Opinion piece | In&Vertebrates

The value of collaboration between animal cognition and cognitive science

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https://doi.org/10.52732/VPOI8524

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Peer Reviews: The peer review reports are published alongside the article.

Received 22 May. 2022
Published 29 May. 2022

It is impossible for anyone to begin to learn that which one thinks one already knows – Epictetus (c. 55 – c. 135 AD) Discourses, Book II, ch. 17

Many studies of comparative non-human cognition would benefit if the scientists involved would spend more time discussing their topics with scholars studying cognitive sciences, particularly scholars examining logical reasoning. Such is not to say that the work of the latter is faultless; rather, my point is that researchers in those fields are generally more often aware of the so-called “known unknowns” — and thus more likely to investigate concepts at a depth far beyond that typical of comparative psychologists, digging deeper to differentiate between and among concepts that might initially seem equivalent. Only by examining a given concept in greater depth can we begin to understand what it is about that concept that we still do not fully understand and how that lack of understanding not only impedes our progress but may also cause us to draw unwarranted conclusions about a given species and unjustified parallels among various species.

A fairly recent special issue of Current Opinion in *Behavioral Sciences* (37:2021) dedicated to “Same-Different Conceptualization” is a case in point. With few exceptions (see [1]), endless papers over many decades have declared that various non-humans are capable of understanding same versus different, when all that had been demonstrated was the ability to recognize identity or non-identity, familiarity versus novelty (e.g., comparing identical pictures of a cat versus pictures of that cat and a flower [2]) — relatively simple tasks on which most species should succeed, given the critical importance of such knowledge for survival (i.e., the need to recognize familiar foods, to detect any changes in the environment that could indicate the presence of a predator). In contrast, as the special issue clarifies, same-different comprehension is a far more complicated task and can be claimed only when a subject can represent the abstract relations themselves, independently from the individual objects that enter into these relations, and can recognize, for example, that individual objects can be ‘same’ with respect to some attributes while simultaneously ‘different’ with respect to others [1,3]. For ‘identity-non-identity’, a subject can make the decision based on a simple perceptual cue (or based on familiarity/novelty, depending upon the task); for ‘same-different’, the subject must instead perform a detailed feature analysis of the items involved, determine — based on their ability to interpret the question being posed ("What's same?" versus "What's different?") — which of several attributes are being targeted as identical or non-identical (e.g., is one green and one red, are they both triangular, is one wood and one paper?) and then produce the label for the hierarchical category of the appropriate attribute (e.g., "colour", "shape", "material" [4,5]). Thus, conflating 'same-different' with 'identity-non-identity' seriously underestimates the more complicated levels of cognitive processing involved in the former as compared to the latter [1,3,5] — and can result in claims for the equivalence of human and non-human capacities on the 'same-different' task when, with few exceptions [1,3,4], no such equivalence exists.

Other extremely interesting work currently being explored in non-human cognition, based on studies developed for children, also likely conflates levels of complexity in the concepts being examined. The issue is what Leahy and Carey [6] describe as the difference between minimal and modal concepts. The former requires no symbolic means to represent the requisite logic that would enable more than a single possible heuristic solution; the latter involves symbolic representation of multiple logical possibilities from among which a subject chooses. If the task is simple enough that it concerns only a minimal concept, a single heuristic is sufficient; if, however, it concerns a modal concept, a single heuristic is insufficient. Leahy and Carey use their research on minimal/modal concepts to explain some disconcerting results from studies of childhood cognition: why, on tasks involving probabilistic learning and inferential reasoning, infants appear to be brilliant, yet older children seem rather stupid. The explanation is possibly even more important when claims are being made about comparative abilities of non-humans, who are often given similar tasks. The explanation hinges on the fact that not all probability and inferential reasoning tasks are equivalent: various types of tasks exist, each with differing levels of complexity. The simpler tasks require merely the capacity to generate a representation of only one single, likely possibility — a capacity that is present in infants and most non-humans. In contrast, the more complex tasks require the ability to consider multiple possibilities simultaneously — which seems to begin to develop in children only at about four years of age and is rare in non-humans. Unfortunately, researchers often fail to understand the differences in these types of tasks, conflate the capacities involved, and claim that any success of the younger subjects (and some non-humans) on the simpler tasks actually demonstrates the more advanced capacities. According to Leahy and Carey [6], it is the ability to verbalize concepts of possible/impossible/necessary in a symbolic manner that allows the older children to go beyond simple, single representations and solve the cognitively more complex tasks. Specifically, although the tasks given to the infants (and often non-humans) might appear to test the same concepts of probability and inference as those given to the older children, such is not the case; the differences among the various levels of complexity involved are comparable to the those involved in 'same/different' versus 'identity/non-identity.'

A simplistic example comparing two experiments on probability may make this minimal/modal separation apparent. In the first experiment, a researcher shows an infant (e.g., [7]) or a non-human (e.g., [8,9]) two buckets: one has a preponderance of an item that the subject prefers over another item (e.g., a favourite food versus a less-favoured one); in the other bucket, the preponderance is reversed. In one variant, the subject is simply allowed to choose the bucket from which they wish to obtain a treat. In another variant, the researcher places one hand in each bucket, grabs two treats (i.e., one treat from each bucket in each hand), keeps the treats hidden, presents both hands to the subject, and indicates that the subject should make a choice. If the subject chooses either the bucket with more of the favoured item or the hand that came from the bucket with more of the favoured item, the researcher claims that the subject understands probability — that the likelihood of receiving the favoured item depends upon the draw coming from the bucket with more of that item. And, at a statistically significant level, many infants and non-humans succeed. Now, please note that in reality the researchers performing these studies are extremely careful to include many more complex forms of each task (different proportions, different overall quantities, etc.) and that I am presenting only the simplest case as an example. The issue, however, is that in almost all of these experiments, each task continues to test another minimal concept, and although the subjects do need to calculate relative proportions of items for success in each task, they do not have to express an understanding that failure is also possible (e.g., that there is some chance that the researcher might have grabbed the less desired treat). That is, they make a prediction based on the observed data (a prediction that, in many instances, is sufficient), act on that prediction and succeed, but the task does not require them to consider multiple simultaneous alternatives. In contrast, a different result occurs in the second experiment, in which a researcher gives a much older child (say, about 3-4 years of age) a related task that originated with Piaget [10]. Here the child sees, for example, the insertion of three blue balls and one red ball into an opaque bucket. The experimenter grabs a single item, keeps it hidden, and asks the child to label its colour. At that age, the child is likely to respond with phrases like "Red, because it's my favourite colour" or "Red, because you put one red in and you took one out, so it has to be red." Unlike the infants and the non-humans, the child seems not to have any understanding of probability, and the prediction appears to be based on what appears to be irrelevant data. However, the task here is different: The earlier task is merely a prediction about expectancies, whereas this task involves a post-hoc, symbolic declaration of what is possible/impossible. Notably, it is only when the child is somewhat older that the response will be something like "Blue, because it's the mostest...but it could be red." (see [10]) Here the child actually demonstrates some real understanding about probability — that one outcome is more likely, but another outcome is still possible. Interestingly, if a Grey parrot that understands something about symbolic representation is given the same task, its responses are comparable to those of the older children [11]. Again, on the surface, both tasks seem to test 'probability'— but they test different levels of understanding. The first task requires the subjects to generate a likely hypothesis, but only in the second task do the older children (and the parrot) consider multiple possibilities simultaneously; in the 3- 4-year-old range, the children are likely beginning to do so and their answers likely demonstrate their struggle with the emerging concepts (note also [12]). My point is that without fully understanding the complex levels of cognitive processing that are necessary to solve the actual logical task, researchers often design experiments that test only much simpler versions of the task and then declare that their subjects have succeeded on comprehending a modal concept when only simpler versions — requiring only minimal concepts — have been mastered, for both humans and non-humans.

To be clear, Leahy and Carey's [6] paper primarily discusses studies of inference by exclusion, a task initially performed on apes by Premack and Premack [13] and later adapted by Call [14]. In a common form of the task, a treat is put in one of two cups without the subject knowing which one; one cup is then shown to be empty; the subject subsequently gets to choose. Many non-human species and children no more than 2 years old are successful and, as with same-different, endless papers on numerous species argued that their subjects had achieved inferential understanding. As Leahy and Carey [6] explain (see also [15-17]), this purported "A or B; not A, therefore B" type of task does not truly test inferential competence. These authors describe how a simpler hypothesis that does not require inference by exclusion works quite well to explain the data observed and why, in order to demonstrate full inferential comprehension, the subjects must succeed on far more complicated tasks. Leahy and Carey's paper is extremely elegant and my following summary will barely do it justice; again, I present a simplified version of their argument to make my point.

To explain the difference between minimal and modal concepts in exclusion tasks, Mody and Carey [17] suggested the following: what if, instead of the children thinking of the options as "A or B" for the position of the treat in the two-cup task, they instead conjecture "maybe A, maybe B" (a perfectly reasonable heuristic) when shown the original hiding? When shown "not A", simply eliminating it causes them to choose B by default, not because of any complicated inference. That they still think "maybe B?" (rather than "therefore B") is the case was demonstrated by using more complicated three- and four-cup tasks (see [17] for a discussion of the three-cup experiment). In the four-cup task, the subject is shown that one treat is hidden under A or B and another hidden under C or D; the experimenter shows that, for example, A is empty; then asks the subject to choose. To receive a reward with certainty, the subject should choose B, as there is no way of knowing whether C or D is filled. Two-year-old children now fail, treating B, C, and D as equally likely (i.e., as if all positions were considered 'maybe'), and even older children (3- to 5-years) are not at ceiling. The argument was, again, that the younger children did not have modal concepts (simultaneously understanding what about the task is possible/impossible) and the older children were in the process of acquiring them. Interestingly, the Grey parrot versed in symbolic representation that had succeeded on the probability task was also given the three- and four-cup tasks, with the addition of two control tests; the bird out-performed the five-year-olds [18]. Ferrigno and colleagues [19] claimed that monkeys could succeed on a comparable version of the four-cup task (one lacking the controls given the parrot) — that is, that the monkeys had modal concepts without necessarily having symbolic representation — but their findings were contested by Gautem and colleagues [20], who argued that success was required on yet another version — one where A is shown to be full and is emptied by the subject, who then gets yet another chance to choose; here subjects that fully understand the task should gamble on C or D and ignore B, which they should infer is empty. Only 5-year-olds could pass this version of the task [20]. Younger children and monkeys, by choosing B as well as C or D, specifically demonstrate that they have not made specific inferences about B [20]. Note that the Grey parrot also succeeds [21]. However, the issue still comes down to whether successful subjects can pass by a different, simple heuristic — i.e., they recognize that one treat is hidden on each side; if A is shown to be full and is emptied, they simply avoid that side without (again) making any explicit inference about B, and choose something on the other side — that is, succeed without requiring the most complex understanding of the underlying concepts. Additional experiments, now being designed, are needed to rule out such a possibility.

The point of this piece is to highlight how collaborative efforts between researchers with different types of expertise can clarify many important issues when investigating which levels of cognitive processing are needed for demonstrating understanding of a given concept; that is, in determining the full complexity of the concept and in designing appropriate experiments for testing the various levels of understanding. Designing experiments on which subjects can succeed by using simple heuristics is definitely a good first step, as subjects that fail these tasks are unlikely to succeed on the more complex ones; however, only by designing tasks that cannot be solved in such a manner can we truly test and compare the competencies of our subjects, be they differently-aged humans or non-humans. And, as I hope this piece points out, it is often only by working with researchers in different fields that we become aware of these "known unknowns."

ACKNOWLEDGEMENTS

This paper was written with the support of donors to The Alex Foundation. I thank various colleagues for their comments and suggestions, which greatly improved the manuscript.

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