US National Science Foundation. The project explored how public value is increased through transdisciplinary efforts at communicating science content through exhibitions displayed within zoos and science centers in the same area. The professional practice aspects of this study explored the influence of transdisciplinary thinking in professional and paraprofessional discourses.

The following paper emerged as part of the content development efforts to support the Wild Minds exhibits. A transdisciplinary meeting was convened with leading researchers working in informal science learning, the social sciences that explore moral concern and belief in animal mind (BAM) and researchers advancing understanding of non-human animal cognition. While the latter two disciplines examine animal minds and our perceptions of them, it became apparent that the language and constructs used in both fields remain mutable, which may hinder public understanding of this important field of study.

To address this problem, the research team undertook an extended effort to describe A Transdisciplinary Framework to Align Comparative Psychology and Social Science Research on Animal Minds. The following paper proposes a nine-category framework uniting loosely defined constructs and categories from animal cognition science and BAM research. This work was done in an effort to create a common language and research agenda that provides a basis for examining animal minds and how the public develops understanding of such. At the completion of the project, the paper was submitted to two leading peer-reviewed journals that publish articles in this field. To address concerns raised about the paper, the team undertook a rewriting effort that resulted in the attached manuscript. The paper was once again declined for publication as the grant period came to a close, for reasons that the authors respect. As a final product of the grant, the authors felt that self-publication of this paper alongside a summary of the reviews to support a broader discussion in both fields was warranted. We wish to thank the many reviewers and commentators who helped shape this paper and hope that this might contribute to advancing a more holistic public understanding of animals' minds.

A Proposed Transdisciplinary Framework to Align Comparative Psychology and Social Science Research on Animal Minds

Social science research into public understanding of animal cognition has tended toward a disciplinary focus with conceptual frameworks, questionnaires, concepts and categories that do not appear to align with the findings emerging from the scientific study of animal cognition. The goal of this paper is to present a framework that aligns the dimensions of these two disparate research fields to allow for better assessment of public perceptions of animal minds. The paper identifies different dimensions that have been categorized through the empirical study of animal cognition, as well as the constructs used in social science research about animal thinking, and then seeks to align constructs that seem conceptually equivalent. Based on this alignment, the paper proposes a set of cross-disciplinary categories that might serve as a framework for reporting results in ways that can increase public understanding about the overall concept of animal thinking: social learning, tool use, concept formation, spatial awareness, numerosity, communication, decision-making, awareness, and creativity. The paper provides a description of the framework's utility by highlighting how clarification and alignment of constructs can promote research in both fields. It concludes by suggesting that this framework offers the opportunity to more proactively engage in dissemination of new information about animal cognition in public forums. More importantly, such an approach can facilitate study of the nuanced ways in which the public engages with scientific information to learn about animal minds.

Keywords: Belief in Animal Mind; Animal Cognition; Animal Minds; Animal Perception

INTRODUCTION

Studies of non-human animal cognition over the past fifty years have revealed a vast amount of information about the evolution of intelligence in the animal¹ world. These findings come from many scientific disciplines, including animal behavior, biology, cognitive and experimental psychology, neuroethology, and cognitive ethology. In parallel to the expansion of research on animal minds, social science researchers have sought to describe how public perceptions of animal minds impact attitudes and behaviors toward animals.

These two research fields approach the important issue of how we perceive and understand animal minds from different perspectives. Scientists studying animal cognition focus primarily on what is empirically known about the processes and functions of animal minds rather than what the general public might choose to believe or disbelieve about animal cognition. Conversely, social scientists examining public perceptions of animal minds focus first on the beliefs and practices of humans toward animals and what these beliefs and practices might mean for animals that come into contact with people as a result of this primary inquiry.

We would argue that it is self-evident that both groups have a vested interest in how advances in scientific knowledge find purchase in public discourse, and in many cases, that this knowledge might increase the quality of interaction people have with animals based on a better understanding of how these animals understand the world

¹ For simplicity, we refer to non-human animals as 'animal(s)'.

around them. This puts scientists studying animal cognition and social scientists studying public beliefs about animal cognition in an ideal situation to work together on shared concerns. We suggest that such collaborative endeavors can benefit both research fields by improving the transmission of information regarding animals' capacities and the evolution of cognition to the non-scientific public.

In 2009-2010, a nation-wide survey of US citizens who visit museums, conducted to inform a traveling exhibit on animal minds called "Wild Minds: What People Think about Animal Thinking" (Maust-Mohl, Fraser, & Morrison, 2012) demonstrated that the public does not have an organized way of thinking about types of animal cognition, nor a good understanding of animal cognitive abilities. Furthermore, in developing that survey, it became apparent that the general concepts and language used by animal cognition studies and social science research on humans' perceptions of animals do not align with those used by social psychologists who study reasoning about animals. In conjunction with additional research conducted with science advisors involved in the creation of the exhibit, the results of this survey were an instigating factor in the writing of this paper.

There appears to be little communication between the researchers working in these two disciplines and little evidence that these two groups are sharing knowledge about either the conceptual categories that describe animal cognition or human perceptions of animals. This lack of communication and coordination limits the opportunities for researchers in both fields because it does not ground the social

science research in emerging and current evidence of categories of animal cognition (Fraser et al., 2006; Griffin, 2001; Jamieson & Bekoff, 1992; Mitchell, Thompson & Miles, 1997; Shettleworth, 2009; Wasserman, 1997), which may be producing a disciplinary jargon in

animal cognitive science that limits public access to this knowledge. Indeed, one of the main challenges to discussing animal cognitive processes and human perceptions of animals, concerns the range of terms that are sometimes used interchangeably across both fields without agreement on their meanings or operational definitions. This makes it exceedingly difficult to facilitate interchange of information between the two disciplines, which in turn hinders not only scientific research but also public understanding of this research.

There is growing evidence that public misconceptions about animal cognitive research is being exacerbated by media reporting, the primary vector for scientists to share their findings with the general public. Studies have found that most people primarily receive scientific information through the popular media where animal cognition is often presented as disaggregated facts that limit the public's ability to interpret these results and consider their implications as part of a larger systemic understanding of mind (Fraser et al., 2006; Norris, Phillips, & Korpan, 2003). Despite this lack of clarity in the media, animal minds remain a popular topic that fuels the ongoing social discourse that tends toward categorical comparison of how "smart" animals are (e.g., Herzog & Galvin, 1997; Rasmussen, Rajecki, & Craft, 1993). We believe this discontinuity has contributed to a growing chasm between scientific findings regarding animal cognition and popular understanding of this field of scientific research.

Animal cognition studies likely influence how the public perceives animals by informing them about what scientists claim their data show. This information however, is only understood in the context of the public's beliefs about the legitimacy of this scientific enterprise within their cultural worldviews. Therefore, we suggest that there is a reciprocal relationship between these two areas of research and both disciplines offer value to science. The use of separate constructs not only hinders the acquisition of knowledge in the public sphere, but may also hinder a broader critical review and our assumptions about public knowledge.

In this paper, we propose a framework that organizes mental capacities and abilities of humans and other animals into a set of cognitive dimensions. This framework provides social scientists wishing to study human understanding of animal minds and cognitive scientists studying animal minds with a set of references with which to situate their findings in a larger, non-disciplinary discourse. We do not propose to challenge how the science itself is conducted, nor

how cognitive scientists debate meaning about types of evidence within their community; however, we do suggest that a common transdisciplinary framework offers a useful tool for guiding non-specialists toward engagement with this type of science.

BACKGROUND

In 1956, two landmark conferences, one at the Massachusetts Institute of Technology and one at Dartmouth College, marked a paradigm shift in the way scientists approached the study of intelligence in humans, animals and computers. These meetings resulted in what has been termed the "cognitive revolution," a tipping point that changed the way that scientists approached the question of animal thinking. Miller (2003) described this "revolution," or more appropriately, a realization of a critical shift in academic research from an exclusively behaviorist paradigm toward the study of mental processes. This move beyond the behaviorist paradigm led to a transformation in scientific discourse and research in animal behavior and comparative psychology (henceforth referred to as animal cognition research).

Studying the mental processes of other animals is inherently difficult. Scientists are faced with the challenge of developing species-appropriate methodologies and experimental designs to compare different species of animals, including humans. These challenges are only exacerbated by difficulties surrounding experimental design and methodologies that accurately and validly measure similar abilities across multiple species. Moreover, the principle of parsimony in science can and has often resulted in reductionist interpretations of animal behavior. Nevertheless, continued study of these abilities is a necessary part of the larger investigation into the evolution of cognition overall and the convergence of shared abilities in humans and animals with a high degree of evolutionary divergence (Burghardt, 1985; Griffin, 2001; Griffin & Speck, 2004; Jamieson & Bekoff, 1992).

Beginning in the late 1980s, social scientists became interested in the emerging field of animal cognition and began to examine public ideas about the animal mind. Much of their work focused on the ethical aspects of the human-animal relationship through articles presenting philosophical discussions of animal awareness and consciousness (e.g., Burghardt, 1985; Francescotti, 2007; Lurz, 2009; Rollin, 2007; Wasserman, 1997), animal welfare and ethics (e.g., Burghardt, 2009; Herzog, 1993; Singer, 2005; Wise, 2003), representations of animals (e.g., Carmack, 1997; Herzog & Galvin, 1992; Howe, 1995; Paul, 1996), the human-animal relationship (e.g., Beck & Katcher, 2003; Blackshaw & Blackshaw, 1993; Serpell, 1996; Vining, 2003), and the multiple factors that influence perceptions of animals and animal use (e.g., Boogaard, Oosting, & Bock, 2006; Driscoll 1995; Furnham &

Heyes, 1993; Galvin & Herzog, 1992; Haeglin, Hau, & Carlsson, 1999; Herzog, 2010; Herzog, 2007; Herzog & Burghardt, 1988; Kellert, 1985; Knight & Herzog, 2009; Knight, Bard, Vrij, & Brandon, 2010; Matthews & Herzog, 1997; Phillips et al, 2011; Preylo & Arikawa, 2008; Serpell, 2004; Taylor & Signal, 2005; Taylor & Signal, 2009; Wells & Hepper, 1997).

Since the turn of the millennium, there has been a notable growth in the number of studies assessing the public's belief in animal minds as a factor that underlies perceptions of and attitudes toward animals and animal use. Social science researchers have sought to clarify their focus by categorizing this emerging strand of research as the study of belief in animal mind (BAM), a term coined to describe "beliefs about the extent to which animals have awareness, thoughts and feelings" (Hills, 1995, p134), and have begun the process of considering the elements or dimensions that constitute BAM (e.g., Knight, Nunkoosing, Vrij, & Cherryman, 2003; Knight, Vrij, Cherryman, & Nunkoosing, 2004; Knight, Vrij, Bard, & Brandon, 2009). From a strict evolutionary biology standpoint, humans represent only one outcome of evolutionary processes that have shaped and selected the physical and cognitive characteristics requisite for survival. Contemporary animal cognition research has provided evidence that many other species demonstrate advanced cognitive abilities that were previously believed to be uniquely human. However, studies by social scientists referenced in the preceding few paragraphs have demonstrated that beliefs do not align with or reflect scientific findings.

Aligning the Disciplines

Unlike animal cognition scientists who generally work to parse aspects of the animal mind, social scientists evaluating human perceptions of animal minds have tended to focus on the mind as a whole, using a generalized concept of intelligence as an undifferentiated category (e.g., Burghardt, 1985; Davis & Cheeke, 1998; Driscoll, 1995; Matthews & Herzog, 1997; Nakajima, Arimitsu, & Lattal, 2002; Serpell, 1996). The BAM literature has in some cases used terminology that appears remarkably similar to the terms used in animal cognition literature. However, the terms used may not represent the same constructs for the animal cognition researchers or for the research participants who responded to questions posed by social scientist researchers. Therefore, this paper attempts to align the constructs used in the BAM literature and the animal cognition literature for the purpose of developing a strategic alignment of categories. It seeks to clarify terminology in a manner that can be useful to both fields and that will result in new ways of describing the results of research so that both the science and the public's understanding of animal cognition will be enhanced.

The impetus for this project emerged following a meeting of experts in animal cognition research to discuss content organization for the public exhibition mentioned above. The meeting was led by three of this paper's authors: an exhibition development expert with disciplinary expertise in the teaching of evolutionary science; a conservation psychologist who has studied belief in animal mind; and their co-investigator, an animal cognition researcher. During the meeting, the subject of taxonomic categories and organizing structures emerged as a topic, but it became apparent to all present that there was little agreement on how to categorically define what animal research shows, despite an apparent wealth of data that indicated trends in the fields. Following this meeting, it was determined that a more thorough review of the literature was needed to understand the topic holistically.

Review of Animal Cognition Literature Process

Adhering to procedures for a systematic literature review (Cronin et al., 2008), three researchers conducted a literature review of animal cognition research guided by the question, "What are the categories being used by animal cognition scientists to classify the results of their research?" Only peer-reviewed articles published by peer-reviewed journals and books held to the same standards of peer review were included as criteria in the search. Reviewers initially examined literature that presented reviews or meta-analyses of the cognitive abilities of animals. Following this first step, a secondary effort was made to examine articles that discussed specific cognitive abilities in an attempt to identify proposed categorical definitions of those abilities and to expand our search to ensure representativeness of different perspectives on a mental capacity. These secondary searches however, revealed little information that had not already been uncovered in the other aspects of the search, leading us to believe that we had achieved redundancy in our review.

From the literature review a tentative list of representative indices of the cognitive abilities of animals that were most commonly grouped together was developed. Using the results from a national survey of American citizens who visit museums (Maust-Mohl, Fraser, & Morrison, 2012), this list was further consolidated to represent the main categories of animal cognition to form the indices for this paper. We circulated this list to colleagues in the field of animal cognition including all those who served as science advisors and attended the exhibit development meeting described above. This review produced a revised list that incorporated this expanded peer-review and an affirmation of consensus from our reviewers that the list of categories was considered broadly representative of the field of animal cognition. In this case, all 10 reviewers working with animals from across a range of species from bees to great apes assented to the final list

as inclusive and representative. With this confirmation from the cognitive psychology field, we undertook a secondary review of the social science literature to identify similar and different dimensions in the papers themselves and any survey instruments or documents that indicated possible ways of categorizing public perceptions. During this phase, we identified areas where current constructs overlap, and where there were gaps in one of the two literature sets. At this time, another researcher from public understanding of animal minds was added to our team as a contributing author.

Developing Categories of Cognitive Abilities

In the animal cognition literature there were several sources that listed categories representing the cognitive abilities of animals, but we found a lack of clear definitions regarding these terms and some differences in how to categorize the abilities that were described. Most articles and books on this topic tend to focus on either one index of animal cognition (e.g., self-awareness-Gallup, 1982; representation of space, time, and number-Gallistel, 1989; language-Hauser, Chomsky, & Fitch, 2002; creativity-Kaufman & Kaufman, 2004; Kaufman, Butt, Kaufman, & Colbert-White, 2011; Mitchell, 2013) or a single species (e.g., honey bees-Gould, 1990; Gross et al., 2009; African Grey parrots-Pepperberg & Gordon, 2005; Asian elephants-Plotnik, de Waal, & Reiss, 2006). Of the few published reviews of animal cognition (e.g., Byrne & Bates, 2011; Gallistel, 1989; Griffin & Speck, 2004; Jamieson & Bekoff, 1992; Shettleworth, 2001, 2009) and books that report findings from animal cognition (e.g., Bekoff, Allen, & Burgardt, 2002; Dukas & Ratcliff, 2009; Griffin, 2001; Hauser, 2000; Shettleworth, 2010; Tomasello & Call, 1997; Wynne, 2001), the authors seemed to allude to a more generalized “list” of the cognitive abilities of animals used by researchers, although the taxonomies tend to vary.

One of the seminal books on animal cognition, Griffin’s (2001) *Animal Minds* includes chapters on indices of animal behavior that involve thinking, illustrated with examples that involve species ranging from insects to dolphins and apes. Griffin’s list contains more than eight categories of animal cognition that are described as separate behaviors with specific characteristics and appeared to offer the greatest alignment with reports and references used by other scholars publishing on the topic (e.g., Bekoff, Allen, Burghardt, 2002; Shettleworth, 2001, 2009; Tomasello & Call, 1997; Wynne, 2001). We note, however, that since Griffin’s publication, there continued to be rapid growth in the list of cognitive abilities identified by researchers in their studies whose inclusion in the framework has the potential to further refine what we propose. These findings led us to suggest modifications to Griffin’s original categorization.

Based on our review of these reports, and the findings from recent research presented at animal cognition conferences during our research phase from 2008 - 2011, and our previously described findings from the survey of US museum visitors (Maust-Mohl, Fraser, Morrison, 2012), we proposed a summary list of categories from the animal cognition literature as the basis for developing a transdisciplinary framework. This framework would be used to support the social science study of belief in animal minds and to help create an organizing framework for public education about this science (Table 1).

We organized the indices representing what emerged from our literature review and discussion with peer advisors as the most distinct way to categorize cognitive abilities of animals into a set of categories based on evidence that they involve similar mechanisms or mechanisms that are likely to co-occur. Our list accepts that learning, memory, problem-solving abilities, and social knowledge permeate all of these categories, and thus will not be considered mutually exclusive when describing animal minds. Social knowledge in particular is an important element for consideration with respect to the social intelligence hypothesis, which implies complex processing of information relative to the social world (Whiten & van Schaik, 2007).

Description of the Categories of Animal Cognition

1. Social learning has been defined in a number of ways by different researchers, but can be summarized as the process of acquiring information by watching the behavior of others, and is widespread throughout the animal kingdom in multiple contexts, such as foraging, mate selection, and anti-predator strategies (Neilsen et al., 2012; Reader & Biro, 2010; Zentall, 2001). Social learning is adaptive, as demonstrated by the number of important social influences resulting from observing or interacting with other individuals (Heyes, 1994; Galef & Laland, 2005). Within social learning, information can be obtained from other individuals through several different mechanisms such as observational learning, imitation, and teaching, and may involve cultural traditions (Heyes, 1994; Galef, 2004; Galef & Laland, 2005; Reader & Biro, 2010). Culture refers to behaviors that are “transmitted repeatedly through social or observational learning to become a population level characteristic” (Heekeren, Marrett, & Ungerleider, 2008, p.467). There is much debate over how to define animal culture and the capacity in which animals demonstrate culture (Laland & Hoppitt, 2003; Price, Caldwell, & Whiten, 2010).

Some researchers prefer to describe the behavioral variations observed across populations of a species as traditional behaviors

(e.g., Galef, 2004) because of the implications of using the term “culture” and the challenge of identifying these behaviors both in captivity and in the wild. However, the terms used may depend on how culture is defined and the species being evaluated (Nielsen et al., 2012; Price, Caldwell, & Whiten, 2010; Whiten, Horner, & Marshall-Pescini, 2003). There is also disagreement among researchers on the modes in which this information is transmitted (e.g., active and intentional teaching or observational learning), but the common thread is that these behavioral practices are passed down vertically (from generation to generation) or horizontally (within social groups) through some form of social transmission.

2. Tool use refers to behavior in which animals use objects in their environment or manipulate the space around them to serve a purpose. These behaviors demonstrate types of problem solving that are not necessarily common across all species. Tool use, once thought to exist only in humans and apes, has been documented in several other species. Tool use has been defined in many ways, but the most recent definition includes a slight revision of Beck’s (1980) widely accepted definition. According to the modified definition, tool use is “the external employment of an unattached or manipulable attached environmental object to alter more efficiently the form, position, or condition of another object, another organism, or the user itself, when the user holds and directly manipulates the tool during or prior to use and is responsible for the proper and effective orientation of the tool” (Shumaker, Walkup, & Beck, 2011, p. 5).

3. Concept formation, also known as concept learning, can be considered “the ability to respond to a common quality or characteristic shared by a number of different specific stimuli” (Sappington & Goldman, 1994, p. 3080). Katz, Wright, and Bodily (2007) describe three types of concept learning: natural/perceptual, associative/functional, and abstract. The first two types are considered examples of lower level learning, both involving categorizing stimuli. A detailed review of conceptual categorization revealed two criteria that involve rapid generalization to a class of items and categorization that goes beyond observing similarities between objects to characteristics shared by a number of different specific stimuli (Zayan & Vauclair, 1998). Abstract concept learning (i.e., same/different (S/D) and match-to-sample (MTS) discriminations) involves rule-based judgments of relationships between stimuli and is considered to be higher-order learning (Katz, Wright, & Bodily, 2007).

4. Spatial awareness refers to the ability of animals to use information about direction and distance often relying on multiple cues in the environment (Cheng, Shettleworth, Huttenlocher, & Rieser, 2007; Dolins & Mitchell, 2010). This can also be used to describe the evolved

ability of animals to interact with their environment in terms of space and time (Gallistel, 1989). Recent studies have investigated the variety of methods used by animals for navigation and orientation, which rely on spatial memory and representations of space that may involve the use of landmarks to follow a basic route, or the use of a cognitive map to compute direction and distance (Normand & Boesch, 2009).

5. Numerosity refers to the ability of animals to understand quantity and to make numerical judgments about the quantity of things (Davis & Perusse, 1988; Pepperberg & Gordon, 2005). In a recent review by Nieder and Dehaene (2009), numerical cognition is discussed as having two components: numerical quantity, and numerical rank, or serial order (e.g., which position). The ability to judge the relative quantity of items in one’s environment is highly adaptive.

6. Communication refers to the exchange of information between or among individuals (Bradbury & Vehrencamp, 2011; Rendall, Owren, & Ryan, 2009). More specifically, in 1974 Otte described this exchange as using “signals that are behavioral, physiological, or morphological characteristics fashioned or maintained by natural selection because they convey information to other organisms” (Searcy & Nowicki, 2005, Individual or combinations of multimodal signals can be used to convey complex messages in different contexts to maintain contact between individuals or groups, find mates, and advertise or defend territory. Hockett and Altmann (1968) provided an initial delineation and comparison of the “design features” found in human languages with those features found in other animal communication systems and offer a set of terms that has proved to be effective in the reporting and description of the latter.

7. Decision-making is based on the concept that a decision is a “deliberative process that results in the commitment to a categorical proposition” (Gold & Shadlen, 2007 p. 536) or it can be considered as a process that weighs priors (the probability that something is true before knowing any information about it), evidence (information that determines whether to commit to a hypothesis) and value (costs and benefits of potential outcomes), to generate a commitment to a categorical proposition intended to achieve particular goals (Gold & Shadlen, 2007). Decision-making, or perceptual decision making, can also refer to “the process by which information that is gathered from sensory systems is combined and used to influence how we behave in the world” (Heekeren, Marrett, & Ungerleider, 2008, p. 467). In order for animals to effectively adapt their behavior to continually changing environments, decision-making processes may need to be more flexible (Dumas, St-Louis, & Routhier, 2006).

Table 1.
Index of cognitive abilities of animals identified in animal cognition research

Cognition Category	Related Animal Cognition Indices	References (representative references)
1. Social Learning	Culture Teaching Imitation	Bekoff, Allen & Burghardt, 2002; Galef, 2004; Galef & Laland, 2005; Hauser, 2000; Heekeren, Marrett, & Ungerleider, 2008; Heyes, 1994; Laland & Hoppitt, 2003; Neilsen et al., 2012; Price, Caldwell, & Whiten, 2010; Reader & Biro, 2010; Rendell & Whitehead, 2001; Tomasello & Call, 1997; Whiten, Horner, & Marshall-Pescini, 2003; Whiten & van Schaik, 2007; Whiten et al., 1999; Zentall, 2001.
2. Tool Use	Architecture Tool manufacture	Bekoff, Allen, & Burghardt, 2002; Clayton, Dally, & Emery, 2007; Finn, Tregenza, & Norman, 2009; Griffin, 2001; Griffin & Speck, 2004; Hauser, 2000; Hunt, 1996; Jones & Kamil, 1973; Shumaker, Walkup, & Beck, 2011; Tomasello & Call, 1997; Wynne, 2001.
3. Concept Formation	Categorization Discrimination	Bekoff, Allen, & Burghardt, 2002; Cook et al., 1995; Griffin, 2001; Griffin & Speck, 2004; Hauser, 2000; Katz, Wright, & Bodily, 2007; Sappington & Goldman, 1994; Shettleworth, 2001, 2009; Tomasello & Call, 1997; Wynne, 2001; Zayan & Vauclair, 1998.
4. Spatial Awareness	Orientation Navigation Cognitive Maps	Bekoff, Allen, & Burghardt, 2002; Bregy, Sommer, & Wehner, 2008; Cheng, Shettleworth, Huttenlocher, & Rieser, 2007; Dolins & Mitchell, 2010; Gallistel, 1989; Griffin, 2001; Hauser, 2000; Normand & Boesch, 2009; Shettleworth, 2001, 2009; Tomasello & Call, 1997; Wynne, 2001.
5. Numerosity	Estimating quantities Counting More/Less Judgments	Bekoff, Allen, & Burghardt, 2002; Davis & Perusse, 1988; Gallistel, 1989; Gross et al., 2009; Hauser, 2000; Hauser, Chomsky, & Fitch, 2002; Nieder & Dehaene, 2009; Pepperberg & Gordon, 2005; Shettleworth, 2009; Tomasello & Call, 1997; Wynne, 2001.
6. Communication	Referential Symbolic Language	Bekoff, Allen, & Burghardt, 2002; Bradbury & Vehrencamp, 2011; Crist, 2004; Gardner & Gardner, 1969; Griffin, 2001; Griffin & Speck, 2004; Hauser, 2000; Hauser, Chomsky, & Fitch, 2002; Herman, Richards, & Wolz, 1984; Hockett & Altmann, 1968; Jamieson & Bekoff, 1992; Pepperberg, 1981; Rendall, Owren, & Ryan, 2009; Savage-Rumbaugh et al., 1986; Searcy & Nowicki, 2005; Seyfarth, Cheney, & Marler, 1999; Shettleworth, 2001, 2009; Tomasello & Call, 1997; Wynne, 2001.
7. Decision Making	Attention Advanced Planning Intention	Bekoff, Allen, & Burghardt, 2002; Clayton, Dally, & Emery, 2007; Dumas, St-Louis, & Routhier, 2006; Gold & Schadler, 2007; Griffin, 2001; Griffin & Speck, 2004; Hauser, 2000; Heekeren, Marrett, & Ungerleider, 2008; Jamieson & Bekoff, 1992; Shettleworth, 2001, 2009; Tomasello & Call, 1997.
8. Awareness	Self-awareness Mirror Self-recognition Theory of mind Empathy Deception	Bekoff, Allen, & Burghardt, 2002; Call & Tomasello, 2008; Clayton, Dally, & Emery, 2007; de Waal, 1992, 2008; de Waal & Ferrari, 2010; Gallup, 1982; Griffin, 2001; Griffin & Speck, 2004; Hauser, 2000; Jamieson & Bekoff, 1992; Plotnik, de Waal, & Reiss, 2006; Premack & Woodruff, 1978; Reiss & Marino, 2001; Shettleworth, 2001, 2009; Tomasello & Call, 1997; Trivers, 1971; Wynne, 2001.
9. Creativity (Imagination)	Insight Innovation Imagination	Griffin, 2001; Kaufman & Kaufman, 2004; Kaufman, Butt, Kaufman & Colbert-White, 2011; Mitchell, 2013; Tomasello & Call, 1997; Wynne, 2001.

8. Awareness constitutes two distinct areas of study, theory of mind and self-awareness, combined to represent a range of related indices reported by scientists studying animal cognition. The term theory of mind (TOM) refers to the ability to attribute mental states (goals, intentions, knowledge, perceptions, beliefs, and desires) to oneself and others (Call & Tomasello, 2008; Premack & Woodruff, 1978) and the ability to take the perspective of another. Self-recognition, or mirror self-recognition, a form of self-awareness, has been defined as the ability to become the object of your own attention (Gallup, 1982), consciousness as being aware of your own existence and mind as the ability to monitor your own mental states (Gallup, 1982). Social awareness also includes the social self as a cooperative individual interacting in groups. Deception and empathy have been shown to exist within this tier because they imply knowing yourself in relation to those around you and anticipating outcomes based on an intentional action.

9. Creativity² in the animal world has been evidenced through the study of novel or innovative responses that are both relevant and useful to the animal (Kaufman & Kaufman, 2004; Mitchell, 2013). Early studies of creativity in animals focused on a few aspects such as problem-solving, insight and other adaptive innovations. Later work has revealed that creativity may contain up to three categories of thought (recognition of novelty, observational learning, and innovative behavior) (Kaufman & Kaufman, 2004). More recently, Kaufman, Butt, Kaufman, and Colbert-White (2011) have expanded on their initial model and are considering the three previously mentioned categories as different degrees of creativity that fall on a spectrum, with cognitive complexity increasing as you move from one end (recognition of novelty), through pretending to innovation.

Limitations of Indices Used for Initial Categorization

This categorization alone cannot necessarily resolve how to support public understanding of the findings from animal cognition research because it does not fully account for how perceptions might influence acceptance or challenge firmly held worldviews. Complicating matters further, science journalists and the popular press often filter research results for public consumption through the mass media (Cassidy, 2005), with implications for how the public understands scientific research on animal cognition. For example, within the media, scientific findings are frequently characterized as curiosity, suspect science, or unarguably correct facts with no discussion of the larger significance of these findings and the caveats surrounding

² We note that Mitchell (2013) argues that the term “imagination” may more broadly account for the cognitive capacities of creativity and the pretending.

the work (Schafer, 2010; Weiss, 1987). In addition, many researchers have analyzed and described the challenges people have interpreting scientific results from various media sources. As a consequence, misconceptions about these findings persist (e.g., Norris, Phillips, & Korpan, 2003; Taylor & Kowalski, 2004). The exception may be research in evolutionary psychology, which appears to have a higher number of academics presenting their work in the popular media, including articles linked to books on related topics, facilitating more discussion of scientific controversy in the public domain (Cassidy, 2005). In some cases, the earlier representation of animals exaggerated animal cognitive abilities to the point of misrepresentation (e.g., Bryld & Lykke, 2000; Carmack, 1997; Fraser et al., 2006; Herzog & Burghardt, 1988; Herzog & Galvin, 1992; Howe, 1995; Paul, 1996; Weiss & Singer, 1987).

Therefore, it is necessary to consider the relationship between the public’s BAM and the hard evidence of animal cognition, in order to organize and relay research findings to the public. In the following section, we identify the cognitive dimensions that are represented and measured in the BAM research with the goal of aligning these dimensions with the animal cognition indices we identified in the preceding section.

Review of Social Science Literature on BAM

To expand our review, once again, three researchers reviewed the social science literature to determine the variety of ways animal minds have been presented and to determine which dimensions of animal minds have been measured. Online social science research databases were searched using key words such as “animal cognition”, “animal intelligence”, and “perceptions of animal thinking” in order to find journal articles and books with methods and strategies to help guide this work. We reviewed published social science articles representing the diverse areas in which the topic of animal minds is covered including significant websites and publications that have sought to describe the literature on animal thinking (i.e., Kalof, Bryant, & Fitzgerald, 2011; <http://animalstudies.msu.edu/bibliography.php>). These were written in the English language or were available in translation. We excluded papers that focused exclusively on philosophy, logic, opinion or solely qualitative studies that did not describe categorical information. We did not exclude studies with small sample sizes if they considered thinking in any categorical way. We also conducted a reverse search of citations in our primary dataset and conducted secondary searches using key authors identified in our first search as guides and used their work as stepping-stones for this review. Furthermore, we conducted searches under the broader heading of ‘perceptions of animal minds’, as BAM is a focused subset

of this category and we did not want to exclude research that did not fall under the BAM literature directly, yet may still be relevant to the current discourse. To supplement this, we conducted a search of articles and books in the popular media using similar key words and topic searches to identify other sources in which the topic of animal minds is presented. For brevity in this report, we do not mention or report all of the 500+ articles included in this analysis, but instead cite only those representative articles that demonstrated the range of central categories and concepts revealed in our review and the summary reports that have consolidated prior research.

Alignment of Animal Cognition and BAM Categories

Although a summary list of categories may be a useful way of organizing the field of animal cognition, the general public may not understand or be aware of many of the distinct categories reported in animal cognition (e.g., Maust-Mohl, Fraser, & Morrison, 2012). To date, many social science studies have focused on measuring a general concept of animal thinking or intelligence of different animals (e.g., Davis & Cheeke, 1998; Mitchell & Hamm, 1997). For example, Burghardt (1985) measured public beliefs (of American undergraduates, scientists attending the 1982 Animal Behavior Conference, and groups of creationists and evolutionists that attended a philosophical debate) concerning mental continuity between humans and animals, finding that the idea of emotional continuity was accepted more than intellectual continuity regardless of people's religious beliefs. Much of the literature on the perceptions of animal minds gathers data on a range of species, although some animals such as dolphins and honeybees have been singled out for specific evaluation, perhaps due to their popularity with media and the general public (e.g., Amante-Helwig, 1996; Barney, Mintzes, & Yen, 2005; Crist, 2004; Fraser et al., 2006; Sickler et al., 2006a, b).

Many of the early studies measuring public perceptions of animal minds found that people tend to organize animals on a single linear continuum of thinking based on general questions about animal intelligence. The concept of phylogenetic scale has been used by social scientists to examine how the general public views species differences according to where they fall on a sort of hierarchy, where mammals more closely related to humans or that have big brains are "higher" than other species such as small mammals, birds, reptiles, amphibians, etc. (e.g., Herzog & Galvin, 1997).

In a study of common sense reasoning about animal minds, Herzog and Galvin (1997) developed an attributions questionnaire to assess people's beliefs and anthropomorphic tendencies toward the mental capacities of animals, which included the categories of intelligence,

consciousness, emotions, affection to humans, reason, suffering, and self-awareness. Using factor analysis, the researchers found that the items fell into three categories representing cognition, affect, and sentience. Herzog and Galvin reduced their results into a hierarchical list that ranked each animal on a linear scale with many similarities to a phylogenetic scale. Herzog and Galvin's studies have emerged as foundational work upon which others have built (e.g., Davis & Cheeke, 1998; Fonseca et al., 2011; Knight, Nunkoosing, Vrij, & Cherryman, 2003; Knight, Vrij, Cherryman, & Nunkoosing, 2004; Knight & Barnett, 2008; Knight, Vrij, Bard, & Brandon, 2009; Nakajima, Arimitsu, & Matthew, 2002).

Although these aggregated scales may be a convenient approach for social scientists to consider animal type as a variable, we suggest that scales may not necessarily measure all of the relevant dimensions that comprise peoples' perceptions of animal minds, nor can a reduced scale represent the complexity of animal cognitive abilities being uncovered by researchers in animal cognition.

Hills' (1995) pioneering study identified a significant positive relationship between empathy and BAM by illustrating that empathy and judgments of mental similarities between mammals, birds, fish, and insects varied between farmers, animal rights supporters, and the urban public. The group differences suggested that there were conflicting attitudes toward animals that may affect their perceptions of animal minds. Based on these results, researchers have started to focus on a multi-dimensional approach to evaluate BAM, recognizing that beliefs about a range of species may differ, and focusing on a broader range of mental abilities (Knight et al., 2003; Knight et al., 2004). This research has demonstrated that different modes of interactions with animals and other factors mentioned above (i.e., age, gender, occupation, and experience with animals) underlie public attitudes about animals (Knight & Barnett, 2008; Knight et al., 2009). A review of these new findings demonstrates a tentative alignment with animal cognition research, even though that information was not directly used in the development of the studies. These observations suggest that alignment between the two disciplines may benefit both fields by clarifying constructs and creating opportunities for collaborative research.

Table 2.
Framework aligning indices identified in animal cognition research with BAM constructs

Cognition Category	Indices identified in animal cognition research	Overlap at construct level identified in a review of the BAM literature
1. Social Learning	Culture Teaching Imitation	Imitation, observation (Sickler et al., 2006a, b) Learning, culture (Maust-Mohl, Fraser & Morrison, 2012)
2. Tool Use	Architecture Tool manufacture	Tool (Maust-Mohl, Fraser, & Morrison, 2012)
3. Concept Formation	Categorization Discrimination Categorization	Schemata, object permanence (Rasmussen, Rajecki, & Craft, 1993) Object recognition (Maust-Mohl, Fraser, & Morrison, 2012)
4. Spatial Awareness	Orientation Navigation Cognitive Maps	Spatial awareness (Maust-Mohl, Fraser & Morrison, 2012)
5. Numerosity	Estimating quantities Counting More/Less Judgments	Enumeration, sorting, parsimony (Rasmussen, Rajecki, & Craft, 1993; Maust-Mohl, Fraser & Morrison, 2012) More/Less judgments, counting (Maust-Mohl, Fraser & Morrison, 2012)
6. Communication	Referential Symbolic Language	Communication, language (Maust-Mohl, Fraser & Morrison, 2012; Sickler et al., 2006a, b)
7. Decision Making	Attention Advanced Planning Intention	Decision making, capacity to reason, morality (Fonseca et al., 2011; Herzog & Galvin, 1997; Hills, 1995; Knight et al., 2004; Knight et al., 2009; Maust-Mohl, Fraser, & Morrison, 2012; Rasmussen, Rajecki, & Craft, 1993; Sickler et al., 2006a, b) Attention: (Mitchell & Hamm, 1997) Plan for future, foresight, know what will happen to them tomorrow, think what to do next (Furnham & Heyes, 1993; Maust-Mohl, Fraser & Morrison, 2012; Mitchell & Hamm, 1997; Rasmussen, Rajecki, & Craft, 1993; Sickler et al., 2006a, b) (Eddy, Gallup, & Povinelli, 1993; Sickler et al., 2006a, b)
8. Awareness	Self-awareness Mirror Self-recognition Theory of mind Empathy Deception	Self-awareness, mirror self- recognition, consciousness, aware of what is happening to them or what another animal is thinking (Eddy, Gallup, & Povinelli, 1993; Fonseca et al., 2011; Furnham & Heyes, 1993; Hills, 1995; Herzog & Galvin, 1997; Knight et al., 2004; Knight et al., 2009; Maust-Mohl, Fraser & Morrison, 2012; Sickler et al., 2006a, b) Empathy (Maust-Mohl, Fraser & Morrison, 2012; Sickler et al., 2006a, b) Deception, , trick, pretend (Eddy, Gallup, & Povinelli, 1993; Maust-Mohl, Fraser & Morrison, 2012; Mitchell, 2013; Mitchell & Hamm, 1997; Sickler et al., 2006a, b)
9. Creativity (Imagination)	Insight Innovation Imagination	Imagine, creative (Rasmussen, Rajecki, & Craft, 1993; Sickler et al., 2006a, b)

Limitations of Research in BAM

One of the main challenges to investigating the cognitive dimensions represented in BAM and the public's perceptions of animal minds research was the limited number of studies that have considered specific aspects of animals' cognitive abilities. Most of the studies identified in the literature review have measured general beliefs about animal intelligence, learning and memory, the ability of animals to think and feel, and/or the ability to solve problems, while not parceling out more discrete and specific categories within these larger headings.

Proposed Integrative Framework to Study How Animals Think

Based on these reviews there is clearly an emerging alignment between social science studies of BAM and animal cognition research. We propose the following framework for building upon a collaborative transdisciplinary work by professionals in both fields. In the proposed framework (Table 2) we align the findings from both fields into "cognition categories". For each dimension or indicator covered, we note the similarity in terminology or meaning when there are slight variations and gaps that should be addressed in future studies. Likewise, we address any discrepancies between the terminologies where there appears to be divergence in the respective fields of research. The table is followed by a more elaborated description of these cognitive categories that can be used in future research by both disciplines.

Our approach in developing this framework has been an attempt to identify and articulate discrete components of animal cognition in order to examine how those findings might interact with BAM research to date. Two of our nine cognition categories that are represented in animal cognition are missing from the social science literature (except for Maust-Mohl, Fraser, & Morrison, 2012) where BAM encompasses more general concepts. The framework proposed is intended to highlight the links between the two bodies of research, with the hope of facilitating collaborative strategies between the fields to advance public knowledge. In order to move toward this goal, in the following section, we explore how each category can represent both fields, followed by a brief discussion of exogenous and potentially mitigating variables that may play a role in future perception of animal minds studies with recommendations on how to address these challenges.

Critical Analysis of the Results of the Alignment Process

Out of the nine categories, all but two of the indices from animal cognition were represented in social science research (except for Maust-Mohl, Fraser, & Morrison, 2012). 'Tool use' and 'Spatial

awareness' were not represented in the social science perception of animal minds literature, yet represent important areas of research frequently reported in the animal cognition literature and relayed through the media. 'Social learning' was included in two studies (Maust-Mohl, Fraser & Morrison, 2012; Sickler et al., 2006a, b), but in both cases, focused on the most basic ability of learning through observation and imitation.

'Concept formation' and 'Numerosity' were found in the social science study by Rasmussen, Rajecki and Craft (1993), which measured beliefs about concepts such as schemata (categorization), object permanence, enumeration, sorting, and conservation. Numerosity and capacity to count or exercise more/less judgments were assessed by Maust-Mohl, Fraser and Morrison (2012). These terms reflect concepts such as categorization, concept formation, discrimination, and numerosity that are referred to in the animal cognition literature. Similarly, numerosity has been reported in the media (e.g., Morell, 2008; Schmid, 2009; Tenneson, 2009) and continues to draw attention, so the presence of this construct may contribute to the larger public perception of animal minds.

'Communication' is also only represented in one article from social science research (Maust-Mohl, Fraser, & Morrison, 2012) other than those topics that emerged as popular reports from animal cognition researchers themselves. This may be the result of the controversy surrounding the animal language debate (e.g., Hauser, Chomsky, & Fitch, 2002) or may be the result of the complexity involved in understanding how to broach the topic with multiple species. Sickler and colleagues (2006a, b) touched on beliefs about the language capacity of dolphins, concluding that conspecific communication may be more easily accepted by the public because this species is already considered highly intelligent, with individual dolphins frequently portrayed in the media communicating among themselves and with people (Fraser et al., 2006). In contrast, animal cognition findings such as the study of bee communication (e.g., Crist, 2004) may have the potential to increase acceptance of the cognitive abilities of this species and a range of others that currently appear outside of the public's consideration on animal minds; this may have an impact on the larger discourse in public perceptions of BAM.

'Decision-making' is mentioned in a few social science studies, but examination of the literature reveals that this concept is often grouped with the capacity to reason, moral decision-making, and problem-solving, attributes that are not necessarily linked in animal cognition (e.g., Fonseca et al., 2011; Rasmussen, Rajecki, & Craft, 1993). We suspect that there are underlying assumptions about the concept of decision-making. These assumptions may differ depending on the

field of research and we recommend increased attention to clarify this construct through transdisciplinary collaborative research in order to develop a common language that can aid both fields and help shape the evolving public discourse surrounding mental abilities. Mention our paper?

'Awareness' represents a complex array of abilities and is possibly one of the most controversial topics in animal cognition due to the challenges surrounding how to define and measure these abilities and the potential implications of higher levels of awareness in animals. In contrast to other dimensions, theory of mind and self-awareness, have emerged in the social sciences as central areas of study. Various terms such as self-awareness (agency), mirror self-recognition or self-recognition (recognizing images of the self), and consciousness (sensory awareness of the self) have been used in various studies to assess attitudes toward awareness in animals, often in comparison to humans or based on degrees of similarity (e.g., Eddy, Gallup, & Povinelli, 1993; Maust-Mohl, Fraser, & Morrison, 2012; Rasmussen, Rajecki, & Craft, 1993). However, empathy is missing from social science research (except Maust-Mohl, Fraser, & Morrison, 2012). It would appear that social scientists have adopted these terms to explore acceptance of the possibility that some species have the capacity for higher order thinking, but they have not probed the ways in which the terms themselves impact public responses. Scientists studying animal cognition, on the other hand, use these terms with specific reference to the cognitive abilities demonstrated by a particular species. In recommending this category for future research, we do not wish to dissuade social scientists from studying the impact of different terms, but seek to suggest that researchers recognize the distinction between terms and use care in reporting on this category to ensure their findings have the greatest transdisciplinary value.

Another term that falls into the 'awareness' construct is deception, which has only been considered in a few studies on public perceptions of animal minds studies (e.g., Eddy, Gallup, & Povinelli, 1993; Maust-Mohl, Fraser, & Morrison, 2012; Mitchell & Hamm, 1997; Sickler et al., 2006a, b), perhaps because both fields find the topic challenging to operationalize. We do not propose that the indices of this category are complete, but suggest that increased focus on this category will bring clarity to both sciences and the public understanding of this knowledge.

'Creativity', also appears to be a popular topic in the social science literature on the perception of animal minds, perhaps due to the frequency of this topic in popular media reports on animal behavior (Rasmussen, Rajecki, & Craft, 1993; Sickler et al., 2006a,

b). Although both fields use similar terms they offer different ways of operationalizing the construct in research. Problem-solving and insightful problem solving are terms used by scientists studying animal minds in describing creativity and innovation but these terms tend to be unmentioned in operationalizing a study of animal "creativity" in the social sciences. We suggest that social scientists may benefit by drawing examples from animal cognition literature to operationalize constructs in their research. Through this transdisciplinary approach, we believe the social science community can help to expand understanding of how the public interprets the behavior of animals in their midst (such as pets or wildlife), and the role that creativity plays in advancing beliefs about animal mind.

DISCUSSION

We present an organizing framework that offers scientists in animal cognition and social scientists studying BAM the opportunity for transdisciplinary collaboration through the use of a common language with which to share their results. This framework is intended to help bridge the gap between the rapidly growing research emerging from the field of animal cognition and the dissemination of that information into popular discourse. The development of an initial structure as a scaffold to situate animal cognition and BAM research offers a starting point for future studies in these fields to produce meaningful results towards advancing scientific and public knowledge.

The main challenge for researchers in animal cognition will continue to be the lack of common reference terms and agreed upon definitions, a problem that may also limit these scientists' ability to communicate to the public about their research. While we acknowledge that the organization of the dimensions from animal cognition may need modification as scientists develop new knowledge, we believe this organization can help expand knowledge about the discourses surrounding animal thinking.

As we consider the utility of the proposed framework in strengthening research in both fields of animal cognition and public understanding of BAM, it is important to consider the reasons for the disconnect in scientific research and the general public's understanding of animal cognition. For example, public acceptance of the extent of animal mindedness may be limited in part by the inability to consider the perceptual worlds of animals. More recent results from animal cognition studies have revealed evidence that the cognitive abilities of animals have evolved to help them adapt to their environment, sometimes resulting in convergence of these abilities across different taxa, including humans (e.g., Griffin, 2001; Shettleworth, 2001, 2009).

Scientists have traditionally eschewed the use of anecdotes or anthropomorphism (the assumption that animals think and feel as humans do) (de Waal in Mitchell, Thompson, & Miles, 1997) in their explanation of findings in order to demonstrate an objective stance (e.g., Davis, 1997; Griffin, 2001; Shettleworth, 2009). On the other hand, social scientists and scientists studying animal cognition have explored the pros and cons of anthropomorphism as a useful tool to aid public understanding of animal minds (e.g., Mitchell, Thompson, & Miles, 1997). For example, several studies have demonstrated that anthropomorphic reporting can be used to demonstrate examples of animal minds and can guide the development of new methods to test animal cognition (e.g., Crist, 1996; Crist, 2000; Daston & Mitman, 2005; Davis, 1997; Eddy, Gallup, & Povinelli, 1993; Lulka, 2008; Mitchell & Hamm, 1997; Serpell, 2003). However, anthropomorphism in the study of animal cognition is not the same as anthropomorphism in public reasoning about animal minds. While there may be growing acceptance of anthropomorphism as a legitimate way of explaining animal minds, this strategy may also promote an inclination to reduce the cognitive abilities of animals to a single scale with humans at the top (Sickler et al., 2006b).

We suggest that the so-called ‘speciesist’ tendencies among people who make decisions about animals based solely on their own human capacities and beliefs in human superiority will continue to be a challenge. These treatment decisions challenge us to acknowledge individual characteristics (Bekoff & Gruen, 1993; Steinbock, 1978) with popular metaphors and discourses having the potential to inhibit popular acceptance of new ideas about the continuity of life (Fraser et al., 2006). Therefore, exclusive of the framework but equally important, we suggest that both fields recognize the role of *umwelt*, or what is known about a particular species as an external mitigating factor influencing human perceptions of cognitions in that species. The term “*umwelt*”, coined by von Uexküll in 1905, refers to the unique sensory world that each organism experiences (Gould, 1982). Each individual of a species can have a different *umwelt* even though they share the same environment. Researchers have suggested that human empathy for animals may be linked with the empathy we have towards other people (e.g., Ascione, 1992; Beck & Katcher, 2003; Taylor & Signal, 2005), but the *umwelt* approach can emphasize the different sensory worlds of diverse species and mitigate the tendency to compare animals to humans (de Sa-Nogueira Saraiva, 2006). While this may not specifically relate to our recommended framework, as an overarching principle, acceptance of *umwelt* may expand willingness of a general public to consider the framework to organize their thinking.

This approach can facilitate discussion of how continuity of cognitive abilities across animal species influences willingness to accept perceptions of animal minds, while at the same time revealing how different members of the public might understand the differently evolved sensory and perceptual worlds of animals. We exclude *umwelt* as a framework dimension but anticipate that discussion of this point in both fields can contribute to new knowledge about each dimension within the framework.

Lastly, despite the number of articles on animal cognition in scientific journals, the popular media has become a main source for public information about animal minds. An examination of articles depicted in media sources revealed that the popular press continues to have a vast appetite for science articles presenting stories of animal cognition as isolated facts (e.g., Bryner, 2009; de Seve, 2001; Kluger, 2010; Lewin, 1987; Linden, 1993; Morell, 2008; Penisi, 2006; Sayre, 2006; Schmid, 2009; Sloan, 2009; Tennesen, 2009). For example, our review of print and online articles for magazines such as *Time*, *Discover*, *Scientific American*, and *Science World*, identified recent findings with little if any discussion of the significance of these findings to science or how this information can enhance the public’s understanding of the continuity of cognitive abilities across humans and other animals. A few articles, such as “Are we in Anthropodenial” (de Waal, 1997) and “Think animals don’t think like us? Think again” (Pepperberg, 2009) were both written by eminent researchers, but only the titles appear to hint at the importance of the findings and the potential of the results to change public perceptions of animal minds. Therefore we assert that what people read in the popular media will continue to be a mitigating factor influencing the public’s perceptions and beliefs about animal mind. As such we believe the media’s potential and how it is used should be a point of great consideration amongst scholars and laypeople alike.

Future Research and Implications

We do not anticipate that this taxonomy represents definitive recommendations for research in either discipline, but rather, as a common concourse that will allow each field to offer benefits to the other and to facilitate public understanding of the science by helping to organize the information. We believe future studies can expand the evaluations of animal minds to investigate perceptions of the missing dimensions with an eye to broadening both scientific knowledge and to inform public discourse in ways that can aid in reasoned policy decision-making. As such, this framework represents only the beginning of detailed examination into how animals’ minds are perceived when they fall within categories such as wild, domestic, pet, and pest that are subjects of human choice and public policy.

Beyond application of this framework, we also believe that transdisciplinary research in the fields of comparative animal cognition and BAM will benefit from the study of where and how the public derives information about animals and their mental abilities. Improving the specificity of the cognitive dimensions for social science study and grounding that work in an assessment of animal cognitive research and media portrayals, will help reveal a more accurate understanding of how perceptions of animal minds are shaped. We suggest that parallel studies of public perception and animal research can help inform how an ongoing project is conceived of and communicated to the public and help the public understand emerging evidence from the cognitive research. But to do this, it would require that researchers in both fields be open to the methods and practices in other disciplines. And lastly, as an ethical responsibility, we imagine that this collaboration can ensure broad scale dissemination of findings in ways that are most easily conceived by a public so the benefits of the research inform and shape animal welfare, management and conservation policy.

The implications for how the public conceives and understands animal minds are of direct relevance to the field of animal cognitive research. Disregard or diminishment of animal cognitive and emotional capabilities can lead to significant deprivations that can harm animals and the perceptual worlds they inhabit (Cole et al., 2009; Herzog, 2010). The conceptual frames in which we situate various species influences both direct treatment of animals and policies that can have more extended effects on biodiversity loss and overexploitation, and can lead to habitat fragmentation by disrupting animals' perceptual understanding of space.

As scientists, we have an obligation to the participants of our studies to communicate our findings to the broadest possible audience including other scientists, policy makers and the public. Although we did not address how perceptions of animal minds can influence the moral consideration of animals in this paper, we recognize that presentation of animal cognition knowledge may have important implications for what people attribute to animals' minds, animal use, and animal welfare. Indeed, as new findings come to light, examination under this rubric may help determine whether there is a relationship between research findings and changes to the moral consideration people show toward specific types of animals. Whether our scientific results are applied to advocacy on behalf of the animals or not, we urge scientists to value their participants by making efforts to ensuring the greatest impact of their research. To this end, we are hopeful the framework we have proposed will facilitate the pursuit of knowledge and utility of scientific studies in both the animal cognition and BAM disciplines, so that more informed and educated decisions can be made in the future.

CONCLUSIONS

The framework we propose here is a first attempt to align two distinct, yet related, research fields. The purpose of this framework is two fold: first to facilitate further research within and between these two fields of study, and second, to promote the transmission of this knowledge to the general public. Toward that aim, we demonstrated the need for a transdisciplinary focus where animal cognition researchers and social scientists can collaborate to advance both fields and work to enhance public knowledge and the understanding of animal minds. We identified areas that can be improved to aid in the development of more in-depth analyses of public perceptions of animal minds and noted the importance of the media in helping to achieve these aims. We hope this paper will contribute to the advancement of policy and ethical decisions concerning the animals upon which we depend, even those that are frequently considered competition or those that are often overlooked. Ultimately, however, the use of this framework provides a new approach to evaluating perceptions of animal minds that may contribute to a better understanding of how minds have evolved, and what this knowledge means to human-animal relations.

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Summary of Reviewers' Critiques

In the following section, we offer a summary of the critical reviews in the hope that this information might help others who wish to build on this work.

We were heartened by the encouragement we received from the editors at a leading peer-reviewed journal and the positive feedback offered by the reviewers. Four of the reviewers felt the article contributed value to the field and was a worthwhile effort. Despite these generally supportive statements, the following were considered significant criticisms that led to the paper being declined for publication:

Framework Criticisms:

- There were some concerns about the coherence of the nine-category structure. Certain categories were considered to have overlap or were described as lacking sufficient clarity. Two reviewers felt the final taxonomy was too heavily influenced by animal cognition research and did not reflect the nuance of the BAM literature.
- Reviewers suggested a more pointed criticism on the constructs that define the BAM literature with a focus on encouraging the more specific technical use of language.
- One reviewer felt there may be more agreement over terms such as social learning, navigation and tool use, than reported in the paper. This reviewer qualified their comment by noting that constructs such as memory, play, emotion, motivation and planning remain somewhat elusive as of this writing.
- Reviewers were concerned that some sources for discussions about awareness, self-recognition, consciousness, and empathy had evolved since the initial constructs mentioned in the paper, mentioning a recent publication:
- Leary, M. R. & Tangney, J. P. (2012) (Eds.), *Handbook of self and identity* (2nd ed., pp. 656-679). New York: Guilford.
- A reviewer noted the distinction between emotional continuity and cognitive continuity is not generally agreed. That reviewer noted that Japanese researchers did not acknowledge emotional continuity but did accept cognitive continuity.
- One reviewer argued that *tool use* was a restrictive behavior that did not inherently speak to the underlying cognitive mechanism because it fails to distinguish between naïve use and the capacity to use tools after being trained by humans.
- One reviewer dismissively suggested that the public would be best served by three simple categories: everything related to the cognitive abilities of animals; human-like cognitive capacities; and abilities humans share with other species.
- One reviewer was concerned that the discussion of Umwelt did not reference Jacob von Uexküll's research.
- Zentall has provided the most useful and complete taxonomy of social learning

Background Theory Criticism

- One reviewer commented that it is difficult to believe or understand that in fact these two fields are not communicating. That reviewer felt that the majority of researchers who engage in BAM research were either ethologists or comparative psychologists who were aware of the current research.
- That same reviewer felt that the paper was more biased toward categories from the cognitive psychology rather than a nuanced negotiation between the two fields. That reviewer felt an alternative taxonomy might emerge if more focus was given to the influence of popular culture has on research science. The reviewer suggested Waller, S. (2012). *Science of the monkey mind: Primate penchants and human pursuits*. In J. A. Smith & R. W. Mitchell (Eds). *Experiencing animal minds: An anthology of animal-human encounters*. New York: Columbia University Press.
- Two reviewers were concerned that the language used in both fields has had to contend with a great deal of ambiguity since the field was founded, and will likely continue irrespective of the efforts made to bring clarity to the topic.
- One reviewer was concerned that many of the studies of public understanding of animal cognition reveal that the average person has little knowledge on the topic and tend to default to a linear scale unless they have topical knowledge. That reviewer drew attention to the issue as addressed by the Rasmussen, Rajecki & Craft (1993) paper referenced in the text and by Hodos, W., &

Campbell, C. B. G. (1969). *Scala naturae*: Why there is no theory in comparative psychology. *Psychological Review*, 76, 337-350.

- A reviewer felt that the paper's recommendation that social scientists should adopt terms used by animal cognitive research had already begun, referring to one cited text and again referencing Waller's essay.
- One reviewer felt that the paper did not make a strong case that the BAM literature was distinct enough to be treated as a separate discipline.
- A reviewer seemed concerned that the mention of convergence across taxa did not reference two specific publications that find similarities between cetaceans and primates, and convergent evolution in corvids and apes.

AUTHORS' NOTES ON THE REVIEWS

We appreciate the careful attention that the reviewers brought to this question and have used a number of their comments to refine or clarify arguments in this publication. We have also incorporated a number of the new publications offered by our reviewers that were not published during the development of the paper.

The vast majority of the work that led to this paper was undertaken between 2008 and 2010, a period where many other exciting parallel efforts to look across the two fields seemed to have occurred. In August 2011, we received a useful and instructive review from a peer-reviewed journal and completed the revision of the paper published here in summer 2012 when it was re-submitted for peer-review and received the commentaries summarized here. As a result, we decided to self-publish this paper and hope that our efforts continue to add focus to this conversation.

We dispute the comment that the majority of researchers working in the Belief in Animal Mind arena are also undertaking empirical research into animal cognition. We fundamentally disagree and stand by our review of the literature which found that the pedagogical stance of the two fields is starkly different and that there is little conversation between these two areas of research. The deficit model of public knowledge rather than a more expansive attempt to understand human reasoning remains a challenge that is exacerbated by the ambiguous jargon that exists within the cognitive psychology field. While the BAM literature may focus on the metacognitive level, the efforts by the authors of this paper and others who work on understanding why human reasoning discounts animal thinking are distinctly different pedagogies that continue to be referred to

pejoratively as "soft" by those involved in experimental studies with animals.

We were heartened by the suggestion that our transdisciplinary approach appeared biased toward using the "hard science" as a guide. We note that our taxonomy did use this strategy because cognitive psychologists have a much more complex description of what is known about animal thinking, while the social sciences have tended toward more reductive descriptions. This is a deficit in BAM that we propose should be addressed.

In writing this note, we feel it important to describe our writing process. Half of our writing team work almost exclusively in animal cognitive science research, while the other half work exclusively on the study of human reasoning. As a collective, this writing effort was challenging because we saw deficits in each other's fields and how language was used. Pedagogically, we agree that there is a great need to consider how popular culture influences what is pursued in science or shifts how information that emerges in research informs our understanding.

We remain disappointed that the reviewers accept ambiguity as an impasse and we cannot overemphasize our own frustration at how words are used indiscriminately, that thinking, cognition, mentation are treated equally in the field. Despite our own frustration with this ambiguity, we cannot agree that this ambiguity should be allowed to continue. For those in the BAM field in particular, the ambiguity may be acceptable to those in academia but it presents a persistent barrier to public understanding of the literature, which will have direct impact on the advancement of reasonable policies and public behavior toward animals that respects the full range of cognitive processes of animals who fall within our sphere of influence.

As authors, we elected to focus our paper exclusively on the factors related to empirical study of animal minds rather than the broad range of thinking about animal cognition. We elected to ignore issues of animal emotions, spirituality, telepathy, or metaphor as social influencers. While important to the BAM literature, our focus was exclusively on identifying factors that can promote public understanding of the cognitive scientific research. We believe that animal cognitive researchers have an ethical responsibility to the individuals and species they study. We believe that cognitive psychologists have an ethical responsibility to ensure their research is understood by the general public, and that their findings have the greatest potential to influence human behavior and public policy in ways that benefit the animals and species they study. Our attempts in this paper were to suggest that the study of animal thinking in

isolation from public perception may benefit the scientific enterprise, but failure to act on that new knowledge has moral challenges that we feel need redress. Hence, we publish this paper in the hope that animal cognitive scientists undertake a more critical perspective on their own publication records, their reporting, and how they can ensure that they are fulfilling the moral promise to the species they study by focusing on how to develop communications strategies that can achieve the highest level of adoption in public discourse.

With regard to the note that a reviewer felt we had not addressed the zoo and aquarium literature, this comment took us by surprise. As authors, we have many years experience working in zoo and aquarium field. The reviews helped us realize we may have been so aware of our own bias that we may have ruled out research that we considered common knowledge. We apologize for these oversights of the work by our colleagues and can only hope that scholars who choose to build on our work may redress our failings.

We noted in our paper that early BAM literature did tend to consider the linear understanding of cognition and we did reference this issue in the paper. Our own work explicitly challenged this bias. We undertook research that sought to challenge the linear reduction that emerges through the use of surveys and other quantitative methods (see Fraser et al., 2006; Knight, Nunkoosing, Vrij & Cherryman, 2003; Knight, Vrij, Cherryman & Nunkoosing, 2004; Knight & Barnett, 2008; Knight & Herzog, 2009; Knight, Vrij, Bard & Brandon, 2009; Knight, Bard, Vrij & Brandon, 2010; Maust-Mohl, Fraser & Morrison, 2012; Sickler et al., 2006). In particular, our research into public understanding of dolphin cognition using Q-Methodology explicitly challenged that assumption and revealed that the public does have quite complex and nuanced ways of thinking about cognition, despite the results reported from many positivist surveys. We hope that others continue to delve deeply into human reasoning processes about animal cognition and how evidence is negotiated to expand this area of research. Clearly, a paper that seeks to engage people from across the disciplines will not achieve its goals if it takes as strident a stand on what remains a rather narrow field of study, but we hope others will build on our work.

Lastly, we are concerned that some reviewers hoped we would account for every possible variation in the literature. Our goal was to identify the broad modes of thinking about the empirical data and elected to omit a vast number of papers that focused narrowly on one species or elaborated a general theme. We also elected to omit some research when it moved beyond reliable empirical evidence of cognitive ability or when the authors' actions have brought discredit to their work through misrepresentation or overstated claims. Since

the age of Clever Hans, the research continues to build on a solid foundation, and there continues a rather uncomfortable tradition of researcher emotion and bias having the potential to attempt to change policy at any cost, factors that call all researchers' findings into question.

We were grateful for the reviews and guidance offered as part of the peer-review process and hope that others can challenge our assumptions in order to advance both fields for the benefit of public understanding and the animals with whom we share this planet.

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