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The Uncertainty Response in Animal-Metacognition Researchers

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Abstract

Kornell (2013) considers whether and in what sense animals may be considered metacognitive. He questions whether tests that rely on animals assessing their internal memory strength can provide useful data. He offers his own strategies for determining what internal cues animals use in making metacognitive judgments. We endorse his call for an increased focus on animals' metacognitive errors as true reflections of metacognitive states shorn of associative bases. We endorse a sharper focus on information-processing analyses of the executive or attentional level that metacognitive responses may occupy in animals' cognitive systems. Some of these analyses are being implemented in contemporary research, with positive results. Finally, we endorse the possibility that metacognition may not be an all-or-none thing, so that animals may share some facets—but not all facets—of metacognitive experience with humans. Kornell's interesting contribution makes clear that in this area the animal-metacognition literature needs further theoretical sharpening.

Introduction

We welcome Kornell's (2013) interesting and measured perspective on animal metacognition. Research in this area has progressed steadily, frequently supported by theoretical analyses like the one that Kornell provides. However, uncertainties remain in this challenging area as one also sees in this thought-provoking article. It questions whether animals are metacognitive, but then concludes that they are, with the proviso that it may not be a fully self-imbued kind of metacognition, with the problem then of deciding whether a self-less metacognition really counts. Just like Tolman's (1927) rats facing difficult discriminations, animal-metacognition researchers have always shown indecisive "lookings and runnings back and forth" between the yes and the no of animal metacognition, the explicitness and implicitness of metacognition, and the associative and cognitive bases for metacognition. Animal-metacognition researchers have made as much use of uncertainty responses in their writings as have the animals tested in various paradigms. So, there is a lot to think about and to respond to within the target article.

The Reinforcement Problem

We strongly agree with Kornell's point that external cues and concrete reinforcement signals are obstacles to interpreting metacognition in animals. He says, "if the cues are not internal cognitive states, metacognition would lose its 'meta-ness'." There is broad agreement here, as this has been the principal theoretical concern about comparative metacognition research (Crystal & Foote, 2009; Hampton, 2009; Jozefowicz, Staddon, & Cerutti, 2009; Le Pelley, 2012; Smith, Beran, & Couchman, 2012; Smith, Beran, Couchman, Coutinho, & Boomer, 2009; Smith, Beran, Coutinho, & Couchman, 2008; Smith, Beran, Redford, & Washburn, 2006; Smith, Couchman, & Beran, 2012). The first phase of animal-metacognition research was devoted to this problem.

Many studies have now shown that animals' metacognitive behaviors show flexibility, generalizeability, abstractness, and independence from direct reward of uncertainty responses and reinforcement history (Beran, Smith, Redford, & Washburn, 2006; Hampton, 2001; Kornell, Son, & Terrace, 2007; Shields, Smith, & Washburn, 1997; Smith et al., 2006; Smith, Redford, Beran, & Washburn, 2010; Smith, Shields, Allendoerfer, & Washburn, 1998). Animals can report uncertainty about abstract cognitive judgments and indeterminate memories. They can do so absent cueing stimuli and on the first trial of novel tasks. Therefore, there are grounds for granting these behaviors a higher-level interpretation that rises above external stimulus cues and reinforcement history. Accordingly, there is some consensus that some animals' and humans' uncertainty systems have strong similarities (e.g., Fujita, 2009, p. 575; Roberts, Feeney, McMillan, MacPherson, & Musolino, 2009, p. 130; Sutton & Shettleworth, 2008, p. 266). Philosophical analyses have concluded that animals' uncertainty performances cannot be explained in low-level associationist terms (e.g., Carruthers & Ritchie, 2012). Even Kornell (2013) concludes that animals likely do make metacognitive judgments.

Metacognitive Errors

Of course not everyone agrees (Le Pelley, 2012). And here Kornell offers a crucial insight supporting further progress in this area. He suggests that metacognitive errors provide uniquely strong evidence of animal and human metacognition. He says: "Ironically, examining errors might be the best way to demonstrate animals' metacognitive accomplishments." The reason is that "metacognitive" behaviors can often be attributed to reinforcement maximization when they occur in lock-step with performance metrics like percent correct (a proxy for a task's reward richness). But if you can catch an animal irrationally confident or needlessly unsure in a task, those states are dissociated from reward richness and may be truly metacognitive. This is a profoundly important idea deserving more research attention.

Unfortunately, Kornell (2013) erred when he said: "There is no evidence that animals are prone to systematic metacognitive errors." There is that evidence. In Smith et al. (2006), rhesus monkeys completed four trials in a perceptual uncertainty-monitoring task before receiving summary feedback. This feedback delivered all rewards bunched together and then all penalty timeouts. Consequently, not only was there no trial-by-trial reinforcement that

could condition metacognitive responses, there was not even any correspondence between the order of stimuli/responses during the trial block and the order of feedback events. Specific outcomes could not be linked to specific stimulus-response pairs—the normal mechanisms of associative learning were disrupted.

Figure 1A shows a macaque's metacognitive uncertainty responses in this task. At Trial Level 9, he made many URs (23%) for trials he answered 97% correct (when he tried them on other occasions). This is irrational uncertainty—he should have eagerly accepted these easy, winning, rewarding trials. Conversely, at Trial Level 20, he made fewer uncertainty responses (19%) for trials he answered 78% *incorrectly* when he tried them (i.e., far below chance level). This is irrational certainty—he should have assiduously avoided these trials. Figure 1B shows that over most of the range of performance accuracy there was no relationship between the proportions of correct and uncertainty responses. This animal's metacognitive responses were strikingly independent from the task's performance metrics. Smith et al. (2008) showed that an associative model cannot explain this independence. Smith, Couchman, and Beran (in press) showed that Le Pelley's (2012) associative framework cannot explain this independence, either. This is a compelling demonstration of animal metacognition.

Thus, we endorse the importance Kornell attaches to metacognitive errors, and metacognition freed from performance metrics. The research in Smith et al. (2006) represents an important first step—hopefully of many—in this direction.

True Cognitive Analyses

As Kornell (2013) points out, one might judge that the animal-metacognition literature has spent inordinate energy on the external-cue and reinforcement environments that attend metacognitive performances by animals. This emphasis was inevitable, because comparative psychology carries the 100-year-old burden (or gift!) of a deeply conservative interpretative stance toward animal behavior. Nonetheless, we agree—with no blame cast—that the field has too seldom lifted the hood of animals' minds to see how the metacognitive engine runs. Kornell's article is also timely because it encourages these true, information-processing analyses of metacognitive performances. We strongly agree, and we point out that researchers are beginning to address this issue.

For example, Smith, Coutinho, Church, and Beran (2013) began to trace the information-processing signature of animals' metacognitive responses by asking whether these processes are especially working-memory intensive. Macaques performed a Sparse-Uncertain-Dense task in which they identified stimuli as Sparse or Dense or responded Uncertain for trials deemed too difficult, or a Sparse-Middle-Dense task in which they identified stimuli as Sparse, Middle, or Dense. However, a concurrent working-memory load was sometimes added to ongoing perceptual-discrimination performance. Figure 2 shows the article's main results. Concurrent tasks disrupted macaques' uncertainty responses far more than their Sparse, Middle, or Dense perceptual responses. In particular, middle responses survived the concurrent load nearly intact. For one macaque, they survived completely intact.

This result transcends external cues and reinforcement history. It forces a true information-processing description of the uncertainty response. Apparently, uncertainty responses are especially demanding of working-memory resources. They may be more executive and attentional in psychological character, just as Schwartz (2008) has found for humans' metacognitive responses. Thus, we agree with Kornell (2013) that there is substantial value in analyzing the true information-processing content of metacognitive responses.

50 Shades of Meta

The weakest thread in this interesting article lies in its discussion of the varieties of the metacognitive experience. For one thing, this discussion seems to embody a striking contradiction. Kornell (2013) appears to down-interpret human metacognition when those processes are indirect and inferential, not directly reflective of access to true memory strength. But he appears to take those untethered and misguided metacognitive responses to be the truest forms of metacognition. His viewpoint does need clarification. Our view on this is that even when humans' metacognitive states are indirect, they are still metacognitive, and often verbally declarative and consciously aware. They are not to be down-interpreted on this basis. This is why Smith et al.'s (2006) result was important. That macaque apparently thought he knew when he was right or wrong, even though by the task's reinforcement rules he clearly did not.

For another thing, Kornell (2013) seems to favor the idea that "the essential property of metacognition is that monitoring one's own cognition involves self-reflection (Metcalf & Kober, 2005)." However, in many other passages he describes metacognitive performances that do not need to have any self-imbued character. He also argues that animal-metacognition researchers have linked self-reflection and metacognition. This is factually incorrect. Metacognition researchers have fallen over themselves distancing themselves from the selfness claim. He cites the mirror-recognition paradigm in making this incorrect claim. However, animal-metacognition researchers widely understand that that paradigm may not assess self-awareness. In any case, that macaques show robust metacognitive performances but never any mirror recognition opens a crevasse in Kornell's (2013) discussion of this issue. In this passage, we thought his theoretical perspective still needed sharpening.

Still, it appears overall that Kornell (2013) supports the possibility that metacognition is not a monolithic, all-or-none thing. This is constructive because—in our view—some harm has come from the assumption that nothing is metacognition except the ultimate self-referential, metarepresentational dialog that human adults rarely have with themselves. That rarefied interpretative standard disallows exploring the earliest roots of human children's metacognition, which must originate as some less lofty cognitive capacity. It disallows exploring the evolutionary roots of human metacognition in the primate order. In the main, we think that Kornell would endorse the idea—as we do—that metacognition is a multi-faceted information-processing capability that emerges gradually in the primates, and gradually in human children, and that interesting theoretical questions surround its waypoints and the course of its emergence.

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Figure 1.

Monkey Murph's performance in Smith et al. (2006). *A.* Sparse and Dense responses, respectively, were correct for boxes at density levels 1–20 and 22–41 shown on the horizontal axis. The open circles show the proportion of trials attempted that were answered correctly. The dark circles show the proportion of trials on which Murph made the escape response at each density bin. *B.* Murph's performance in the same task, with the proportion of trials declined at each trial level plotted against the proportion of correct responses for those same levels. From "Dissociating Uncertainty States and Reinforcement Signals in the Comparative Study of Metacognition," by J. D. Smith, M. J. Beran, J. S. Redford, and D. A. Washburn, 2006, *Journal of Experimental Psychology: General*, 135, p. 292. Copyright 2006 by the American Psychological Association. Reprinted with permission.

Figure 2.

A,B. Proportion of uncertainty responses (solid line), sparse responses (dashed line), and dense responses (dotted line) made by macaques Murph and Lou in their baseline performance and in their first phase of concurrent-load testing. *C,D.* Percentage of middle responses (solid line), sparse responses (dashed line), and dense responses (dotted line) made by macaques Hank and Gale in their baseline performance and in their first phase of concurrent-load testing. From “Executive-attentional uncertainty responses by rhesus macaques (*Macaca mulatta*)” by J. D. Smith, M. V. C. Coutinho, B. A. Church, & M. J.

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