Editorial: Animal Cognition, Past Present and Future, a 25th Anniversary Special Issue

Debbie M. Kelly (University of Manitoba) & Stephen E. G. Lea (University of Exeter)

Twenty-five years ago, *Animal Cognition* released its first volume. This new peer-reviewed journal sought to fill an open niche in scientific publishing for studies "investigating how animal (including human) minds function and how they evolved" (p.1). The inaugural editor, Tatiana Czeschlik, declared that the scope of this new journal was to publish studies that sought "to establish the course of the evolution of 'intelligence', of the mechanisms, functions, and adaptive value of basic and complex cognitive abilities – the evolution of intelligent behaviour and intelligent systems from invertebrates to humans." (Czeschlik, 1998, p.1) The manuscripts published in the first volume, which comprised of two issues, supported this aim by including publications reporting on theoretical positions, such as an argument by Griffin (1998) that the study of animal behaviour and cognition must be expanded to include an organism's conscious experiences or Benhamou's (1998) configuration-based model of place navigation by mammals, as well as the results of empirical works, including studies examining whether stimulus preexposure would influence problem solving abilities in octopus (*Octopus vulgaris*) (Fiorito, Biederman, Davey & Gherardi, 1998), the tracking and updating of visual information by young chicks (*Gallus gallus*) (Vallortigara, Regolin, Rigoni & Zanforlin, 1998), if chimpanzees (*Pan troglodytes*) are capable of using human gaze when searching for the location of hidden food (Call, Hare & Tomasello, 1998), and on a related topic, whether dogs (*Canis familiaris*) could use cues given by humans to locate hidden food items (Miklósi, Polgárdi, Topál & Csányi, 1998).

In celebration of the journal's 25th anniversary, we (as present and past Editor-in-Chief) endeavoured to invite contributions from authors who published in the first volume of *Animal Cognition* and continue to influence the field, alongside researchers with international reputations as established or rising leaders in the study of animal cognition. As this is a single issue dedicated to the anniversary of *Animal* Cognition, out of necessity we were unable to include many deserving individuals who have contributed to the field of animal cognition through their exemplary foundational or ground-breaking research. We hope this issue serves as a spark that ignites submissions for further empirical research articles, commentaries or dedicated special issues arising from the thought-provoking ideas communicated through the publications within this anniversary special issue.

In honour of Tatiana Czeschlik's direction, we have organized the manuscripts within this issue roughly in accordance with the five areas that she proposed, in her inaugural editorial, needed further development. As Beran (2023) notes in his contribution to this issue, some of them call for yet further development in the next twenty-five years, but we believe that we have progress to report at the present anniversary, and that the papers in this issue (including Beran's) demonstrate these achievements.

1. **Theoretical models and theory-derived hypotheses.** Czeschlik (1998) argued that theoretical models and theory-driven hypotheses on the evolutionary roots of "intelligence" was needed, and although this issue contains several manuscripts directly addressing this concern, we have chosen to use a broader theme to include those that may only tangentially consider evolution to permit a broad range of topics to be explored.

    This issue starts off with a contribution authored by Michael Tomasello. Along with his colleagues Josep Call and Brian Hare (Call, Hare, & Tomasello, 1998), he published a three-part study investigating whether chimpanzees would use a human's gaze to find hidden food items in the first volume of *Animal Cognition*. In his current contribution, Tomasello (2023) reflects upon a broader theme in primate cognition through his review on the progress in Great ape social cognition and metacognition. Using this foundation of knowledge, Tomasello proposes a theory that describes how social cognition and metacognition may be evolutionarily related. In the present issue, Benson-Amram, Griebling and Sluka (2023) provide a compelling argument in their review that, although many studies of animal cognition have historically focused on primates and birds (also see Section 2 below), Carnivora will provide a distinct opportunity critical for testing of evolutionary hypotheses as well as much needed laboratory and field comparative studies.

Philosophers and cognitive scientists have debated whether cognition extends beyond the brain, not only to the body but the environment surrounding an organism. Questioning "*what is cognition"* (and what is *not* cognition) is a fundamental question to the area of animal cognition – and a topic we will return to at the conclusion of this editorial. In the present issue, Lucia Jacobs (2023) adopts the 4E cognition framework of philosophy to explore the implications of embodied cognition for olfactory cognition, and in doing so presents the PROUST (Perceiving and Reconstructing Odor Utility in Space and Time) hypothesis, which includes proposing a fifth "E" – that of evolution.

Studies of animal cognition often question what *representation* is present in the brain that supports the behavior or cognitive processes under investigation. In the current issue, Ken Cheng (2023) reflects on his research journey, which started with explorations to understand the representational content of a navigating animal (initially focusing on rats and pigeons), but further developed into a conceptualization of navigational servomechanisms. Cheng builds on this view by proposing that these servomechanisms modulate the performance of oscillators that propel movement. Exploring the interaction between oscillators and servomechanisms provide fertile ground for understanding processes beyond navigation.

The study of representations in orientation and navigation are further examined by Lee (2023) in the, with an exploration of how spatial boundaries provide structure for both space and time. Building on early research on geometric representations by Cheng (1986; also described by Cheng 2023), Lee reviews select comparative research to elucidate the connection between spatial mapping and temporal sequencing.

The differentiation between human cognition and nonhuman cognition is central to the history of comparative psychology and continues to be evident in studies of animal cognition. Hoeschele and colleagues (2023) argue in the current issue that human cognition, and our own introspective experience of it, are fertile sources for hypotheses about animal cognition – but that we need to use such hypotheses with an open mind, not least because introspection is an unreliable guide to the facts even of human cognition. An example of this process can be seen in the paper by Kacelnik, Valconcelos and Monteiro (2023) in the current issue. Kacelnik et al use ideas drawn from economics and the study of human decision making to devise elegant experiments that lead to clear conclusions about an aspect of animal cognition, in their case showing that choices made by European starlings depend on valuations learned previously, rather than value comparisons made at the moment of choice. Not dissimilarly, Lemaire and Vallortigara (2023) in their contribution to the current issue use the literature on the development of animacy perception in human infants to guide experimentation on how newly hatched chicks respond to similar visual stimuli.

Concept learning and categorization has certainly been an area of comparative interest shared among researchers interested in human and animal cognition (e.g. Castro et al. 2015; Brooks et al 2022). In the present issue, Mercado and Scagel (2023) present an argument that an important component of concept learning, supporting why many species fail to show a capacity to form "higher-order" relational concepts, may depend on an ability to shift attention. Birds, and historically pigeons, have been the subject of considerable study when it comes tom concept learning and categorization. Pusch, Clark, Rose and Güntürkün (2023) not only present an excellent complementary review of this literature for the current issue, but they also link the perceptual and cognitive research to the neuroanatomical and computational mechanisms supporting these cognitive abilities in birds; their review supports the need for ongoing comparative avian research to build a stronger foundation of knowledge informing our understanding of concept learning and categorization.

2. **A larger number of species.** The study of animal cognition has historically been criticized as a field for concentrating on only a few species (e.g. Beach 1950, Shettleworth, 1993, 2009). One aim in developing *Animal Cognition* was to address this weakness.

As a proxy to visualize whether the range of species under investigation has changed, we counted the number of articles published, using general groupings (not meant to reflect proper animal classes) within a five-year period (keeping in mind special issues published during this time may cause biases in species represented for single years; see Figure 1). Although the graph below is only meant to highlight patterns of changes over the years, it does suggest that the number of species is likely increasing.

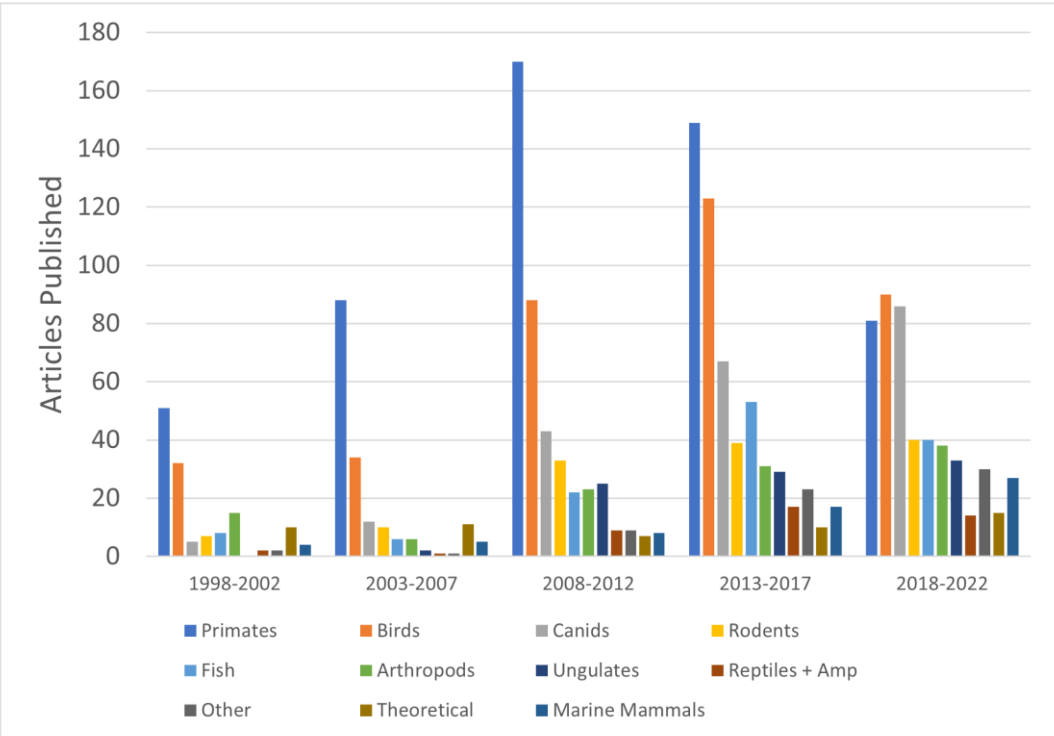

Figure 1. Number of articles published, within five-year periods, from the first issue of *Animal Cognition* through to mid-2022. Note that the graph is not intended to reflect proper grouping, as orders and classes are presented.

Some of the papers in this special issue reflect this drive to widen the range of species whose cognition we study and report the fruits of that endeavour. One can clearly see that when *Animal Cognition* began studies of fish cognition were limited, but there is now a substantial body of work (see Brown, 2015). Most of that was on the larger class of fishes, the bony fish. However, in the present issue, Brown and Schluessel (2023) summarise research on the cognition of the other class of fish, sharks and their relatives. Within the present issues, one may also return to the review of Benson-Amram and colleagues (2023) for another excellent of an area of animal cognition research which has seen an increase in the diverse taxa under study Another way in which the range of species studied is extended is by consideration of applied questions; in the present issue, Ghosh, John and Wilkinson (2023) consider how the study of cognition could support the use of biological methods of pest control, and that leads them to report on numerous species that are making their first appearance in our journal.

The comparative approach is a fruitful method for increasing the number of species studied (as well as for developing theory-driven hypotheses on the evolutionary roots of cognition). Roessler and colleges provide an updated review of parrot cognition. Extending upon a recent review in this area by Lambert and colleagues (2018), Roessler et al., report that more than 50 studies on parrot cognition have been published in the previous four years. Many of these studies have taken a comparative approach permitting the study of species differences in areas such as inhibitory control, flexibility, memory, or problem-solving.

Vanhooland, Szabó, Bugnyar and Massen (2023) in the current issue likewise use the comparative method to evaluate self-recognition in birds by examining three corvid species. Documenting the behaviours these corvids engaged in when presented with a mirror and using a modified version of the Mark task (Gallup, 1970), the results support an ongoing need for comparative studies to evaluate whether current differences in self-awareness among species are due to phylogeny or methodology. Our updated understanding of the avian brain (see Pusch et al. 2023) will undoubtedly drive further insights into this important area of animal cognition.

3. **Methodological improvements and innovations as well as ingenious field and laboratory experimental setups complementing each other are needed.** Clearly related to the aim of increasing the number of species represented in the study of animal cognition, is the need for innovative and novel methodologies. The development of these approaches and apparatuses may be for different purposes. For instance, the study of biological pest control (Ghosh et al. 2023), ecological relevance (e.g., see Benson-Amram et al., current issue, anthropogenic impacts anthropogenic impacts (see special issue *of Animal Cognition 2017 Issue 1*: *Animal Cognition in a Human-Dominated World*, introduced by Griffin et al. 2017), animal-human interactions (see special issue *of Animal Cognition 2021 Issue 2*: *Animal-Human Interactions,* introduced by Kelly and Katz 2021) or comparative investigations of cognitive processes in natural and human-made environments to highlight only a few of the many possibilities.

The study of avian food-storing is one such area where researchers have developed novel methodologies to investigate the behaviour, cognition, and neuromechanisms underlying spatial learning and memory. Healy (2023) provides the current issue with a comprehensive review of this area and proposes the study of avian nest building as a fruitful area for future innovative research linking the study of cognition in the laboratory and the wild.

A further exciting avenue for animal cognition is through insights from artificial intelligence and computer science. Abdai and Miklósi (2023) argue strongly in the current issue that new robot technology offers unique advantages for the study of cognition, allowing controlled simulation of social situations in a way that has not been possible until now.

Scientific controversy is of course a great driver of methodological innovation. In the present issue, Huber and Lonardo (2023) review studies of one area that has been highly controversial, the capacity of dogs to understand the world from another's perspective, and lay out the sequence of methodological refinements that have gradually narrowed down, if not eliminated, the scope for argument between researchers on this issue. Rather similarly, in their contribution to the current issue, Gazes, Templer and Lazareva (2023) show how increasingly sophisticated experimental techniques lead them to the conclusion that animals have available a unified, domain-independent, representation of order.

4. A wider range of situations demanding cognitive processing need to be sampled for the same individuals, and in particular laboratory and field studies need to be linked.

The natural bridge between field and laboratory studies is the field experiment – creating artificial cognitive challenges for animals living in their natural environment. Such techniques were in use well before we began to think of them as involving animal cognition (e.g. Croze, 1970). Throughout its existence, *Animal Cognition* has published many such studies, on species ranging from chimpanzees (e.g. Biro et al. 2003) through songbirds (e.g. Tvardikova & Fuchs 2010) and lizards (Pérez- Cembranos & Pérez- Mellado, 2015) to arthropods (for examples see the special issue of *Animal Cognition 2020 Issue 6, Arthropod Spatial Cognition,* introduced by Pfeffer & Wolf 2020). In the present issue, these links are perhaps best exemplified by Freas and Spetch's (2023) review of spatial navigation in insects, which highlight the ingenious studies reporting the flexible and adaptable use of spatial cues for orientation and navigation.

5. Studies with larger samples are also needed to assess the extent of inter-individual differences in cognitive abilities.

Individual differences in animal cognition have become a major field of study during the lifetime of the journal, particularly with an ongoing search for any kind of general intelligence that might underlie performance in multiple cognitive challenges (see Shaw and Schmelz 2017; Cauchoix et al 2018). In the present issue, we see attempts to go beyond merely establishing that such consistent differences exist, whether on a single task or in a correlated fashion on many, to the arguably more important question of what causes them. One stellar example of this initiative is Brubaker and Udell's (2023) work to consider how the style of relationship between dogs and their owners might influence the dogs' performance in cognitive tests. Many investigations into animal cognition must contend with the challenge of sample sizes, which may limit the study of inter-individual differences or cause concerns or replicability; we return to this topic below.

The process of co-editing this anniversary issue not only provided us with an opportunity to reflect upon empirical research, theoretical approaches, and area reviews presented by our colleagues. This process has also permitted us the venue to consider these works within the wider perspective of the field as a whole. In particular, several of our authors posed the question, implicitly or explicitly, of just what we mean when we use the phrase "animal cognition"; and in reviewing their contributions, we found ourselves asking the same question. This anniversary issue seems a good moment to try to answer it. To do so, we look first at some history, and then at some possible definitions – particularly definitions that have implicitly guided us, and might help guide future authors and editors, as to what belongs in our journal.

A bit of history

If we go back not 25 years but 50, to when one of the present authors was a PhD student, no-one was using the phrase “animal cognition”. Nonetheless, there was and had been for a long time a conflict between what we would now call more cognitive and more behaviouristic accounts of animal learning, particularly focused around animal problem solving. That conflict goes back at least to the different approaches of Conwy Lloyd Morgan (1852-1936) and George Romanes (1848-1894): the history has been well described by Boakes (1984). The fundamental difference of approach between these two pioneers continued to structure research on animal learning throughout the first half of the twentieth century, with the debate between different theories of learning, from the more behaviouristic such as those of Hull (e.g. 1943), Spence (e.g. 1956), and Mowrer (e.g. 1960) to the more cognitive, such as those of Krechevsky (1932) and Tolman (e.g. 1932). Fifty years ago, there were still echoes of these disputes. But by then, the big theoretical debate lay between Skinner’s “radical behaviourism” (e.g. 1950, 1969) and anyone who wanted to say anything at all about the processes underlying animal behaviour.

To someone coming into the study of animal learning at that time, this seemed a lopsided and frustrating situation. No coherent alternative framework to radical behaviourism was on offer, and attempts to show that particular phenomena in animal behaviour could not be understood in behaviouristic terms seemed negative and, ultimately, sterile. And yet radical behaviourism seemed unable to capture some of the most interesting phenomena that could be studied, and were already being studied – even though a large majority of researchers were using essentially Skinnerian methodology, rather than the mazes and puzzle boxes that had been the common tools of earlier decades.

The 1980s saw a sudden change of direction. In a short space of time, a number of books with rather similar titles appeared, such as Mellgren (1983, *Animal cognition and behavior*); Walker (1983, *Animal thought*); Roitblat, Bever & Terrace (1984, *Animal cognition*); Pearce (1987, *An* *introduction to animal cognition*); Gallistel (1992, *Animal cognition*); Vauclair (1992, *L'intelligence de l'animal*; English translation 1996, *Animal cognition*); Zentall (1993, *Animal cognition*); Gould & Gould (1994, *The animal mind*); Balda, Pepperberg and Kamil (1998, *Animal cognition in nature*); Roberts (1998, *Principles of animal cognition*); Shettleworth (1998, *Cognition, Evolution and Behavior*); Wynne (2001, *Animal cognition*): Bekoff, Allen & Burghardt (2002, *The cognitive animal*). Small wonder, then, that 1998 also saw the first issue of this journal.

Obviously, these books had considerable overlap in content; indeed, several of them were edited books, and there was overlap in contributing authors, too. Nonetheless, this burst of publishing bore witness not just to a substantial and widespread upsurge in activity, but also to a widespread reconceptualisation of what researchers were doing. It bore, in fact, a lot of the marks of the kind of scientific revolution discussed by Kuhn (1970), where once a new way of looking at a scientific problem is formulated, many researchers realise that what they have been doing for some time fits that new paradigm.

As you would expect, however, what all these authors had been doing beforehand differed, and accordingly what they described as "animal cognition" also differed. For example, Pearce, coming from a background of theoretical modelling of classical conditioning (e.g. Pearce and Hall, 1980) dwelt on the need to include representations of stimuli in such models; Vauclair, coming from the francophone environment and work in developmental psychology (e.g. Vauclair, 1984), stressed the role of Piagetian tasks in assessing animals' cognitive performance; while Shettleworth, coming from research on biological constraints on learning (e.g. Shettleworth, 1975) looked for the evolutionary origins of such performances.

So why did these different approaches cohere so quickly into a recognizable field of study, with the common label, "Animal cognition"? We suggest there were two reasons. First, that label offered a way out of sterile debates with ideologically committed radical behaviourists, and the unanswerable question of whether behaviour is simply governed by conditioning, or whether more complex processes need to be invoked. Taking the label "Animal cognition" signalled that we were setting that debate aside in order to look at the phenomena with an open mind. Secondly, it suggested a general methodological approach: to take performances that we label as cognitive when humans do them, and see whether animals of different species can do anything similar – either in their natural environment, or after specialist training. This approach has wide applicability, and further circumvents any debate with radical behaviourism – because a rigorous behaviourism believes that what is described as cognition in humans can also be explained by conditioning processes (e.g. Skinner, 1969).

A third factor was also important. Revolutions do not occur in isolation. The emergence of animal cognition followed shortly after, and built upon, the widespread realisation that there was a need to bring together historically biological, and historically psychological approaches to animal behaviour. Some of the first encounters between these two approaches were confrontational; Lorenz was frequently highly critical of hypothesis-driven laboratory science and comparative psychologists' lack of expertise in the animals they studied (e.g. Lorenz, 1950, 1979). But later generations of behaviour researchers, schooled in both approaches, soon realised that there were important synergies between them (Lea, 1985; Balda et al, 1998). To study animal cognition is to recognize that it may look different in different species, and that those differences may have an adaptive explanation. The idea of such "niche-specific cognition" has remained controversial (e.g. Macphail & Bolhuis 2001; Bolhuis 2015), but it is still regularly deployed (e.g. Lucon-Xiccato & Bisazza 2016; Pull et al. 2022), as it is by authors in the present issue, e.g. Brown and Schluessel (2023). And the general proposition that different evolutionary niches set different challenges is unarguable, and studying cognition has therefore become an important part of understanding how animal species are adapted to their unique ecological niches.

Thus, there were good reasons why a field of study called animal cognition could emerge in the 1980s. It would hardly have done so, however, if there had not already been a field of study called "cognitive psychology", and it may be surprising to realise that that term was also the product of a Kuhnian revolution, and one that had occurred not many years before. The phrase was scarcely in use until Neisser (1967) published a book with that as its title: a book that, as the author recognizes in his Preface and Introduction, is as much a manifesto as a textbook. The speedy adoption both of the term and of the research approach Neisser advocated was recognized as revolutionary almost immediately (Gardner, 1985).

That is not to say that no-one had been studying cognition, of course. Indeed, the term "cognition" has a long history in philosophical psychology, as part of a tripartite classification of psychological phenomena into those to do with affect or emotion, conation (will or motivation) and cognition. Hilgard (1980) traces the history. He shows how, in the 18th century Scottish and German mental philosophers thought of these as three distinct faculties or capacities of the mind, but by the end of the 19th century authors like Alexander Bain (1818–1903) and William James (1842-1910) were using the terms simply as a convenient classification of mental phenomena. Perhaps not recognizing the revolutionary effect of Neisser's work, Hilgard argued that the usefulness of this tripartite classification had come to an end; in fact, however, it is still regularly referred to; a search in Web of Knowledge revealed nearly 400 papers referring to it that had been published since Hilgard claimed it had been laid to rest.

The wide acceptance of the term "cognitive psychology" has been essential for the development of a research field called "animal cognition". All definitions and classifications are apt to leak around the edges, and there are certainly psychological and behavioural phenomena that bridge between affect, conation and cognition, and others that do not fit easily into any of those categories. But to a great extent, we can recognize what kind of phenomena we label as cognitive in humans; and that opens the way to asking the question of what kind of behaviour we see when we expose other animal species to the same tasks or problems.

The broad sense and the narrow sense of "animal cognition".

When we apply the tripartite distinction between affect, conation and cognition to animals other than humans, it leads to a broad sense of the phrase "animal cognition". In this broad sense of the word, animal cognition encompasses everything that enables past experience or current perception to guide behaviour. In many ways adopting this broad definition is in tune with Abdai and Miklósi's (2023) call in this issue, echoed by Kacelnik et al. (2023) also in this issue, to focus not on the mechanisms underlying behaviour, but the problems that the behaviour solves. And obviously, many of the problems animals face can be solved by simple mechanisms such as classical and operant conditioning; indeed, it has been argued that the reasons these mechanisms are so widespread in the animal kingdom is that they solve a key problem that almost all animals face, the need to forage approximately optimally (Lea, 1982). If this is our definition of animal cognition, it makes no sense to ask questions like, "Is it cognitive or is it just conditioning?" Conditioning is just one mechanism – maybe an all-pervasive mechanism, maybe not – underlying animal cognition in this sense of the phrase.

There is a danger in such a broad definition. It risks a degree of "cognitive bloat", to borrow a term from Kaplan (2012), discussed by Jacobs (2023) in this issue. Kaplan was concerned with the risk that "extended cognition", which takes account of the effects of environment, sensory and motor capacities would end up with everything, and therefore nothing, being classed as cognition. The same could be said of including even the most obvious cases of conditioning within animal cognition.

But, in any case, if this broad sense is all that is meant by "animal cognition", it would be hard to explain the surge of books with that phrase in their title during the 1980s, or the need to found a journal with that as its title in 1988. There was no shortage of books about how animals learn, and no shortage of journals where studies involving conditioning could be published. We suggest that this minor revolution was due to a widespread impatience with the need to explain everything that animals do in terms of conditioning, or even to discuss whether it could be explained by conditioning at all – an impatience that is still felt, as by Beran (2023) in this issue. There was and is a feeling that, in some situations where animals solve problems, something other than simple association is going on.

That feeling derives, at least in part, from our subjective experience as humans. Humans can certainly undergo both classical and operant conditioning. But, subjectively, we also experience an active mental life, in which we are aware of how we are solving problems and of what problems we have solved. There are many situations where humans seem to have two modes of response in an experiment, one of which can easily be described in terms of associative learning, and the other of which cannot (e.g. Meier, Lea & McLaren, 2016). Outside the realm of science, people regularly attribute the same kind of mental life to animals. Within the realm of science, it has been an enduring question whether such attributions can be justified. This suggests that a narrower definition of "animal cognition" might be that it studies those means other than conditioning by which animals solve problems.

Two warnings need to be heeded before we adopt such a definition. The first is well expressed in this issue by Hoeschele, Wagner and Mann (2023). Human subjective experience is a good source of hypotheses about animal cognition but a poor source of data about human cognition. Cognitive psychology is replete with examples where people's introspection comes up with completely false descriptions of how they were solving problems: although the pioneering studies of Nisbett and Wilson (1977) have been criticised, the general phenomenon stands (e.g. Johansson et al., 2006). Secondly, the opposition "association vs cognition" is potentially naïve. Often when human behaviour differs from what is predicted from simple conditioning, it is because humans are using symbolically expressed rules to determine their behaviour (Penn, Holyoak & Povinelli, 2008). But a sufficiently determined associationist can adopt such rules as discriminative stimuli in a conditioning process (e.g. Skinner 1969). It seems it would be poor tactics to restrict the realm of the truly cognitive to phenomena where no trace of conditioning can be postulated.

But if we follow the positive side of Hoeschele et al.'s recommendations, what hypotheses might we come up with? How might we define "animal cognition" in a way that does not rely on excluding conditioning, but does capture our intuition that there are processes more complicated than conditioning going on when some animals solve some problems? Reflecting on the history of studies in animal cognition, both before and after the term "animal cognition" came into wide use, we suggest that an interesting candidate would be the use of what we humans call "reflection": the capacity to weigh up a situation in our minds, and try out possible solutions. This seems to call for a capacity which, mischievously, we shall call a Cartesian Theatre, though not quite in the sense in which that term was contemptuously used by Dennett (1991, Chapter 5). For Dennett, the Cartesian Theatre was the (in his view, non-existent) point in the mind/brain where "it all comes together". For us, it is the capacity of the brain/mind to see (or, more generally, sense) and manipulate events that are not currently happening. You might call it "thinking" or "reasoning"; or, if you were Tolman (1938) you might call it "Vicarious trial and error" or even "non-practical runnings-back-and-forth (Tolman, 1932, Chapter XIII). You might think of it as what is happening in episodic memory (Tulving 1972) or episodic future thought (Atance & O'Neill 2001).

The intuition that lies behind all these different approaches is that, to a limited extent, we humans can view our current behaviour as if we were outside it; we can replay our past behaviour; we can imagine what we might do in future; we can view situations we have never been in and indeed situations that could never exist. And all that without moving a muscle. It is important to realise that this does not involve positing a homunculus who views current sensory input and decides what to do about it, falling into the trap of an infinite regress. The intuition is agnostic as to how we deal with current sensory input; it merely asserts that we can deal with imagined sensory input in the same way. It is also agnostic as to whether associative learning plays any role in the process, at any stage. What matters, as Hoeschele et al. recommend, is that we can use this intuition about human cognition to formulate hypotheses about animal cognition: do other animals appear, by their behaviour, to be using any of these kinds of reflective process when they are solving problems, whether those are the problems posed by their inherited ecological niche, or by us as experimenters?

An important aspect of our human intuition about the Cartesian Theatre is that we can view ourselves acting within it. However, analysis suggests that this possibility is logically separate from the capacity to reflect on states of the world that do not currently exist. Indeed, Hofstadter (1979, chapter XII) argues that using a symbol for the self involves significantly greater complexity than using other symbols. So we should not be surprised that the investigation of self-concepts in animals, in the tradition of Gallup (1970), is a distinct field of animal cognition, and that the existence of self-concepts can be seriously doubted in species to which we unhesitatingly ascribe other advanced cognitive capacities (Gallup & Anderson 2020).

To conclude our discussion of definitions, we believe that there are two useful, and usable, definitions of animal cognition. Unsurprisingly, the journal Animal Cognition has used both of them. One is broad, and it encompasses all the ways in which animals modify their behaviour as a result of experience. Such a definition is particularly useful when we are beginning the study of a new taxonomic group, a new problem (whether artificial or natural) or a new ecological niche, and the journal has been and should be hospitable to such investigations. But a narrower definition can also be useful, and we believe that “reflection” provides a useful cue to it. In this narrower sense, animals are using cognition when they are reviewing information that is not available in their current environment. And the journal has been and should be hospitable to investigations that are trying to find out whether particular animals use such reflective capacities when they are solving particular problems.

New methodological challenges

The problem of defining animal cognition is much older than the wide use of the phrase, and therefore older than our journal. But we turn now to mention briefly some methodological problems that have come to prominence within the lifetime of the journal. Like all problems, these are also opportunities – opportunities for research leading to new understanding.

Replication. A neighbouring field of research, social psychology, has suffered what has become termed the "replication crisis": it has appeared that some highly newsworthy and much-cited results do not reappear when the procedures are replicated (Pashler & Wagenmakers 2012). While the interpretation of single failures to replicate is complicated (Maxwell, Lau & Howard 2015), the most robust response to the apparent crisis has been to launch large-scale projects in which many different laboratories attempt replications of the same studies (Klein et al., 2014). While animal cognition has not yet suffered high profile failures to replicate, our field is clearly vulnerable to them: we do often produce newsworthy results, and our sample sizes are often unavoidably small. Some attempts have already been made to address this issue (e.g. Szabó, et al 2017). But it is therefore encouraging to know that the "many labs" approach of Klein et al. is already being adopted in our field, the first examples being the ManyPrimates, ManyBirds, and ManyDogs projects, which several of the authors of papers in the current issue are involved in (Many Primates et al 2019; Miller et al., 2021; ManyDogs et al, accepted). Beran (2023) in this issue suggests that the principle will be used on many other species in future. Alongside multiple-lab replication, pre-registration of studies, followed by publication regardless of whether positive results were obtained, has been strongly urged as a precaution against the "file-drawer" effect, including in animal science (e.g. Parker, Nakagawa & Gurevitch 2016). An additional means of enhancing transparency is making fuller details of experimental and observational procedures and results openly available, through data repositories, it is to be hoped that as digital storage becomes ever cheaper and more flexible, that will come to include complete video records, as advocated by Kampis et al (2010).

Subject-experimenter relationships. When we are looking not at the cognition animals show in the wild, but at what they can be trained to do (perhaps educated would be a better word), some of the most spectacular claims involve single subjects, or small numbers of subjects, with whom the experimenters have a close social relationship. This was true of most of the early attempts to teach apes language (e.g. Hayes & Nissen, 1971; Gardner & Gardner, 1969; Savage-Rumbaugh et al., 1986), and also in Pepperberg's work on language-trained parrots (e.g. Pepperberg, 1981). But it is also a feature of much of the work on cognition in cetaceans (reviewed by Herman 2010) and other sea mammals (see the special issue *of Animal Cognition 2022 Issue 5*: *Cognition in marine mammals: The strength of flexibility in adapting to marine life*, introduced by Hanke et al, in press), and in some of the most impressive demonstrations of dog cognition (Kaminski, Call and Fischer, 2004; Pilley & Reid, 2011). It is strongly and plausibly argued by experimenters using such procedures that the social bond between experimenter and subject is essential to the success of training (see, for example, Fouts & Mills, 1998 chapter 4; Pepperberg, 1999, chapter 2): without flexibility, social responsiveness and empathy in the teacher, animals' full potential as learners will never be manifested, just as children's would not be. But precisely those properties of sociality and flexibility make it very difficult to exert normal scientific control over the situation, and to ensure that artefacts such as the Clever Hans effect are excluded – even if, as scientists, we can avoid attributing more than the data strictly justify to animals with whom we have an emotional as well as a practical relationship. And though all the studies we have referred to have used carefully controlled test procedures to evaluate the effects of training, animals that are used to flexible, sociable interaction during training will not necessarily show their full ability when put into a more sterile test environment. Anyone who has ever sat an unseen examination should be able to understand that. It seems to us that this will always be a challenge when we are pushing animal cognition beyond its previously known limits. This means that as a scientific community we should be sympathetic to the pioneers, but also that we must accept that there may have to be follow-up studies with more closely-defined procedures, and that sometimes exciting pioneering results may be cast into a colder light when that is done.

The "natural" environment: The strong evolutionary emphasis within the animal cognition research community, exemplified by Shettleworth's (1998, 2010) influential reference text, has directed our attention to the cognitive feats animals show in their natural environment. But over the lifetime of our journal, the question of what some animals' natural environment might be has become crucial. Even when one of us was a PhD student, long ago, it was a standard joke that the natural environment of the laboratory rat is the laboratory. But it can be argued more interestingly that the natural environment of a pet dog is a human household, and working dogs and even street dogs (the majority of the world's dogs) live in some kind of mutualism with humans (Coppinger & Coppinger 2016). And dogs do not just live among humans, they have adapted to doing so, and it has been strongly argued that those adaptations include cognitive changes (e.g. Hare et al 2002; Kelly & Katz 2021). All farm animals also live mutualistically with humans, and some of the same processes may be at work in them; and as Figure 1 shows, it is not just research on dog cognition that has grown during the lifetime of our journal, but also research on cognition in groups like ungulates which include most of the species of agricultural importance. More widely, however, many animals now live in anthropogenic environments especially towns and cities, and the cognition of urban animals has been a rapidly growing research field (see Griffin, Tebbich & Bugnyar 2017). We also need to consider the cognition of animals that because of human activity find themselves in new environments, whether as invasive species (such as the Eastern grey squirrel, see for example Leaver et al 2007), or because humans introduce them to serve as pest controllers, as reviewed by Ghosh et al (2023) in this issue.

A conclusion for the time being

Animal Cognition has witnessed remarkable strides in our understanding of how animals reflect upon, respond to, and modify their behaviour based on experiences. The selection of articles presented in this issue and our own reflections reveal that the field has made considerable advances along the themes suggested by Tatiana Czeschlik 25 years ago. Several avenues continue to need attention, such as the study of inter-individual differences or comparative work of individuals across environments such as the laboratory and the wild. However, the field is witnessing the development of clever methodological procedures, advances in technology, and creative insight, which is allowing researchers address these issues. The trends that have been visible over the past 25 years of research in animal cognition will, without much doubt, continue into the next 25 years – as Beran (2023), in this issue has humorously explored. And yet, the future is necessarily unpredictable: not just because it always is, but because some of those trends themselves imply constant change. Continuing to expand the range of species we study, and the range of problems we challenge them with; continuing to exploit new methodologies and expanding technologies; and continuing to seek a deeper theoretical and conceptual understanding of what we mean by animal cognition – any one of those could lead to new information that provokes a revolution as significant as the one that led to the foundation of our journal. Perhaps the seeds of such a revolution are being sown even now; perhaps, indeed, within the papers that we have collected for this issue.

Inevitably, there are important topics, questions, and contributions that we have been unable to touch upon within the constraints of this editorial and the invited manuscripts published within the special issue. Nonetheless, we are honoured to present the work of our colleagues, who offer their expert studies, reviews, and thoughtful insights into the past, present, and future of animal cognition – both the field and our journal.

References

Abdai J, Miklósi Á (2023) After 150 years of watching: Is there a need for synthetic ethology? Anim Cogn 26

Atance CM, O’Neill DK (2001) Episodic future thinking. Trends Cogn Sci 5:533-539

Balda RP, Pepperberg IM, Kamil AC (1998) Animal cognition in nature. Academic Press, San Diego

Beach FA (1950) The snark was a boojum. Am Psychol 5:115-124 doi:10.1037/h0056510

Bekoff M, Allen C, Burghardt GM (2002) The cognitive animal. MIT Press, Cambridge MA

Benhamou S (1998) Place navigation in mammals: A configuration-based model. Anim Cogn 1:55-63

Benson-Amram S, Griebling HJ, Sluka CM (2023) The current state of carnivore cognition. Anim Cogn 26 doi:10.1007/s10071-022-01709-2

Beran MJ (2023) Congratulations to Animal Cognition on its 50th birthday! Some thoughts on the last 50 years of animal cognition research. Anim Cogn 26

Biro D, Inoue-Nakamura N, al (2003) Cultural innovation and transmission of tool use in wild chimpanzees: Evidence from field experiments. Anim Cogn 6:213-223 doi:10.1007/s10071-003-0183-x

Boakes R (1984) From Darwin to behaviourism. Cambridge University Press, Cambridge

Bolhuis JJ (2015) Evolution cannot explain how minds work. Behav Proc 117:82-91 doi:10.1016/j.beproc.2015.06.008

Brooks DI, Cook RG, Goto K (2022) Perceptual grouping and detection of trial-unique emergent structures by pigeons. Anim Cogn 25:717-729 doi:10.1007/s10071-021-01586-1

Brown C (2015) Fish intelligence, sentience and ethics. Anim Cogn 18:1-17 doi:10.1007/s10071-014-0761-0

Brown C, Schluessel V (2023) Smart sharks: A review of chondrichthyan cognition. Anim Cogn 26 doi:10.1007/s10071-022-01708-3

Brubaker L, Udell MAR (2023) Does pet parenting style predict the social and problem-solving behavior of pet dogs (*Canis lupus familiaris*)? Anim Cogn 26 doi:10.1007/s10071-022-01694-6

Call J, Hare BA, Tomasello M (1998) Chimpanzee gaze following in an object-choice task. Anim Cogn 1:89-99

Castro L, Wasserman EA, Fagot J, Maugard A (2015) Object-specific and relational learning in pigeons. Anim Cogn 18:205-218 doi:10.1007/s10071-014-0790-8

Cauchoix M, Chow PKY, Van_Horik JO, Atance CM, Barbeau EJ, Barragan-Jason G, Bize P, Boussard A (2018) The repeatability of cognitive performance: a meta-analysis. Phil Trans Roy Soc B 373:20170281 doi:10.1098/rstb.2017.0281

Cheng K (2023) From representations to servomechanisms to oscillators: My journey in the study of cognition. Anim Cogn 26

Coppinger R, Coppinger L (2016) What is a dog? University of Chicago Press, Chicago

Croze H (1970) Searching image in carrion crows. Z Tierpsychol Suppl 5:1-86

Czeschlik T (1998) Animal cognition: The phylogeny and ontogeny of cognitive abilities. Anim Cogn 1:1-2

Dennett DC (1991) Consciousness explained. Little Brown, Boston

Fiorito G, Biederman GB, Davey VA, Gherardi F (1998) The role of stimulus preexposure in problem solving by *Octopus vulgaris*. Anim Cogn 1:107-112

Fouts R, Mills S (1998) Next of kin. Penguin, London

Freas CA, Spetch ML (2023) Varieties of visual navigation in insects. In: (ed) Animal Cognition. ,

Gallistel CR (1992) Animal cognition. MIT Press, Cambridge MA

Gallup GG (1970) Chimpanzees: Self-recognition. Science 167:86-87

Gallup GG, Anderson JR (2020) Self-recognition in animals: Where do we stand 50 years later? Lessons from cleaner wrasse and other species. Psychol Conscious 7:46-58 doi:10.1037/cns0000206

Gardner A, Gardner B (1969) Teaching sign language to a chimpanzee. Science 165:664-672

Gardner H (1985) The mind's new science. Basic Books, New York

Gazes RP, Templer VL, Lazareva OF (2023) Thinking about order: A review of common processing of magnitude and learned orders in animals. Anim Cogn 26

Ghosh D, John EA, Wilkinson A (2023) Clever pest control? The role of cognition in biological pest regulation. Anim Cogn 26

Gould JL, Gould CG (1994) The animal mind. Scientific American Library, New York

Gould JL, Gould CR (1994) The animal mind. Scientific American Library, New York

Griffin AS, Tebbich S, Bugnyar T (2017) Animal cognition in a human-dominated world. Anim Cogn 20:1-6 doi: 10.1007/s10071-016-1051-9

Griffin DR (1998) From cognition to consciousness. Anim Cogn 1:3-16

Hanke FD, Biolsi KL, Harley HE (in press) Cognition in marine mammals: The strength of flexibility in adapting to marine life. Anim Cogn :- doi:10.1007/s10071-022-01681-x

Hare B, Brown M, Williamson C, Tomasello M (2002) The domestication of social cognition in dogs. Science 298:1634-1636

Hayes KJ, Nissen CH (1971) Higher mental functions of a home-raised chimpanzee. In: Schrier AM, Stollnitz F (Eds) Behavior of nonhuman primates, Vol. 4. Academic Press, New York, pp 50-115

Healy SD (2023) Adding the neuro to cognition: from food storing to nest building. Anim Cogn 26

Herman LM (2010) What laboratory research has told us about dolphin cognition. Int J Comp Psychol 23:310-330

Hilgard ER (1980) The trilogy of mind: Cognition, affection, and conation. J Hist Behav Sci 16:107-117 doi:10.1002/1520-6696(198004)16:2<107::AID-JHBS2300160202>3.0.CO;2-Y

Hoeschele M, Wagner B, Mann DC (2023) Lessons learned in animal acoustic cognition through comparisons with humans. Anim Cogn 26

Hofstadter DR (1979) Gödel, Escher, Bach : an eternal golden braid. Harvester, Brighton

Huber L, Lonardo L (2023) Canine perspective-taking. Anim Cogn 26

Hull CL (1943) Principles of Behavior. Appleton-Century, New York

Jacobs LF (2023) The PROUST hypothesis: The embodiment of olfactory cognition. Anim Cogn 26

Johansson P, Hall L, Sikstrom S, Tarning B, Lind A (2006) How something can be said about telling more than we can know: On choice blindness and introspection. Conscious Cog 15:673-692 doi:10.1016/j.concog.2006.09.004

Kacelnik A, Vasconcelos M, Monteiro T (2023) Testing cognitive models of decision making: Selected studies with starlings. Anim Cogn 26

Kaminski J, Call J, Fischer J (2004) Word learning in a domestic dog: Evidence for "fast mapping". Science 304:1682-1683 doi:10.1126/science.1097859

Kampis G, Miklosi A, Viranyi , Z, Gulyas L (2010) Video deep tagging and data archiving in the Comparative Mind Database. In: Spink AJ, Grieco F, Krips OE, Loijens LWS, Noldus LPJJ, et al (Eds) Proceedings of Measuring Behavior 2010 (Eindhoven, The Netherlands, August 24-27, 2010). Eindhoven

Kaplan DM (2012) How to demarcate the boundaries of cognition. Biol Philos 27:545-570

Kelly DM, Katz JS (2021) Lean on me: Animal–human interactions. Anim Cogn 24:217-217

Klein RA, Ratliff KA, Vianello M, Adams RB, Bahnik S, Bernstein MJ, Bocian K, Brandt MJ, Brooks B (2014) Investigating variation in replicability: a "many labs'' replication project. Soc Psychol 45:142-152 doi:10.1027/1864-9335/a000178

Krechevsky I (1932) Hypotheses in rats. Psychol Rev 39:516-532

Kuhn TS (1970) The structure of scientific revolutions, 2nd edition. Chicago University Press, Chicago

Lea SEG (1982) The mechanism of optimality in foraging. In: Commons ML, Herrnstein RJ, Rachlin H (eds) Quantitative analyses of behavior, Vol. 2: Matching and maximizing. Ballinger, Cambridge MA, pp 169-188

Lea SEG (1985) Operant psychology and ethology: Failures and successes in interdisciplinary interaction. In: Lowe CF, Richelle M, Blackman DE, Bradshaw CM (eds) Behaviour analysis and contemporary psychology. Erlbaum, London, pp 43-51

Leaver LA, Hopewell L, Caldwell C, Mallarky L (2007) Audience effects on food caching in grey squirrels (*Sciurus carolinensis*): evidence for pilferage avoidance strategies. Anim Cogn 10:23-27 doi:10.1007/s10071-006-0026-7

Lemaire BS, Vallortigara G (2023) Life is in motion (through a chick's eye). Anim Cogn 26 doi:10.1007/s10071-022-01703-8

Lorenz KZ (1950) The comparative method in studying innate behaviour patterns. In: Danielli FJ, Brown RE (eds) Physiological mechanisms in animal behaviour (SEB Symposium IV). Cambridge University Press, Cambridge, pp 221-268

Lorenz KZ (1979) The year of the greylag goose. Harcourt Brace Jovanvich, New York

Lucon-Xiccato T, Bisazza A (2016) Male and female guppies differ in speed but not in accuracy in visual discrimination learning. Anim Cogn 19:733-744 doi:10.1007/s10071-016-0969-2

Macphail EM, Bolhuis JJ (2001) The evolution of intelligence: Adaptive specializations versus general process. Biol Rev 76:341-364

Maes E, DeFilippo G, Inkster AB, Lea SEG, DeHouwer J, D'Hooge R, Beckers T, Wills AJ (2015) Feature- versus rule-based generalization in rats, pigeons and humans. Anim Cogn 18:1267-1284 doi:10.1007/s10071-015-0895-8

Many_Dogs , al (in press) ManyDogs 1: A Multi-Lab replication study of dogs' pointing comprehension. Anim Behav Cogn

Many_Primates , Altschul DM, Beran MJ, Bohn M, Call J, DeTroy S, Duguid SJ, Egelkamp CL, al (2019) Establishing an infrastructure for collaboration in primate cognition research.. PLOS One 14:e0223675 doi:10.1371/journal.pone.0223675

Maxwell SE, Lau MY, Howard GS (2015) Is psychology suffering from a replication crisis? What does "failure to replicate" really mean? Am Psychol 70:487-498 doi:10.1037/a0039400

Meier C, Lea SEG, McLaren IPL (2016) A stimulus-location effect in contingency-governed, but not rule-based, discrimination learning. J Exper Psychol Anim Lng Cogn 42:177-186 doi: 10.1037/xan0000098

Mellgren RL (1983) Animal cognition and behavior. North Holland, Amsterdam

Miklósi Á, Polgárdi R, Topál J, Csányi V (1998) Use of experimenter-given cues in dogs. Anim Cogn 1:113-121

Miller R, Lambert ML, Frohnwieser A, Brecht KF, Bugnyar T, Crampton I, Garcia-Pelegrin E, Goul (2022) Socio-ecological correlates of neophobia in corvids. Curr Biol 32:74-+ doi:10.1016/j.cub.2021.10.045

Mowrer OH (1960) Learning theory and behavior. Wiley, New York

Neisser U (1967) Cognitive psychology. Appleton-Century-Crofts, New York

Nisbett RE, Wilson TD (1977) Telling more than we can know: Verbal reports on mental processes. Psychol Rev 84:231-259

Parker TH, Nakagawa S, Gurevitch J (2016) Promoting transparency in evolutionary biology, ecology, and ornithology. Auk 133:779-782 doi:10.1642/AUK-16-122.1

Pashler H, Wagenmakers EJ (2012) Editors' introduction to the special section on replicability in psychological science: A crisis of confidence? Perspec Psychol Sci 7:528-530 doi:10.1177/1745691612465253

Pearce JM (1987) An introduction to animal cognition. Erlbaum, Hove

Pearce JM, Hall G (1980) A model for Pavlovian learning - variations in the effectiveness of conditioned but not of unconditioned stimuli. Psychol Rev 87:532-552 doi:10.1037/0033-295X.87.6.532

Penn DC, Holyoak KJ, Povinelli DJ (2008) Darwin's mistake: Explaining the discontinuity between human and nonhuman minds. Behav Brain Sci 31:109-130 doi:10.1017/S0140525X08003543

Pepperberg IM (1981) Functional vocalizations by an African Grey parrot (*Psittacus erithacus*). Z Tierpsychol 55:139-160

Pepperberg IM (1994) Vocal learning in grey parrots (*Psittacus erithacus*): Effects of social interaction, reference, and context. Auk 111:300-303

Pepperberg IM (1999) The Alex studies: Cognitive and communicative abilities of Grey Parrots. Harvard University Press, Cambridge, MA

Pérez-Cembranos A, Pérez-Mellado V (2015) Local enhancement and social foraging in a non-social insular lizard. Anim Cogn 18:629-637 doi:10.1007/s10071-014-0831-3

Pfeffer S, Wolf H (2020) Arthropod spatial cognition. Anim Cogn 23:1041-1049

Pilley JW, Reid AK (2011) Border collie comprehends object names as verbal referents. Behav Proc 86:184-195 doi:10.1016/j.beproc.2010.11.007

Pull CD, Petkova I, Watrobska C, Pasquier G, Fernandez MP, Leadbeater E (2022) Ecology dictates the value of memory for foraging bees. Curr Biol 32:4279-4285 doi:10.1016/j.cub.2022.07.062

Pusch R, Clark W, Rose J, Güntürkün O (2023) Visual categories and concepts in the avian brain. Anim Cogn 26 doi:10.1007/s10071-022-01711-8

Roberts WA (1998) Principles of animal cognition. McGraw-Hill, Boston, MA

Roessler T, Auersperg AM (2023) Recent developments in parrot cognition:a quadrennial update. Anim Cogn 26

Roitblat HL, Bever TG, Terrace HS (1984) Animal cognition. Erlbaum, Hillsdale NJ

Savage-Rumbaugh S, McDonald K, Sevcik RA, Hopkins WD, Rubert E (1986) Spontaneous symbol acquisition and communicative use by pygmy chimpanzees (*Pan paniscus*). J Exper Psychol Gen 115:211-235 doi:10.1037/0096-3445.115.3.211

Shaw RC, Schmelz M (2017) Cognitive test batteries in animal cognition research: evaluating the past, present and future of comparative psychometrics. Anim Cogn 20:1003-1018 doi:10.1007/s10071-017-1135-1

Shettleworth SJ (1975) Reinforcement and the organization of behavior in golden hamsters: Hunger, environment, and food reinforcement. J Exp Psychol Anim Behav Proc 1:56-87

Shettleworth SJ (1998) Cognition, evolution and behavior. Oxford University Press, New York

Shettleworth SJ (2009) The evolution of comparative cognition: Is the snark still a boojum? Behav Proc 80:210-217 doi:10.1016/j.beproc.2008.09.001

Shettleworth SJ (2010) Cognition, evolution and behavior, 2nd edn. Oxford University Press, Oxford

Skinner BF (1950) Are theories of learning necessary? Psychol Rev 57:193-216

Skinner BF (1969) Contingencies of reinforcement: a theoretical analysis. Appleton-Century-Crofts, New York

Spence KW (1956) Behavior theory and conditioning. Yale University Press, New Haven

Szabó D, Mills DS, Range F, Virányi Z, Miklósi Á (2017) Is a local sample internationally representative? Reproducibility of four cognitive tests in family dogs across testing sites and breeds. Anim Cogn 20:1019-1033 doi:10.1007/s10071-017-1133-3

Tolman EC (1932) Purposive behavior in animals and men. Century, New York

Tolman EC (1938) The determiners of behavior at a choice point. Psychol Rev 45:1-41 doi:10.1037/h0062733

Tomasello M (2023) Social cognition and metacognition in great apes: A theory. Anim Cogn 26 doi:10.1007/s10071-022-01662-0

Tulving E (1972) Episodic and semantic memory. In: Donaldson W, Tulving E (eds) Organization of memory. Academic Press, Oxford

Tvardikova K, Fuchs R (2010) Tits use amodal completion in predator recognition: a field experiment. Anim Cogn 13:609-615 doi:10.1007/s10071-010-0311-3

Vallortigara G, Regolin L, Rigoni M, Zanforlin M (1998) Delayed search for a concealed imprinted object in the domestic chick. Anim Cogn 1:17-24

Vanhooland L- C, Szabó A, Bugnyar T, Massen JJM (2023) A comparative study of mirror self-recognition in three corvid species. Anim Cogn 26

Vauclair J (1984) Phylogenetic approach to object manipulation in human and ape infants. Hum Dev 27:321-328 doi:10.1159/000272925

Vauclair J (1992) L'intelligence de l'animal. Seuil, Paris

Walker SF (1983) Animal thought. Routledge, London

Wynne CDL (2001) Animal cognition: The mental lives of animals. Palgrave, Basingstoke

Zentall TR (1993) Animal cognition. Psychology Press, New York