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Monkey Metacognition Could Generate More Insight

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Abstract

Monkeys demonstrate metacognition by avoiding memory tests when they forget, seeking information when ignorant, and gambling sensibly after making judgments. Some of this metacognition appears to be based on introspection of private mental states. It is likely that nonhuman cognitive systems, like human systems, differ in accessibility to such introspective metacognition, and the extent to which differences in access map to explicit and implicit cognition will be an important topic for future work. It will be exciting to learn more about the distribution of metacognition among species, and the conditions under which metacognition evolves.

Keywords

Introspection; Primate; Cognitive control; Explicit; Implicit

Monkeys are sometimes metacognitive. They avoid memory tests when they forget (Beran & Smith, 2011; Hampton, 2001). They seek information when ignorant (Beran & Smith, 2011; Hampton, Zivin, & Murray, 2004; Tu, Pani, & Hampton, 2015). They express frustration when they expect to be wrong (Hampton & Hampstead, 2006). They avoid difficult discriminations in favor of easier ones (Shields, Smith, & Washburn, 1997). They gamble adaptively based on past judgments (Kornell, Son, & Terrace, 2007). Monkeys monitor their memory for the order of events (Templer, Brown, & Hampton, 2018).

Metacognition in monkeys is sometimes cognitively costly, is sometimes introspective, and is used with some flexibility. Metacognition requires cognitive resources and is degraded by a competing cognitive load (Smith, Coutinho, Church, & Beran, 2013). It can depend on a variety of signals, some of which are “public” and objectively observable, and others that are “private,” meaning that only the cognizer, and not an outside observer, can detect the signal (Basile & Hampton, 2014; Basile, Schroeder, Brown, Templer, & Hampton, 2015; Hampton, 2009). Responses to such private signals are particularly interesting because they seem to reflect “thinking about thinking” rather than responses to observable phenomena in the world that are well accommodated in traditional behavioral analysis. Monkeys that acquire metacognitive skill in one domain can generalize, at least weakly, to other domains, suggesting that the processes serving metacognition are flexible and do not depend solely on information specific to particular types of tests (Brown, Templer, & Hampton, 2017; Kornell et al., 2007; Templer & Hampton, 2012; Washburn, Smith, & Shields, 2006).

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Metacognitive monitoring likely evolved not for idle introspection but due to the roles it plays in adaptive cognitive control. The coordination of monitoring and control allows primates to detect when they are ignorant and seek information (Call & Carpenter, 2001; Hampton et al., 2004), to terminate expensive information seeking when sufficient information is available (Tu et al., 2015), and to hold memories online when they will be needed in the near future (Tu & Hampton, 2014). All three of these types of cognitive control can be conceptualized as taking monitoring as an input that guides the deployment of cognitive control in a feedback process (Nelson, 1996)

It appears that metacognition may not be universal among primates, or at least comes much more easily to some species than others. Strikingly, new world brown capuchin monkeys *(Cebus apella)* are much less likely to behave metacognitively in situations in which old world rhesus monkeys *(Macaca mulatta)* do (Basile, Hampton, Suomi, & Murray, 2009; Beran, Smith, Coutinho, Couchman, & Boomer, 2009; Fujita, 2009; Paukner, Anderson, & Fujita, 2006; Smith, Smith, & Beran, 2018). Though it is not clear why, evidence for metacognition in many other animals, such as pigeons and dogs has also been relatively weak (Belger & Brauer, 2018; Brauer, Call, & Tomasello, 2004; McMahon, Macpherson, & Roberts, 2010; Roberts et al., 2009; Sutton & Shettleworth, 2008), while there seems to be comparatively strong evidence for metacognition in rats (Foote & Crystal, 2007; Templer, Lee, & Preston, 2017). These putative species differences should be fertile ground for comparative studies.

The advances in our understanding of metacognition described above, together with other findings, provide solid grounds for the existence of metacognition in some primates at least. There is more to learn about how metacognition works in primates, and under what conditions and in which cognitive systems it operates. Empirical comparative and theoretical work should be directed at better understanding the conditions under which metacognition evolved. The occurrence of metacognition in nonhumans may prompt us to re-evaluate and expand our conception of the complexity of animal cognition (Smith, Couchman, & Beran, 2014), but see Basile and Hampton (2014) for a less expansive characterization.

Conditions for Metacognition

Metacognition in rhesus monkeys requires cognitive resources associated with executive function. A competing cognitive load has a greater negative impact on metacognitive judgement than it does on the cognitive judgement that is the target of metacognition (Smith et al., 2013). This suggests that primary cognitive judgements and metacognitive judgements are substantially distinct from one another, and that we are only likely to observe metacognition in animals with significant capacity for executive function. More comparative work is required, however, to determine whether the occurrence of metacognition is predicted by “raw” executive function, specific life-history factors that make metacognition evolutionarily important, or both.

Even within a specific cognitive task, the amount of information available to metacognitive processes may vary over time. For example, during the delay interval of memory tests, one of the few targets for introspective metacognition may be the presence or absence of

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memory itself, whereas once subjects are confronted with a specific memory test, additional sources of information about the difficulty of the test may be available (Hampton, 2009; Hampton et al., 2004). Consistent with this view, monkeys get more benefit, in terms of improvements in accuracy, when making metacognitive judgements in the presence of a memory test, than when making the same judgements prior to seeing the specific memory test (Brown, Basile, Templer, & Hampton, 2019; Ferrigno, Kornell, & Cantlon, 2017). We have not yet identified all the sources of information for metacognitive judgement available to monkeys. Humans draw on a rich set of both direct and indirect information about cognitive processes when making metacognitive judgments (Dougherty, Scheck, Nelson, & Narens, 2005; King, Zechmeister, & Shaughnessy, 1980; Koriat, 1997). Further work determining what information is available for metacognitive judgements at different phases of test trials or training will enhance our understanding of cognitive processing generally, and metacognition specifically. It is almost certain that there will be substantial differences between humans and monkeys, given that many of the heuristics used by humans are likely to be unavailable to monkeys.

So-called metacognitive illusions provide another opportunity to identify the information that enters into metacognitive judgement. Metacognitive illusions are dissociations of accuracy and confidence, such that subjects are subjectively either more or less confident than they should be given objective accuracy. For example, monkeys were more confident in metacognitive judgements when tested with high-contrast images than when tested with lower contrast images, even though contrast did not affect accuracy (Ferrigno et al., 2017). Such a dissociation suggests that the information controlling metacognitive judgements and controlling choice are not identical. Other cases where these “illusions” occur will help identify the cues, or information, available to metacognition, and the relation of this information to that controlling primary cognitive performance.

Cognitive Systems Accessible to Metacognition

Metacognition can be used as a tool to advance our understanding of the distinctions between cognitive systems. It is widely recognized in human cognitive science that some cognitive systems are accessible to monitoring, or explicit, while others are not accessible to such monitoring and are therefore implicit (e.g., Nelson, 1996; Squire, Knowlton, & Musen, 1993; Tulving & Schacter, 1990). Work that determines whether monkeys can metacognize about some types of information processing, but not other types, may provide a powerful parallel to the distinction between explicit and implicit cognition in humans (Hampton, 2001, 2003). Characterizing the functional properties of primate cognitive systems that are accessible and inaccessible to metacognition may also help identify the evolutionary function of metacognition (see below, Evolution of Metacognition).

Several paradigms appear especially well suited for testing for dissociations in cognitive accessibility between cognitive systems. Monkeys, like humans, demonstrate “blindsight” in that they can report the location in which an image occurred, even when they fail to report the occurrence of the image itself (Andersen, Basile, & Hampton, 2014). Other work, cited above, clearly shows that monkeys can metacognize about the occurrence of images; perhaps the cognitive processing that underlies “localization without detection” is implicit

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and outside metacognitive monitoring. Monkeys monitor memory for the order in which events occur (Templer et al., 2018), but it is not known whether they also monitor similar cognitive processing about potentially more habitual transitive inference (Gazes, Chee, & Hampton, 2012; Gazes, Lazareva, Bergene, & Hampton, 2014) or simultaneous chaining (Templer, Gazes, & Hampton, 2019; Templer & Hampton, 2013). Some memory in monkeys appears to be under cognitive control, and likely accessible to metacognition, where other types of memory do not (Basile & Hampton, 2013; Tu & Hampton, 2013, 2014; Tu, Hampton, & Murray, 2011). But we do not know whether these cognitive processes differ in accessibility to metacognition as might be predicted on the basis of differences in cognitive control. Finally, there is evidence that monkeys, like humans, show two types of categorization performance depending on the nature of the stimuli. In humans this dissociation is evident in whether subjects can explicitly state a rule guiding their discrimination performance. Perhaps monkeys can better metacognize about “explicit” than about “implicit” categorization (Smith, Zakrzewski, Johnson, Valleau, & Church, 2016; Zakrzewski, Church, & Smith, 2018). Students of nonhuman metacognition might make exciting progress in our understanding of nonhuman cognitive systems by applying metacognition measures to these paradigms, testing for dissociations. Some evidence from humans indicates that tasks that appear to be implicit when assessed by continuous confidence measures, appear to be explicit when assessed by binary confidence judgments (Tunney & Shanks, 2003). Almost all studies with nonhumans have used binary judgements to measure metacognition, and this trend might best be continued in tests for dissociations in cognitive monitoring, as such measures will be the most conservative.

Evolution of Metacognition

Understanding the evolution of metacognition has received less attention than other aspects of this cognitive capacity. Most work has been directed at determining whether or not metacognition occurs in nonhumans at all. When metacognition in nonhumans has been used to make broader points in psychology, it has been suggested to be a case of “higher cognition” (e.g., Smith et al., 2014) or potentially related to philosophical conceptions of consciousness (Carruthers, 2008, 2014). In addition to these interesting issues, the existence of metacognition also raises questions about the function of metacognition and why and when it should evolve. What does metacognition do for animals that would lead to the evolution of this capacity? I have provided a very general answer to this question in stating, as have others (e.g., Nelson & Narens, 1990), that metacognition provides feedback to guide cognitive control, but this answer leaves open questions about which species would need this type of feedback and in which cognitive domains. The fact that it appears that metacognition is not universal among species, and does not apply in all cognitive domains, further highlights the notion that metacognition might evolve under only relatively restricted conditions. Comparative work is required to identify the evolutionary conditions that caused metacognition.

One exciting avenue for pursuing questions about the evolution of metacognition is further comparisons of brown capuchin and rhesus monkeys. Because capuchin monkeys are so much less likely to manifest metacognition than are rhesus monkeys (Basile et al., 2009; Beran et al., 2009; Smith et al., 2018), consideration of differences in the ecology and

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phylogeny of these two primates is a good source of hypotheses about the function of metacognition. It will also be of great interest to acquire results from new world monkeys other than brown capuchins, and old world monkeys other than rhesus macaques. This would allow us to begin to identify phylogenetic and ecological constraints on metacognition, and to characterize their roles in determining which animals are metacognitive. There has been less work reported about non-primate species, and thus there is less evidence about the presence or absence of metacognition in other species, but published work with pigeons and dogs has also been less likely to report strong evidence for metacognition. Clearly, more comparative work is called for to determine whether these putative species differences are due to different amounts research effort across species, lack of optimization of metacognition paradigms for specific species, or other technical factors. Only when these factors are ruled out can we conclude that there are real differences between species. A question that might help organize the comparative research effort is: Under what conditions would metacognition be important enough to evolve?

Evolution involves cost benefit tradeoffs. Given that we seem able to identify some benefits of metacognition in terms of cognitive control, we may wonder what the costs of metacognition are. Does it require unusually expensive neural substrates? Does it interfere with efficient cognition under some conditions, perhaps in the case of habitual behavior, for example? Are there particular ecological/behavioral niches that might be associated with the need for metacognition? Why would rhesus monkeys show metacognition more readily than capuchin monkeys? We have barely begun to address these questions and generating tentative answers will be exciting and will stimulate new research.

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