ANIMAL SENTIENCE
AN INTERDISCIPLINARY JOURNAL ON ANIMAL FEELING

Correia-Caeiro, Catia and Liebal, Katja (2023) Animal communication and sentience. *Animal Sentience* 33(27)

DOI: 10.51291/2377-7478.1819
Date of submission: 2023-06-12
Date of acceptance: 2023-06-18

Animal communication and sentience

Commentary on **Segundo-Ortin & Calvo** on *Plant Sentience*

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Abstract: Segundo-Ortin & Calvo (S&C) argue for sentience in plants on the basis of several studies of what they describe as "cognitive abilities" in plants. As other commentaries (e.g., Brooks Pribac, 2023; Damasio & Damasio, 2023; ten Cate, 2023) have pointed out, however, there is some misuse of several concepts, and a lack of evidence for sentience. We try to clarify three questions in S&C's discussion: (1) How is communication defined and conceptualised in animal research? (2) Is plant communication comparable to animal communication? (3) Is communication (or the process we see in plants) a good basis for inferring sentience in plants?

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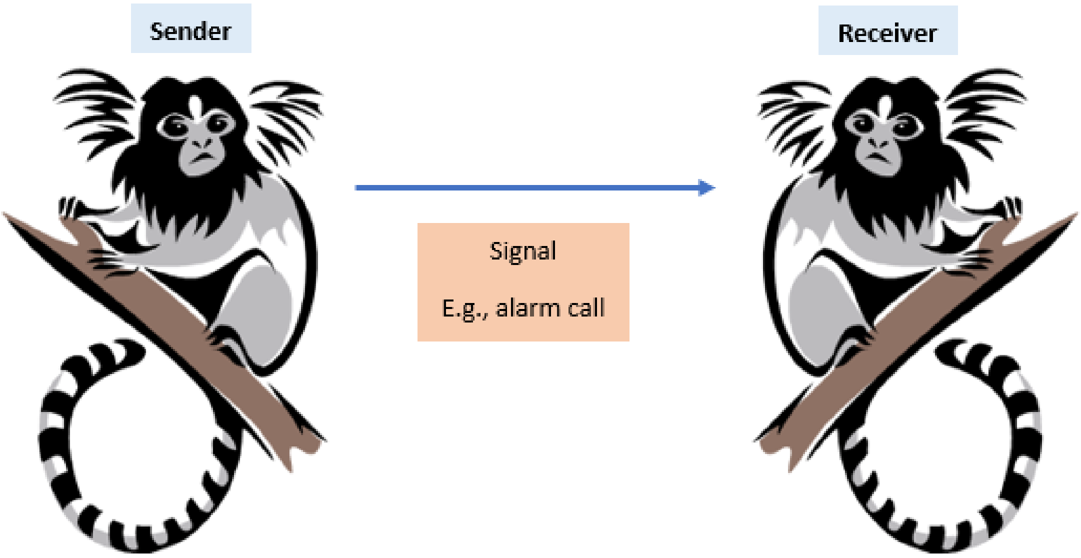
1. What is animal communication? Strict criteria are needed for research on communication in nonhuman animals because they cannot do self-report. The definition of animal communication, particularly in primates, often requires the concept of "intentionality," in which the signal indicates the goal of the sender to the receiver (Dennett, 1983; Hauser & Nelson, 1991; Ullrich et al., 2020). Within intentionality, there is a growing level of cognitive complexity, depending on the sender's and receiver's ability to understand one another's mental states during communicative exchanges (**Figure 1**).



Zero order: no mentality or intentionality in both sender/receiver.

E.g., alarm call due to arousal

1st order: sender produces signal with the *intention* to produce a response in the receiver (but receiver still has no mentality or intentionality and doesn't need to recognise the intention in the sender)

E.g., alarm call to make receiver hide

2nd order: adds to the 1st order by requiring that the receiver attributes *intentionality* to the sender

E.g., alarm call to make receiver hide and know that there is a danger

3rd order: sender *intends* for the receiver to attribute to sender the *intention* to signal

E.g., alarm call *intended* to be understood by receiver as sender *intending* them to hide due to a danger

4th order: sender and receiver mutually understand the sender's goal and intention that the receiver understands that goal

E.g., both sender and receiver understand that the alarm call is *intended* to make the receiver hide, and that the sender had that goal when the call was produced

Figure 1. Orders of intentionality with examples for each level

According to Ullrich et al. (2020), nonhuman animals have at least first-order intentionality. Second-order intentionality is considered a marker of human-like communication (Townsend et al., 2016). A list of criteria has been used to test intentionality in a variety of species (Leavens et al., 2004). Which criteria are used, and how many, varies considerably across studies (Liebal et al., 2014), but they help in distinguishing what is and is not intentional communication. The criteria include:

C1. ***Social use between sender and receiver*****:** The signal must be directed by a sender at a receiver (Schel et al., 2013).

> **C2.** ***Sender sensitivity to receiver's attention*:** The signal is produced only if the receiver is attentive and able to receive it (Waller et al., 2015).
>
> **C3.** ***Sender consideration of receiver's attention:*** The sender adjusts the signal's sensory modality to the attentional state of the receiver (Crockford et al., 2017)

2. Do plants communicate? There seems to be a large gap between the way animal communication is defined and the way S&C describe plant communication. To assess whether plants communicate, we need to examine S&C's claims in terms of intentionality criteria suitably modified to be applicable to plants.

S&C suggest that communication between plants occurs when they release Volatile Organic Compounds (VOCs) during a stressful event (e.g., being eaten). This allows other plants to detect the VOCs and trigger defence mechanisms. However, being able to detect VOCs in the environment is not communication; it is "behaviour-reading" at best, or, more parsimoniously, it is just "environmental-cue-reading".

More important, considered as between-plant communication, VOC-release during stress does not have a directed goal. It fails to meet criterion C1. VOC-release is only an internal signal for the plant to react to the stress; it is picked up *incidentally* by neighbouring plants, which in turn react to it (Holopainen & Gershenzon, 2010). To infer second-order communication, S&C would need to demonstrate that the plants releasing the VOCs intended to inform other plants.

There also seems to be a wide divergence in the use of the same terms in zoology and botany. For example, in plants, VOCs are considered both as *cues*, released spontaneously by the sender, and as *signals,* released because of stress to the sender (Ninkovic et al., 2019). The same terms are defined very differently when applied to humans and other animals (Laidre & Johnstone, 2013; Scott-Phillips, 2008).

The first crucial difference is that the definitions of both cues and signals depend only on the receiver's, not the sender's behaviour: in animal communication, *cues* convey incidental information to the receiver, whereas *signals* were shaped by evolution for the sole purpose of conveying information to the receiver.

The second crucial difference between plant and animal definitions of cues vs. signals is that the difference is not just a matter of information transmission: *signals* are produced by the sender with the intention to influence or modify the receiver's behaviour,

A third crucial difference is that in animal communication, *signals* have an influence on both the sender's and the receiver's fitness. Hence, not only is the distinction between cues and signals in zoology more nuanced, but both terms differ from their counterparts in botany.

Questions thus remain about plant communication: Do plants show any of the evidence of intentionality mentioned above (or equivalent evidence for plants)? For example, do plants release more VOCs if other plants are in close proximity (i.e., do they show "audience effects")? Does VOC-production change if there is wind in the direction opposite to the intended "receiver" plants (i.e., sensitivity to social partner ability to receive signal)? Even to infer first-order intentionality, S&C would need evidence that plants have control over the production of VOCs and are releasing them with a communicative goal.

According to a more general definition of communication in animals, signals must be *learned*, *adaptive*, and *flexible* (Kaplan, 2014; Seyfarth et al., 2010). Plants lack associative learning (see Baciadonna et al., 2023). VOC-release does not seem to be an adaptive mechanism (it does not benefit sender and receiver simultaneously). And it is not flexible (i.e., plants cannot voluntarily emit or omit release under stress).

Hence the evidence presented in the target article does not fulfil any of the criteria necessary for inferring that what plants are doing is communication. VOCs do not act as signals and plants seem to have zero-order intentionality (which excludes communication).

3. Are “cue-reading” or any other cognitive abilities indicators of sentience in plants? S&C argue for an evolutionary view of sentience to infer that plants are sentient. They describe several cognitive abilities in putative support of sentience. However, simply equating sentience with stimulus-response mechanisms or even higher-order cognitive abilities is insufficient. Cognitive abilities are neither necessary nor sufficient to demonstrate sentience. What is also needed is evidence of something like “proto-sentient” behaviour or “proto-structures” underlying the course of evolution of sentience across species. Precursors of sentience in plants could be physiological, like the ocelli (pigmented spots) in planarian flatworms that evolved across organisms into eyes. (Ocelli are not eyes, structurally or functionally; they are predecessors of eyes.) Or the precursors of sentience could be cognitive, for example, something similar to optimistic cognitive biases (Mendl et al., 2009).

Plants and animals belong to different kingdoms. The sensory mechanisms in plants are not necessarily present in animals because plants did not evolve into animals. Instead, a common ancestor, a unicellular organism, split into animals and plants 1.6 billion years ago (Meyerowitz, 2002). Thus, in order to claim that plants and animals have a similar mechanism underlying sentience (which is already very unlikely because of their very divergent adaptations), S&C would need to demonstrate either that:

> (1) the common ancestor or extant similar organisms have a proto-sentience mechanism or at the very least proto-structures for sensory mechanisms that could evolve into both animal and plant sentience,

or that :

> (2) plants have a mechanism homologous to animal sentience (such as mitochondria, Meyerowitz, 2002).

In a unicellular organism, not even the most basic phenomena of cell-to-cell "communication" exist, and what came next for plants and animals evolved independently in widely differing environments. (Meyerowitz reports that the same proteins are found but they are used in a very different way in cell-to-cell communication).

4. Conclusion. It remains highly unlikely that both taxa evolved sentience.

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