

# How (Not) to Study Animal Metacognition

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## *Abstract*

Comparative psychologists are investigating whether nonhuman animals share humans' capacity for monitoring their own cognitive states. Researchers have tested pigeons, rats, a dolphin, capuchin monkeys, rhesus macaques, and apes using perception, learning, memory, numerical, and food-concealment paradigms. Given this broad empirical base, researchers are now pursuing the appropriate theoretical understanding of these performances by animals. In the course of this theoretical dialog, some theoretical perspectives have been offered that are less constructive to the progress of this field. The present article discusses this class of *all-or-none* perspectives on animal mind and metacognition and describes their limitations. Though there are apt and powerful critical perspectives that should be taken toward the empirical findings in this area, these all-or-none perspectives may not be among them. With these set aside, theorists can evaluate the essential criticisms, and researchers can address the empirical challenge those criticisms present.

Keywords: uncertainty monitoring, metacognition, comparative cognition, decision making, philosophy of mind

## *Introduction*

Humans know when they do not know or remember. They respond to doubt and uncertainty by deferring response and seeking additional information. These adaptive responses ground wide-ranging research on metacognition, or thinking about thinking [1-5]. The essential organizing idea in this field is that human minds have a capacity to monitor and control their perception, memory, reasoning, and emotion.

Metacognition has traditionally been considered a sophisticated human capacity [6]. It cooperates with executive supervisory functions to improve the flexibility and adaptation of decision-making and behavior. It reveals hierarchical structure in mind [7], because the executive oversees the rest of cognition. It is linked to declarative consciousness [3,8] because humans declare their conscious states of (not) knowing. This sophistication might imply that metacognition is uniquely human. Therefore, one of comparative psychology's important goals is to establish whether nonhuman animals (hereafter, animals) share a metacognitive capacity with humans.

Toward this goal, researchers have evaluated animals' ability to monitor and respond adaptively to their own uncertainty [9-19]. These paradigms present occasional difficult trials to animals to create within them a state of subjective uncertainty. They grant animals a response beyond the primary discrimination responses so that they can cope with their uncertainty by declining to complete difficult trials or by seeking additional information before responding. Animals often produce data patterns in cognitive-monitoring tasks that are strikingly like those of humans. Monkeys avoid the most difficult trials in a variety of perceptual discrimination tasks [20]. They respond uncertainly adaptively facing more cognitively derived same-different tasks [21]. Their

uncertainty-monitoring capacity extends to tests of their numerical judgments [9]. They report when their stimulus memories are faint and unreliable [13,15,16], showing a capacity that is tantamount to human metamemory. They seek hints on the first trial of novel tasks [19]. Great apes and macaques—with essentially no training—seek information adaptively in a food-concealment paradigm [10-11, 14]. Orangutans choose a smaller, safe reward when uncertain where the preferred food was hidden [17].

Given this broad empirical base, researchers are pursuing the appropriate psychological interpretation of uncertainty-monitoring performances by animals, and the appropriate theoretical description of the reflective mind revealed by those performances. In the dialog attending this pursuit, some theoretical perspectives have been offered that are less constructive to the field. We discuss this class of *all-or-none* perspectives on animal mind and metacognition and describe their limitations. Though there are apt critical perspectives that can be taken toward the area's findings, these all-or-none perspectives may not be among them. With these set aside, theorists and researchers can focus on the essential criticisms and the challenge they present.

#### *All-or-None Self-Awareness*

Gallup and his colleagues [22-23] made a lasting contribution to comparative psychology. They used the dye-mark test to ask whether animals show bodily self-recognition by rubbing at a facial mark they can only observe in a mirror. Some ape species show this self-recognition capacity more readily than other primate species. This intriguing phenomenon has motivated a far-reaching theoretical conjecture. It states that self-directed mirror-guided behavior (of which the dye test is one instantiation) is the diagnostic symptom of the emergence of all aspects of self-

awareness (including self-consciousness and self-recognition) and that this emergence occurred just once in phylogeny along the ape-hominid evolutionary line.

This all-or-none conjecture about self-awareness potentially impedes the study of animal metacognition for several reasons. First, it may deny capacities to a wide range of species without empirically evaluating them because there would be no reason for research on monkeys or rats who “cannot” show metacognition [24]. Second, one might denigrate strong experimental paradigms which “cannot” show metacognition in macaques (though they seem to) because macaques do not engage in self-directed mirror-guided behavior. Third, it could conflate different aspects of self-awareness, and discourage research on differentiated facets of self-awareness because its self-awareness construct is all-or-none. Finally, it could slow the development of separate assays for separate capacities. Note that repeated calls for alternative paradigms to the mirror self-recognition test [22, 25] remain largely unanswered [26]. Ironically, the lack of an alternative paradigm could itself prevent a fuller understanding of the cognitive content of the dye-mark test. One does not know from the dye-mark test whether the measured capacity goes farther than skin–deep bodily awareness, or what the relation is between bodily self-recognition and consciousness / metacognition. What better way to see if the dye-mark test reflects cognitive self-awareness than to correlate it to an independent measure of epistemic self-awareness? The potential connections are fascinating, and Gallup’s paradigm remains a distinctive behavioral marker. But those connections remain uncertain.

In our view, metacognition is one component of self-awareness that will be treated most constructively as a stand-alone aspect of mind. Metacognition is a structural claim

that some animals' cognitive systems may include functions that regulate and control first-order cognitive processes. This claim has no implications for animals' self-understanding. The question of animal metacognition is empirical, as is the question of how this facet of self-awareness correlates with body-image awareness. If the field achieves a focused study of animal metacognition as an independent capacity, Gallup's conjecture about self-awareness becomes empirically testable, because then the critical inter-task correlations can occur. But this approach requires that paradigms be evaluated solely for their ability to assay metacognition in animals with no preset constraints on which species are deemed potentially metacognitive. In fact, monkeys' metacognitive performances in many experiments must be reckoned with.

We view the animal metacognition paradigms as potentially complementary to Gallup's dye-mark assay, convergent with it, and friendly to Gallup's theoretical goals. However, these paradigms can contribute the most if they are left to tell their own independent story about animal minds.

### *All-or-None Theory of Mind*

Humphrey [27] made another influential conjecture about the evolution of reflective mind and awareness in animals. He supposed that intensely social species—nature's psychologists, as he called them—have a fitness need for a theory of the other's mind. That is, they must be able to read and represent their conspecifics' mental states, intents, and emotions to navigate the social environment safely and adaptively. In Humphrey's view, cognitive self-awareness and metacognitive evaluation are part and parcel with this mindreading ability, and they may have arisen to support it,

This conjecture has far-reaching implications for studying animal metacognition. Apes who mindread should have metacognition, but monkeys who don't should not. Metacognition and mindreading should be in perfect concordance across phylogeny.

Humphrey's conjecture in itself is interesting, possible, and potentially testable. However, in its use by the field, it may have been an impediment to the study of animal metacognition for similar reasons to those considered in the last section. First, it also might deny metacognitive capacities to many species without testing, given that the question of metacognition in non-mindreading species is already answered (negatively). Second, this conjecture would denigrate the paradigms that seem to show metacognition in monkeys because monkeys don't mindread and therefore "can't" show metacognition [28]. (Note that recent evidence suggests that monkeys and corvids do possess some mindreading abilities—[29,30].

Third, mindreading itself is not an all-or-none capability. It has distinct components that can be segregated from developmental, clinical and comparative perspectives [31-33]. Some forms of perspective taking and goal attribution may be widespread in the animal kingdom, but other metarepresentational forms of mindreading (e.g., false belief attribution) may be restricted to a few species or to humans only. Though some authors have linked the highest-level forms of mindreading with metacognition (next section), these linkages are neither empirically based nor logically necessary.

Finally, it is not clear that metacognition primarily evolved to support mindreading. Indeed, there are more direct and plausible causes for the evolution of metacognition. Animals often face uncertainty and doubt, and they also face situations wherein their habits and stimulus-response associations do not clearly suggest an appropriate

response. In those circumstances, they need an on-line cognitive utility that will let them assemble the relevant facts and recollections that might support adaptive responding. They need to actively and deliberately evaluate their risks and prospects and make the best behavioral choice. A working consciousness that includes a metacognitive capacity would serve well as this on-line utility. In fact, this idea is a cherished and venerable one within cognitive science [34-35], though the issue of whether metacognition necessarily requires consciousness is still pending [36]. Godfrey-Smith [37] recently captured the same idea in his Environmental Complexity Hypothesis. It states that highly variable environments create strong adaptive pressure toward flexible control processes linked to the processes of information acquisition and evaluation. Proust [38] explained how metacognition could have emerged as a family of responses to this pressure.

These perspectives would predict that many species would develop metacognition independently of mindreading. The concordance between metacognition and theory of mind would break down. Monkeys may exemplify this case. They would grant that monkeys are suitable candidates for animal metacognition research, as studies show they are. Notice that these ideas make Humphrey's evolutionary trajectory even more plausible. They explain the evolution of metacognition using its own fitness contribution. Then, this pre-existing metacognitive capacity could have become the pre-adaptive scaffolding on which a mindreading ability was constructed.

This discussion recommends again that metacognition be treated as an independent component of a reflective mind. Basic metacognition—an organism's capacity to monitor and control its own cognitive processes—is logically-empirically-theoretically separate from animals' capacity to send out searchlights of awareness into



conspecifics' minds. Paradigms must be judged solely by whether they fairly test cognitive-monitoring by animals, not rejected if they produce results that surprise an existing conjecture. Species must be tested without pre-strictures and judged by their performance on the paradigms, not by whether they preserve a hoped-for concordance. (They don't.). If metacognition paradigms are left to tell their independent story about animal minds, then they will be supportive of Humphrey's overall theoretical goal of tracing the phylogenetic development of different components of reflective mind. For evaluating the concordances he envisions will depend in the end on the existence and broad use of stand-alone animal metacognition paradigms.

#### *All-or-None Metarepresentation*

Carruthers [28] presents a philosophical and skeptical view toward animal metacognition, based on the notion that metarepresentation underlies all forms of self-awareness. Carruthers begins by endorsing and quoting Smith's [39, p. 224] structural description of metacognition as a second-order, meta- process monitoring a first-order object-level process to resolve ambiguity and close calls. This structural description—endorsed by Carruthers—looms important because it produces a verdict for animal metacognition that Carruthers hopes not to endorse.

Carruthers' goal is to show that some uncertainty-monitoring performances by animals involve only first-order beliefs and desires by animals. He grants animals' use of a practical reasoning schema containing beliefs and desires with disparate strengths that combine lawfully to determine behavior. Animals' uncertainty responses in some current paradigms, he argues, might be only the resultant of conflicting first-order beliefs and response tendencies. However, Carruthers acknowledges that first-order beliefs

and desires will not explain all the wide-ranging empirical findings of uncertainty monitoring and information seeking by animals. A second schema is invoked to explain why an animal, despite having response urges of different strengths, still "is reluctant to act, and seeks either further information, or some other alternative for action".

Carruthers suggests that some species have "a gate-keeping mechanism (most likely evolved, but perhaps constructed through some sort of learning) which when confronted with conflicting plans that are too close to one another in strength will refrain from acting on the one that happens to be strongest at that moment, and will initiate alternative information-gathering behavior instead."

The gatekeeper mechanism fits the definition of metacognition that Carruthers endorsed earlier. It is more complex and demanding than first-order cognitive processes. It contains the extra layer of representational complexity that is prescribed for metacognition and is second order in that sense. It operates on the outputs of cognition to judge their status in supporting a correct response. It adds information and data to the response decision that transcends the present trial (e.g., about the level of noise in the system and about how this level of noise may affect the outcome). The gatekeeper meets the definition of controlled cognitive processes (voluntary, deliberate, etc.; [40]). Indeed, a long history in psychophysics suggests that gate-keeper processes near participants' perceptual thresholds may be higher-level and metacognitive in psychological character [41]. The gate-keeper also engenders a qualitative change in behavior and cognition (hesitancy, information seeking, uncertainty responses, etc.). In short, the gate-keeper ideally typifies the cognitive utility that theorists have envisioned as their construct of metacognition.

Carruthers acknowledges in several places that the mechanism he is describing could be thought to be second order within the cognitive system and metacognitive. He rejects those notions because the gatekeeper does not meet his ultimate, metarepresentational standard for what he accepts as second-order and metacognitive. In his view, there can be no metacognition unless the organism fully represents to itself that it is a self that is having an uncertain, doubtful thought. Proust [42-43] discussed why this criterion is not compelling even for human metacognition. One part of her analysis is to show that metacognitive monitoring can involve judgments of knowing and feelings of uncertainty that bypass the need to construct higher-order representations. Carruthers' criterion is also hardly reconcilable with current descriptions of non-analytic metacognitive processes [44].

Completing his argument, Carruthers concludes that it is unlikely we will find metacognition in non-mindreading species. He recommends restricting testing for animal metacognition to the apes, excluding other primates. We have already described the problems that follow from pre-judgments and pre-strictures of this kind.

The limitations of his all-or-none perspective are clear. One could define mountaineering as the capacity to scale 8,000-meter peaks without supplemental oxygen. But such a rarified construct would tell one very little really about mountaineering, mountaineers, or which and how many humans do climb mountains. It is the same for metacognition. Comparative psychology has the goal to trace the phylogenetic roots of metacognition. It has the goal to examine the interrelationships among the multiple aspects of metacognition (monitoring, control, consciousness, declarative reports, metarepresentation, etc.). To pursue these goals, one has to

examine the metacognition phenomenon in all its elemental and advanced forms across many branches of phylogeny. These goals are undermined by a philosophical arms-crossed obstinacy holding out for a rarefied construct of metacognition that no other species could ever reach, often not even humans.

### *All or None Associationism*

Associative accounts of metacognitive phenomena aim Morgan's Canon at animals' performances, trying to explain them using stimulus-response associations fueled by reinforcement signals. It is a problem, though, that these associative accounts are sometimes broadly cast and generic, not giving sufficient attention to the information-processing situation animals face in the target tasks.

For example, one current idea is that animals use the uncertainty response because it reduces the delay to reinforcement (being never followed by timeout). This idea is mistaken. In some paradigms, if animals always respond Uncertain, they will delay reward indefinitely. In many paradigms, if animals respond Uncertain on easy trials, they delay reinforcement compared to answering the trial straight away. In fact, uncertainty responses only speed reward if the animal uses them to selectively decline difficult trials. But the animal must monitor difficulty to do so. This explanation only stands given an uncertainty-monitoring process in the background. The associative gain follows from the metacognitive strategy. These casual, broad, associative criticisms must be sharpened and focused.

Now there are sharp and focused associative criticisms [45]. For example, animals are sometimes directly rewarded for making uncertainty responses [12-13,15]. This might make the uncertainty response attractive, and motivate its use on difficult trials

when other responses are unattractive, even if the uncertainty response were unrelated to uncertainty monitoring or metacognition. These direct rewards make it difficult to rule out associative interpretations of uncertainty responses.

As another example, difficult discriminative stimuli in uncertainty experiments are typically associated with leaner rewards and negative outcomes. Difficult stimuli might feel aversive to animals who might be conditioned to avoid responses to those stimuli. In those stimulus contexts, the uncertainty response could be an aversion-avoidance response, not a metacognitive judgment.

Facing these concerns, philosophers have described the constraints on experimental paradigms that could disconfirm associative accounts of animals' metacognitive performances. Proust (in preparation) emphasized the importance of novel stimuli, task transfer, and deferred-reinforcement regimens that prevent animals from associating stimuli, responses, and consequences. In fact, researchers have begun to show that animals' performances do transcend associative interpretations. Smith et al. [46] showed that a monkey could still make adaptive uncertainty responses when transferred to new task and when performing under deferred reinforcement that made it impossible to track the consequences earned by particular stimulus-response combinations.

We applaud the goals of strengthening the area's paradigms and demonstrating the flexibility and generalizeability of animals' uncertainty responses, and we work toward those goals in our research. However, we caution that it would be a mistake to try to cleanse metacognitive paradigms of all associative content. Even human metacognition has a strong reinforcement basis. A child's metacognitive assessment—I can't sing—

clearly has a grounding reinforcement history behind it (e.g., teachers who don't call on the child to sing). To study metacognition in a vacuum of domain experience and reinforcement history (success/failure) would be to strip away one of its essential formative elements.

It might also conceal worthy questions concerning the emergence of metacognition. The earliest metacognitive abilities could well be procedural error correction/detection mechanisms strongly tied to specific contents and reinforcement histories. The emergence of metacognition—in human development and primate phylogeny—could be the gradual freeing of those capacities from specificity and associative forces. Thus, we believe that the whole theoretical picture regarding comparative metacognition will be best seen by examining the phenomenon in both its reinforcement-grounded and reinforcement-transcending contexts.

#### *All-or-None Formal/Mathematical Approaches*

It is often useful to test formal-mathematical models of animals' uncertainty-monitoring performances [47]. These models typically have a signal-detection character [48-49]. One assumes that performance is organized along a continuum of psychological representations (memory strength, etc.). One assumes that subjects place decision criteria along the continuum to establish contiguous regions of similar representations that will receive the same response. For example, the metacognitive interpretation of some existing experiments would be that two decision criteria along a continuum define three response regions. The left and right response regions would represent clear examples of the two stimulus classes in the experiment, and the two main discrimination responses would be anchored to these regions. The middle region

would contain indeterminate representations that deserve neither main response and that would receive uncertainty responses instead.

A misconception has arisen about this formal-mathematical framework. It states that if the signal-detection framework applies to a behavioral situation, then that performance can be, and should be, interpreted in a low-level, associative manner. Moreover, this position implies that since *all* existing performances can be modeled using the signal-detection framework, *none* of them demonstrate metacognition.

This misconception needs to be re-considered carefully because it also impedes theoretical progress in our area. The critical problem is that the signal-detection modeling framework can equally well be applied to performances at all levels within the cognitive system, including conditioned stimuli, memory strengths, conscious feelings of knowing, and even the explicit and declarative metarepresentations that characterize full-blown human metacognition. Thus, the signal-detection modeling framework would be equally applicable to a pigeon changing its pecking rate for different visual wavelengths and to a human reporting different degrees of conscious uncertainty in a metacognition task. Because both can be modeled using signal detection, both would be dismissed as an example of metacognitive processing.

This approach artificially equalizes performances that are qualitatively different in psychological level and character. Indeed, this approach is indifferent to the psychological character of performances (i.e., their processes and representations). Instead, it focuses on a formal-mathematical, metaphorical similarity among performances. This perspective is especially problematic because it groups performances together in order to dismiss their metacognitive content.

Therefore, we stress that suitability for signal-detection modeling has no conceivable relationship to or implication for the level or character of a psychological performance. Instead, one must query the relevant processes and representations to make that assessment. Instead of grouping together performances to dismiss them, what the field actually needs to do is to parse phenomena and separate them so as to understand them clearly. We believe this process/representation focus is critical to pursuing metacognition comparatively and equitably.

### *Conclusions*

In a sense, we are advocating a some-but-not-all approach to the study of animal metacognition. Some paradigms (not all, not none) will show metacognition. This claim helps hold the field's empirical conclusions to a high level, and forces the refinement of experimental paradigms so that conclusions are strongly grounded. Some species (not all, not only humans or mind-reading apes) will be metacognitive. This claim lets the field test different species without pre-strictures. Metacognitive animals will have some but not all aspects of self-awareness and theory of mind. This claim lets the field evaluate the existing paradigms on the paradigms' own terms—instead of rejecting paradigms that produce uncomfortable results for the literatures on self-awareness or mind-reading.

In our view, this approach to animal metacognition has many scientific advantages. By testing many species, we can examine the distribution of the metacognitive capacity across phylogeny. By testing “lower” species than apes, we may trace metacognition's phylogenetic roots and perhaps link them with aspects of evolutionary lineage or brain morphology. Important scientific goals also appear if one acknowledges that there are



different facets and components to the overall metacognition or self-awareness capacity, including its second-order nature, its gate-keeper function, its consciousness, its availability to declarative reports, and its metarepresentational aspects. We might find different evolutionary onsets for these different components. We might study the correlational structure among these components. In our view, this scientific program could shine the brightest possible light on the remarkable flowering of reflective mind that came to full bloom in human cognition. However, that program is species diverse, paradigm generous, construct fractionating, and it is in no way all-or-none, because its focal construct—animal metacognition—is not all-or-none either.

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