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OUTLOOK

Bumblebees at work in an emotion-like state

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Summary Pretest sucrose affects a dopamine-modulated response of bumblebees to an ambiguous cue to reward as well as a response to a simulated attack (Perry, Baciadonna, & Chittka, *Science, 353*(6307), 1529–1531, 2016). The contribution of the study lies in opening the door to research on the inner experience of insects, the learning and motivational mechanisms of their behavior, and the evolutionary analysis of emotions.

Keywords Bumblebees · Emotion · Motivation · Evolution

Do ravens have insight into problems? Do dolphins have language? Do elephants have a self-concept? Sound familiar? These questions are too broad and sweeping to tackle, betray an anthropocentric approach to animal behavior, and make headlines (Shettleworth, 2010). Do bees have emotions? All right, do they have *emotion-like* states? According to Perry, Baciadonna, and Chittka (2016) in a recent paper in *Science*, they do. The paper is sure to cause behavioral scientists to take notice, and not only for its tantalizing title: "Unexpected rewards induce dopamine-dependent positive emotion-like state changes in bumblebees". For the readership from psychology (especially in the areas of learning, motivation, and cognition), it touches on many questions that animate our research programs.

The study

The approach, pioneered by Bateson, Desire, Gartside and Wright (2011), was to adopt specific behavioral, cognitive and physiological indices of the emotions in humans and other vertebrates, and apply them to bees. Bumblebees were first trained on a go/no-go task. A reinforcer of 30% sucrose was signaled by one color (e.g. blue) on one side of the foraging arena, while water was signaled by another color (e.g. green) on the other. The trained bees were then tested for their reaction to an ambiguous blue-green card in the middle. How did the bees interpret this ambiguous stimulus? Bees in a group that was fed a drop of 60% sugar solution prior to entering the arena directed themselves to the stimulus significantly more quickly than a control group. The authors took pains to rule out the possibility that the pretest consumption of sugar simply led to higher activity levels or to a higher expectation of subsequent reward. The conclusion that there was a cognitive bias in judgment was all but inescapable. If this is part of what is meant by positive emotion or optimism, then the bees have it.

There was more. Perhaps a little taste of sugar could, well, take the sting . . . out of a potentially unpleasant experience, such as being attacked by a predator. Here, a new and ingenious method was developed. Bees were first trained to forage in the arena. Then, during testing, two things happened: (1) In a little antechamber at the entrance of the foraging arena, one group of bees was given a droplet of 60% sugar, while the other one was not; (2) 10 seconds later, an attack on the bees in both groups was simulated: the sponge-covered ceiling in the antechamber literally came down on a captive worker for 3 seconds, after which it was released. How long it took the bees to just get over the experience was measured. The prefed group started foraging significantly more quickly than the control group.

The icing on the cake in this series of experiments was a neuropsychological consideration. Given that dopamine mediates reward-related processes, a dopamine blocker was expected to abolish both the effects of pretest sucrose described above. It did.

The significance

Theories of learning and motivation The results present new opportunities for investigating 'killjoy' interpretations. Perhaps what is already known about learning and motivation will go a long way towards explaining the findings reported here. Below,

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two well-known theories and their predictions are described for purposes of illustration.

The pretest sucrose was characterized as 'unanticipated' and 'unexpected'. These words are of the essence in the Rescorla-Wagner model of associative learning, from which we know that surprise is at the heart of learning. Certainly, the sugar was at a stronger concentration than experienced during training, and it was also offered in a new place, but the context of the foraging arena almost certainly created some expectation of food. Moreover, if anything was unexpected, it must surely have been being squeezed right after being fed. Since expectation was not experimentally manipulated, however, it remains to be determined whether surprise elements led to new learning, and if so, what were the contents of that learning.

A ready-made model of affective/hedonic states might also be applicable in the current situation. According to the Solomon-Corbit opponent process theory of motivation, reactions to individual stimuli are governed by two opposing processes: a primary process that begins and ends with stimulus onset and offset and a longer lasting process that pulls affect in the opposite direction back towards baseline. If there are two opposing processes for each of two stimuli, one appetitive and one aversive, the net result should much depend on their time course.

If these or other well-established theories are indeed up to the task of accounting for the data, and this remains to be determined, it would by no means undermine the research. On the contrary, it would show how the known mechanisms of motivation and learning are powerful and general enough to generate a host of decisions and behaviors in bumblebees that were heretofore unknown.

The inner experience of insects Notwithstanding Skinner's pointed remarks that our experiences are all locked within our own skins, psychologists are well-positioned to contribute to our understanding of how animals perceive the world—through their eyes and not ours—with a view to improving their welfare. While much of the research in this area focuses on the inner experience, conscious or unconscious, of vertebrates, indices of what is valued by invertebrates can be obtained by behavioral methods such as examining the habituation of a response to a stimulus and the renewal of responding following a change in that stimulus. The new methods advanced by Perry et al. (2016) hold out the promise that answers to questions regarding the inner worlds of organisms—even those that are radically different from ourselves—are not entirely beyond our reach.

The function and evolution of emotions Perhaps the most intriguing aspect of this new research is that it might pave the way to understanding the historic origins and the neural foundations of emotions. In the future, we can expect research to focus on explicit species comparisons informed by evolutionary and ecological considerations, *Bombus terrestris* versus *Homo sapiens* being a nonstarter. In humans and their ancestors, the putative function of emotions such as happiness, empathy, jealousy, fear, and disgust is to orchestrate and guide decisions and actions towards fitness promoting outcomes such as resource acquisition, partner retention, predator avoidance, and disease avoidance. Bees have problems of survival and reproduction too. It is just not known whether their solutions depend on emotions/emotion-like states. Identifying the fitness benefits of emotions and the costs of building the neural hardware underpinning them are a considerable challenge for the future.

Communication strategies in animal cognition In a review of animal cognition 2 decades ago, Wasserman (1997) noted the tendencies to either humanize animals or dehumanize people. He suggested that exploiting the conflict might be a strategic move in reaching new audiences. Given that granting agencies highlight the importance of communicating to the public the value of its investment in research, scientists welcome the broadcasting of their results in nontechnical language. A Google search of 'bumblebees; emotion' revealed that humanizing animals while describing the new study seems to have played well: 'Don't worry, bee happy: Bees found to have emotions and moods'; 'Sugary treats make bumblebees "happy", say researchers'; 'Bumblebees feel emotions, scientific study finds'. In fact, nowhere in the paper was there any claim to have shown that the bees felt anything at all. Better control of public relations messages might be achieved by steering the conversation towards artificial intelligence and robotics. Adamo (2016) urges us to consider whether insects might be more like complicated robots than like little people.

Conservation Eliciting sympathetic reactions towards species conservation efforts is generally easier for animals that are good looking, sweet sounding, and cuddly. Rallying public support behind conservation of stinging insects can be more tricky. Perhaps if these creatures could be thought of as being just a little more like us, it would help. Herein lies a potential pitfall: What if they can't? Research on bee behavior is important because bees are important, whether humans can ever be brought to see their own reflections in them . . . or not.

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