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The octopus: A beautiful (but disorganized) "mind"

Commentary on **Mather** on *Octopus Mind*

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Abstract: Mather (2019) presents convincing evidence that octopuses have minds, but in the first 85% of the target article, the evidence does not come through very clearly because it is hidden by other information and by problems with the paper's organization. I propose ways to build a tighter argument in the author's Response to the Commentaries.

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I appreciate Mather's important contributions to cephalopod studies, from her original research to her multiple review articles. The target article (Mather, 2019) has many strong points. It contains a vast amount of information, with updated findings and new references since her previous articles (Mather, 2012; Mather & Dickel, 2017; Mather & Kuba, 2018). It also has a convincing subject: cephalopods are the invertebrates with the most complex brains and behaviors, so just listing their special abilities will persuade many readers that they have minds (also see Godfrey-Smith, 2016; Montgomery, 2015). The target article's ecological emphasis, on how octopuses act and perceive things in nature rather than in lab experiments, is indeed the most informative approach. The specific pieces of evidence presented for an octopus mind seem very reasonable: the capacities to adjust their behavior to solve problems, to learn a lot, to explore and play, and the cognitive abilities documented in Figure 7 (p. 20).

Here are some more strong points. I liked how the arm-movement section (1.a.2) built a case, step by step, that the brain must be in charge of the unified, whole-body behaviors, thereby arguing against the "two-brain" idea that the arms' nervous system operates independently of the brain (Carls-Diamante, 2017; Grasso, 2014). The section on how cephalopods see polarized light, and how this gives them an adaptive advantage, is particularly well-reasoned (pp. 10-11).

In some areas, I see room for improvement. First, the key terms were not defined. "Mind" and "cognition" are used in many different ways in scholarly studies, so we want to know the author's definitions. Because we are not told precisely what these things are, we don't know her criteria for evaluating whether octopuses have minds. The article's context indicates that having a mind involves voluntary control of behavior, with motivations, but what is Mather's *full* definition? As for defining "cognition," a recent paper by Mather said it consists of the mechanisms for handling information (Mather & Dickel, 2017), but I wish that definition had been presented here as well. "Self" is another term the article could have defined.

Second, some of the octopus behaviors Mather attributes to a voluntary mind could instead be reflexive or automatic, especially if the actions are too fast for thinking to signal, or if they are analogous to the actions that *vertebrates* signal with their autonomic nervous system.

Such actions include fast skin displays (p. 4), the "panicked" escape strategies (p. 21), and head bobbing for stereoscopic vision. I think Mather has answered this objection before (Mather and Kuba, 2018), but it would have been good to address it here as well.

Third, I wish the article had said more about the *sensory* aspects of mind and experience. The *action-based* approach to the mind is valid and commonly used (Cruse & Schilling, 2015; Grasso, 2014; Klein & Barron, 2016; Llinas, 2002; Merker, 2007; Morsella et al., 2016), so there is nothing wrong with it. But this journal is *Animal Sentience,* with a sensory theme, so I expected more on the octopus's sensory experiences (see analysis in Feinberg & Mallatt, 2016, 2018; Mallatt & Feinberg, 2016). The target article does say that octopuses use their senses to build a cognitive map of space to help them navigate through their habitat (p. 12). That is almost enough on sensory experience, but I had hoped for a little more, perhaps on visual consciousness.

Fourth are my concerns about the organization. The article jams too much good-but-secondary information into an "organizational" scheme that does not work, so the main points can get lost. The extra information is mostly ecology-based rather than mind-based. Too many sections read like, "Let me tell you everything interesting about this topic (skin displays, arms, dangers in the habitat); then you the reader can dig out the parts that indicate a mind." I had hoped for a more explicit and focused exposition.

Although the extra material obscures the real arguments for a mind, these arguments come through in some excellent sections of the paper. These good parts are: Section 1b on sensory information; the first part of Section 2a that says exploratory behavior indicates forethought in octopuses; Section 2c on flexible problem solving; Figure 7 on the evidence for cognitively guided behaviors (after Mather & Dickel, 2017); and the Conclusion section that belatedly brings in the complex learning abilities.

The article ends strongly with pages 19-21, but that ending is too late and short to overcome the difficulties with Section 1, which occupies over half the text (pp. 2-14). Section 1 has the largest amount of extra information that the reader cannot easily relate to a mind. The introduction says that Section 1 will largely describe the octopus's sense of *self* (self-mind), but this section instead talks about skin displays, arm movements, and the lack of sociality. It never considers self, except to say that octopuses *fail* to monitor their own skin displays (p. 4) and *fail* the mirror test of self-recognition(!) (p. 6). No evidence for any sense of self there.

Section 2, while much better, also has some organizational and information-overload issues. Section 2a on exploration and play (pp. 14-17) gives lot of extra information about play that is sometimes hard to understand; its concluding paragraph particularly baffled me, with its seemingly unrelated topics of action selection, attention, head bobbing, sociality and "specializing generalists." Another problem with Section 2 is that it claims to be about the three *motivational bases* of mind (pp. 2, 14), namely, exploration, fear, and flexibility. But flexibility is not a motivation; and fear, though it may be a motivation, is never treated as one in the text.

This incorrect claim for motivational bases in Section 2, along with the incorrect claim that Section 1 is largely about self, made me realize that the paper's organization does not quite hold together at the level of its sections and subsections. I would accordingly urge that the author's Response to Commentaries make a tighter argument for octopus mind by avoiding the problems of misarranged extra information and structural disorganization. Did the target article make its case for the octopus mind? Yes, though not efficiently. And all the extra information is nevertheless valuable in its own right for the *Animal Sentience* readership.

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