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Subjective experience in insects: Definitions and other difficulties

Commentary on [Klein & Barron](#) on *Insect Experience*

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Abstract: Whether insects have the potential for subjective experiences depends on the definition of subjective experience. The definition used by Klein & Barron (2016) is an unusually liberal one and could be used to argue that some modern robots have subjective experiences. From an evolutionary perspective, the additional neurons needed to produce subjective experiences will be proportionately more expensive for insects than for mammals because of the small size of the insect brain. This greater cost could weaken selection for such traits. Minimally, it may be premature to assume that small neuronal number is unimportant in determining the capacity for consciousness.

Keywords: cognitive ethology, pain, consciousness, selection, fitness, neuromodulation

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Klein & Barron's (K & B's) (2016) argument that insects have the capacity for subjective experience contains at least two issues that require further discussion: First, K & B's definition of "subjective experience" and second, the possible importance of brain size for the evolution of subjective experience.

As in any argument, definitions are key. K & B use a specialized definition of both subjective experience and consciousness that strips these concepts of many of the attributes considered central to them, such as self-awareness (e.g., [Stanford Encyclopedia of Philosophy](#)). K & B note that their definitions are not universally accepted. However, they state that their definition is the "modal" belief in the field. This is almost certainly not true, given that only 54% of philosophers in a recent survey believe that the mind is equivalent to the brain (Bourget and Chalmers, 2014), let alone that consciousness doesn't require self-awareness. Therefore, it is probably fair to say that K & B's definition is an unusually liberal one.

K & B also argue that their definition is superior to others because it transcends an anthropocentric perspective. However, subjective experience issues will always be anthropocentric, because humans are the only animals we can ask about their private subjective states. To define it otherwise is to take away the "subjective" part, at which point it would be less confusing to come up with a different term (e.g., sensory integration capacity).

K & B further argue that, even if their definition is unusual, it hasn't made their conclusion inevitable. However, if they had used a more standard definition (i.e., that subjective experience includes attributes such as self-awareness), then K & B would have come to a different conclusion. Therefore, their conclusions do indeed require their definition. Could their argument have failed with their definition? If "subjective experience" is defined as the ability to react to the environment in a purposeful way (e.g., have spatiotemporal modeling, learning, and motivated behaviours), then, yes, the conclusion was set up to succeed prior to the argument, as insects are known to have these capacities.

K & B note parallels between some regions of the insect central nervous system and regions of the vertebrate brain that may support subjective experience. However, they also note that there are differences, one of the most striking being neuronal number. Insects have 4 orders of magnitude fewer neurons than humans. Although K & B state that brain size is not critical for consciousness, there are good evolutionary reasons to think that the markedly small brain size of insects implies fewer abilities. Neuronal tissue is energetically expensive. Insect nervous systems are compact, suggesting that they have been selected to minimize space and energy requirements (Sterling and Laughlin, 2015). The ability to have subjective experiences is likely to require additional neuronal resources. For the sake of argument, let's say that it requires only 1,000 extra neurons. In a mammal with millions of neurons, the relative cost of adding an additional 1,000 neurons would be smaller than the relative cost of adding the same 1,000 neurons to an insect brain with less than a million neurons. In other words, the relative cost of various attributes of consciousness (e.g., subjective experience) is likely to be higher for insects than for mammals. The relative fitness benefits must therefore also be greater for insects in order for these traits to evolve in this group.

To make this argument in another way, would we expect insects to have the subjective experience of pain? The ability to respond to damaging stimuli is clearly advantageous for animals, and insects have nociceptive systems (Johnson and Carder, 2012). However, would the additional neural tissue required to have the subjective experience of pain be of selective advantage? An example from robotics suggests that the answer may be no. Ames and colleagues (2012) have built a robotic rat (a MoNeta, modular neural exploring travelling agent) containing a "memristive" device that can change the architecture of its computer circuitry, allowing learning and other higher-order cognitive skills. The robot has a "discomfort drive" that motivates it to move when it senses discomfort (e.g., when wet). Therefore, when placed in a water maze, the robotic rat hunts for a submerged platform, just like a real rat. Once it has found the platform, it modifies its behaviour to find the platform more quickly on subsequent trials. Noxious stimuli can induce modern robots to reprioritize their goals, modulate their behaviour and stimulate learning (Lee-Johnson and Carnegie, 2010). Some robots even have neural circuitry that mimics that of arthropods (Ayers, 2016). What abilities, above and beyond those found in robots like the MoNeta, would an insect have if it invested in the neural circuitry to have a subjective experience of pain similar to what mammals experience? Alternatively, K & B's definition may allow the MoNeta to qualify as conscious, although the robotics community does not consider such robots sentient or capable of subjective experience (Reggia, 2013).

In self-consciously aware animals such as humans, subjective experience may aid in decision-making (Seth and Baars, 2005). Without digressing into the difficult issue of free will, I would argue that insects have fewer degrees of freedom in their behavioural choices than do

humans and other mammals. With fewer behavioural choices to make, insects may receive a relatively smaller benefit from subjective experiences than would humans. Therefore, for insects, the relative costs of investing in the neural circuitry required for consciousness are probably higher, and the returns lower, than they are for mammals (Adamo, 2016).

K & B argue that insects may be able to squeeze more functionality out of their neurons (i.e., that they use them more economically) than mammals. In other words, insects may be able to have subjective experiences using fewer neurons than the same capacity would require in a mammal. Work on simpler neural circuits (e.g., the stomatogastric ganglion, Marder et al., 2014) has taught us that a neural circuit's abilities arise as much from its microcircuitry as from its gross connections to different brain regions. Therefore, insects could compensate for their lack of neuronal number with increased microcircuitry complexity. However, the evidence suggests the opposite, i.e., that mammalian microcircuitry has more complexity. To provide just a few examples, mammalian neurons have a greater diversity of ion channels (Brown, 1990). In mammals, glia play a complex role in synaptic transmission, leading to increased synaptic plasticity (Purves et al., 2012), and immune factors such as cytokines also modulate neuronal function (Dantzer et al., 2008). Glia and cytokines do not appear to be important modulators of synaptic transmission in insects, although it is possible that these phenomena have been understudied in this group. On the other hand, mammalian microcircuitry has been understudied compared to some invertebrates, and its complexity is probably underestimated (Marder, 2012).

Therefore, whether insects have the potential for subjective experiences depends largely on the definition of subjective experience. The definition used by K & B (2016) is extremely liberal and could be used to argue that some modern robots have subjective experiences. The small size of the insect central nervous system suggests that additional neuronal investments will be proportionately more expensive for insects than for mammals. Therefore, investing in attributes of consciousness is likely to be more costly for insects, weakening selection for these traits. It is unlikely that insects can reduce the costs of consciousness by increasing microcircuitry complexity, as they have fewer tools to modulate neuronal function than do vertebrates. Minimally, it may be premature to assume that small neuronal number is unimportant in determining the capacity for consciousness.

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