Inferring emotion from amygdala activation alone is problematic
Commentary on **Cook et al.** on *Dog Jealousy*

Thomas F. Denson
School of Psychology, University of New South Wales

Abstract: Cook et al. investigated neural responses in domestic dogs in an experiment designed to elicit jealousy. Relative to a control condition, watching the dogs' caregivers feed a fake dog activated the amygdala bilaterally. Dogs rated higher in dog-directed aggressiveness showed larger initial amygdala activation. Amygdala activity in this context is insufficient evidence to infer that the dogs experienced jealousy or even negative affect. The experimental design does not provide an adequate level of control to infer the presence of jealousy.

Tom Denson is associate professor of psychology at the University of New South Wales in Sydney, Australia. He is an experimental social-personality psychologist. His primary interests are anger and aggression, social neuroscience, and social neuroendocrinology. He has conducted several functional magnetic resonance imaging studies of anger and aggression in humans. **Website**

Jealousy, anger, and aggressive behavior may strain human-canine relations. Thus, research into understanding the emotional lives of domestic dogs will likely improve human-canine interactions and is therefore an important endeavor. In a very clever experiment, Cook et al. (2018) have conducted an investigation into the neural correlates of jealousy in dogs. Using functional magnetic resonance imaging (fMRI), 13 domestic dogs were trained for the MRI environment and completed three runs of three trial types: dog receives food, dog sees fake dog get food, and dog sees food deposited in a bucket (i.e., no one gets food). Analyses focused on the dog-directed aggression scale of the Canine Behavioral Assessment and Research Questionnaire (C-BARQ) as an additional predictor of BOLD responses in the bilateral amygdala.

Despite my enthusiasm for the topic and the general aims of this research, the claims are not justified by theory or the data. On a theoretical level, it seems unlikely that dogs experience jealousy in the same way humans do, if at all. Dogs certainly experience happiness, fear, anger, disgust, surprise, and sadness, which belong to a class of emotions known as basic emotions (Ekman, 1992). These six emotions are shared with many mammalian species. However, jealousy is part of a class of emotions known as self-conscious emotions or social emotions (Tangney & Salovey, 1999). These emotions are generally thought to be restricted to the human experience because they require higher-order abstract cognition such as theory of mind, complex cognitive appraisals, and attributions. Similarly, in human laboratory experiments, jealousy is invoked by threatened self-esteem (DeSteno, Valdesolo, & Bartlett, 2006). Dogs would require self-consciousness to experience a similar pathway to jealousy.

Examining just one brain structure, the amygdala, is highly unlikely to provide evidence for any specific emotional experience. The authors are right to qualify their findings by noting that amygdala responsivity is not isomorphic with any specific emotional experience. A meta-

analysis of human neuroimaging studies showed that all emotional stimuli increased amygdala activation, including positive emotions (Costafreda, Brammer, & David, & Fu, 2008). Thus, the amygdala can be viewed more as a brain structure that responds to stimuli with emotional relevance regardless of emotional valence. With that in mind, examining only the amygdala is insufficient to make claims about jealously. Based on amygdala activity alone, it is equally possible to claim that the dogs were happy or sad to see the fake dog get a treat, or that they simply found that condition more emotionally relevant than the others without experiencing any emotion at all.

Neuroimaging in humans has become increasingly detailed in its description of brain networks involved in different emotions. During these early days of research into emotions and the brain in dogs, an exploratory whole-brain analysis could be helpful in guiding future research and so could functional connectivity analyses. Future work could examine more widespread brain networks activated during emotions of interest to make stronger claims about the emotional experiences of dogs.

My assessment of this research is aligned with that of Vonk (2018), who suggested that more evidence with additional control conditions is needed before one can ascribe jealousy to dogs. The authors did not provide any convincing data on whether the subjects actually perceived the fake dog to be real. An unmoving statue that smells like another dog could be perceived as strange and hence threatening in its own right initially. In fact, the dogs who were rated highest on the C-BARQ aggression measure (i.e., those dogs highest in threat sensitivity) showed the largest amygdala habituation response. This finding suggests that they may have quickly figured out the charade. The finding that no dogs showed any aggression toward the fake dog is also consistent with this possibility. Jealousy is a robust elicitor of aggression in humans.

Assuming that the subjects did indeed perceive the fake dog as real, the experiment requires a control condition in which the fake dog is fed by someone other than the caregiver. Such a condition would reflect the emotion of *envy* in humans (e.g., coveting what someone else has). If something akin to a jealousy response is elicited, one should only see relevant BOLD responses in the caregiver condition. If relevant neural responses are observed in both conditions, the result is probably more indicative of intraspecific resource competition (e.g., something more akin to envy). The current design does not distinguish between these two possibilities.

One is left with the difficult problem of how to detect jealousy in dogs, if it exists. Detecting jealousy nonverbally is not easy in humans. Unlike basic emotions, jealousy does not have a universal facial expression. The only reliable method with people is to ask — and even then, humans must be willing and able to report their emotional experience. To date, there is no strong evidence for a unique pattern of brain activity during experienced jealousy, suggesting that finding the neural correlates of jealousy in dogs may take some time.

A final issue is that five of the 13 dogs had the lowest aggression score possible. Thus, the results rest on just 8 dogs. Replication and extension with a larger sample is warranted.

In sum, this experiment is part of growing methodological advances taking place in dog imaging, and I commend the authors for the effort. Learning as much as we can about the emotional lives of domestic dogs will no doubt improve human-canine relations and canine welfare.

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Overview. Since Descartes, philosophers know there is no way to know for sure what — or whether — others feel (not even if they tell you). Science, however, is not about certainty but about probability and evidence. The 7.5 billion individual members of the human species can tell us what they are feeling. But there are 9 million other species on the planet (20 quintillion individuals), from elephants to jellyfish, with which humans share biological and cognitive ancestry, but not one other species can speak: Which of them can feel — and what do they feel? Their human spokespersons — the comparative psychologists, ethologists, evolutionists, and cognitive neurobiologists who are the world's leading experts in "mind-reading" other species – will provide a sweeping panorama of what it feels like to be an elephant, ape, whale, cow, pig, dog, chicken, bat, fish, lizard, lobster, snail: This growing body of facts about nonhuman sentience has profound implications not only for our understanding of human cognition, but for our treatment of other sentient species.

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