VITA PENSATA

28

Le Scienze

«La scienza è un processo storico complesso ed eterogeneo che contiene anticipazioni ancora vaghe e incoerenti di future ideologie accanto a sistemi teorici molto sofisticati e a forme di pensiero antiche e fossilizzate»
(Paul K. Feyerabend, *Contro il metodo*, Feltrinelli 2021, p. 120).

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RIVISTA DI FILOSOFIA

REGISTRATA PRESSO IL

TRIBUNALE DI MILANO

N° 378 DEL 23/06/2010

ISSN 2038-4386

LA FILOSOFIA COME VITA PENSATA

INDICE

Anno XIII - n. 28

Aprile 2023

ISSN: 2038-4386

www.vitapensata.eu

SOME OBSERVATIONS ON PLANTS COGNITION

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Fundamentals

Determining what cognition is and which systems are cognitive has long characterized the investigation of philosophy of mind. In this paper, I would like to address the question of cognition in plants[1].
Indeed, plants are capable of an impressive range of behaviors. For example, they can learn, but also make decisions concerning the acquisition of their own resources, which are fundamental to their survival[2].
Thus, I would like to defend the hypothesis of considering a form of cognition in plants. This process has already begun for some non-human animals[3], for which several studies have been carried out and that show that they are capable of human-like cognitive processes[4].
However, it seems that accepting a form of cognition for plants is something more complex. We have considered plants as stationary beings without any form of cognition and they are now studied with technologies, such as time-lapse[5], that display their movement in a timescale closer to the human one.
Thus, I argue that there is minimal cognition in plants, and I discuss in what sense it is possible to speak of *cognition.*

Plant studies issues

In 2003, Anthony Trewavas, discussed the major difficulties about the study of plants and the definition of cognition in plants subjects.
First, the main problem is that the time scales are different from those in animals[6]. Although some contemporary technologies, such as time-lapse, can help us in observing plant behavior as they represent it in a way that is similar with our temporal scale, there are still difficulties. Undoubtedly, our flow of time is completely different from that of a plant because the movements of plants are much slower than those of humans.

Second, to talk about cognition in plants and to be able to formulate a definition, we need some evidence. Technologies, such as time-lapse, have succeeded in speeding up the time of plants, but we need other components to define cognition.
The debate here is very heated, as it is necessary to investigate whether, in the case of plants, we are talking about voluntary movement or adaptation. Certainly, no one has ever seen a plant run through the streets, but there are some plant species that have proven to be able to move in an experimental context.
Therefore, in the next paragraphs I will discuss the time-lapse as optimal technology to study plants behaviors, and I will argue the difficulties of taking about cognition in plants.

A misunderstanding of time?

We still have difficulties in understanding that not all living beings live in the same time scale. Plants are a case in point because the study of their behavior need to speed them up, so that we can appreciate them in a timescale which we can manage. Thus, I will talk about time-lapse, as a way to better understand plants movement.
First, time-lapse and slow-motion were born to accelerate or slow human time thanks to technological devices. Therefore, they have made it possible, already for human beings, to speed up or slow down the times and that is why they have been used in the world of cinema[7].
But in 1906, Wilhelm Pfeffer, a German botanist, had realized how useful photography could also be in plants and had devised time-lapse structures to speed up the movements of plants[8]. Most of the time-lapse observations were all carried out in controlled, experimental, hence laboratory environments. However, it could be very useful to be able to record plants in a wild environment as well, not least because they may perform behaviors that we do not expect or that have never been recorded[9]. There are also other ways of analyzing plant development[10], such as high-resolution imaging techniques[11], but the one that captures the most attention is always the time-lapse, because it plays on the speeding up of the plants.
Thus, time-lapse has changed human perception of plant behavior, although there are still many steps to be taken towards a deeper understanding of plants.
Studies with time-lapse were also carried out to observe the relationship between different species of insects and the natural environment. However, it is necessary to build a system that can collect through the technology of time-lapse high-resolution images, so as to better identify not only the relationship between plants and insects, but also automatically identify which insects visit plants[12]. Indeed, in order to understand the complexity of an individual plant, it is appropriate to analyze everything that revolves around the plant. By this I mean not only the plant species growing near the plant in question, but also the composition of the soil and other life forms in the environment.
Thus, after I have introduced what time-lapse is and discussed the advantages of this technology in the study of plants, I am going to address the problem of cognition that concerns the world of plants.

Similarities between animals and plants

Animal and plant organisms use different strategies to reach their own goals, also because they have a difference in energy required[13].
First of all, we must state that plants are not passive systems. In fact, it is erroneous to think that plants are only sensitive to signals from water, light or minerals in the soil. They are deeply connected to the life of their entire environment[14]. This means that plants are not passive organisms because they are not simply placed in the environment. They are fully integrated, and they can communicate, as I argue, even with other species.
Moreover, plants also seem to compete for physical space. For example, the roots actively compete with chemical signals[15]. This can occur especially in highly arid environments, where plants manage to survive thanks to predictions made by their roots. To perform such behavior, plants are strongly linked to their environment. Thus, there is a similarity with the animal kingdom because the attitude of the roots could be interpreted as a case of territoriality. In fact, roots tend to extend into the areas with the highest concentration of soil nutrients, occupying the territory.
In addition, plants can communicate with each other using different species as a vehicle, as in the case of insects, or with volatile organic compounds, or VOCs, that plants release into the environment[16]. Incidentally, about the transmission of information between plants, I argue that it is important to deal with the concept of plant neurobiology.

Plant neurobiology does not assume that plants have neuronal mechanisms like those of humans[17], but that plants use mechanisms that are similar to our neuronal functioning. These are the action potentials[18], long-range electrical signaling and auxin-mediated transport[19]. Thus, already the presence of auxin, with the function of a neurotransmitter, brings the plant system closer to that of animals. But the other great similarity concerns the presence of substances such as acetylcholine, serotonin, dopamine, GABA and glutamate. Studies have shown that glutamate receptors are similar to neuronal receptors and that it can almost serve as a 'neurotransmitter' and act as a signaling molecule[20].
According to this research, there are similarities between a plant and a neuronal system, such as the role of auxin and glutamate, which resemble that of a neurotransmitter. These findings have already led some botanists and philosophers of biology to question whether it is possible to speak of cognition in the case of plants.
Therefore, from a functional point of view, the role of auxin and glutamate resembles that of human neurotransmitters. As a result of these scientific observations, plant neurobiology was born.
In the following section, I will discuss some examples of cognition in plant kingdom. These will be useful in order to present what plant cognition consists of.

It's possible talk about plant cognition?

To start talking about cognition in plants it might be advisable to first change our point of view.
Despite the appearances, the part that concerns cognition in plants resides precisely in the roots. In a sense, the universe of plants is upside down with respect to that of humans and for this reason the root-brain hypothesis has been spread[21]. This hypothesis had previously been put forward by Darwin[22], who observed that plant roots seem to have a brain-like function for plant and has been taken up and re-evaluated by research in recent decades[23].
Therefore, it is necessary to study plants with the awareness that their position is already different from that of a human being, not to mention physiology. However, the philosophy of biology along with other disciplines move towards the definition of a *Plant Neurobiology*. In this case, plant cognition is studied in relation to integrated signaling and adaptive behavior of plants. For this reason, Paco Calvo speaks of *Philosophy of Plant Neurobiology*, which combines the philosophy of science, in particular the philosophy of biology, and the studies of plant neurobiology[24].
In fact, I argue that it would be desirable to find another nomenclature to refer to these plant studies. The concept of plant neurobiology presupposes a strongly anthropocentric view. Consequently, plants, which do not have a neuronal structure, are defined by something that does not belong to their essence.
However, in many scientific studies of both botany and philosophy of science it is stated that plants have shown behaviors that can be qualified as intelligent. As I will discuss later, these include the ability to anticipate changes in the environment, such as rainfall, to take the opportunity to integrate the necessary resources[25]. To this is also added that plants demonstrate storage capacity. This is based on a learning process and, for example, the temperature variation of the environment in which the plant develops can have effects that are handed down for many generations[26].
We also discussed the ability of plants to produce chemical compounds from their roots in order to identify each other and to spread VOCs in the air. According to Paco Calvo, these behaviors would define a kind of plant social intelligence[27]. Hence, the plant has the ability to understand through the signaling of neighboring species the state of, for example, the soil or whether a danger is near.
In addition, it is noteworthy an experiment carried out by Monica Gagliano and her colleagues concerning the learning of pea plants.
These plants were placed in a Y-shaped maze and made so that the pea shoots could choose which direction to grow. In one of the bifurcations of the Y the plants were subjected to a light of blue color, which facilitated photosynthesis and acted as a reward for growing them in that direction. It is striking that even when the blue light was off, the little plants chose to always grow in the same direction. This behavior shows that this specific plant, even when not subjected to the direct stimulus, has memory of the situation that is most convenient for it and that it learns in which direction to move. Along with this, when the blue light was off in the other direction of the Y a fan was used to reproduce an air jet. The small planks, even though they had grown in blue light, could be induced to change the direction, because the air movement of the fan was visible[28]. Indeed, conditional learning has also been discussed in

the case of plants precisely for this kind of behavior. In fact, the conditioning studied by Pavlov on dogs through experiments made it possible to understand the dynamics of associative learning[29]. In the experiment of Monica Gagliano and her team, plants also showed a type of associative learning, as they grew by moving towards the blue light even when it was turned off, since they perceived that it helped them in photosynthesis.
Therefore, the plant shows that it remembers blue light and can use it to grow. This example I have proposed argues that the plant has a minimal cognition. In fact, the plant seems to be able to use something that has always been considered as cognition: memory. Added to this, the plant is also able to make choices and predictions about the future.
In the last section, I will discuss whether it is possible to speak of extended cognition for plants. For a long time, the monopoly of extended cognition was held by humans, but recently, interesting research has been developed not only on animals, but also on the plant kingdom.

It's possible Extended Cognition in Plants?

Thanks to the new evidence of cognitive science, the classical vision of cognition focused on the brain was questioned. Thus, according to post-cognitivism, cognition arises in a real environment and implies, at the same time, perception, and action. Behavior is, according to this position, be influenced by external stimuli[30]. These approaches also make it possible to consider non-neural organisms among those with cognition, although most of the philosophical positions and experiments carried out still concern only neural organisms.
In particular, Clark and Chalmers have exposed a new hypothesis of cognition, known as extended cognition[31]. The theory of these philosophers is called properly extended because the external environment plays an active role for the cognitive processes of the organism, so is active externalism. Thus, if extended cognition is right, then the extrabodily environment is part of cognitive process.
Therefore, the plant, which is an organism rooted in the environment in which it lives, could show behaviors that support the hypothesis of extended cognition[32]. A relevant example of extended plant matching is the association with mycorrhizal fungi. In fact, when mushrooms colonize the roots of a plant, they can establish an exchange relationship with the plant that concerns molecules and signals[33]. What is relevant and that fits into the hypothesis of the extended mind is that the role of fungi amplifies the perception of the plant. Also, the same activity of strengthening the absorption of soil nutrients helps the plant in perceiving events that, otherwise, would be out of its reach. For example, we have already dealt with the example of the plant that extends its roots towards the blue light to be able to encourage photosynthesis processes. In the same way the plant could extend to the areas that the fungus perceives as rich in nutrients. This example suggests that the plant can extend its cognition beyond its body, which is fixed in the soil in which it is born. Understanding that even a plant can respond to the hypothesis of extended cognition, traditionally thought only of human beings, can help us both to extend the paradigm of cognition and to better understand the plant kingdom.

Conclusion

In this work, I argue not only the possibility of cognition in plants, but also that it can be analyzed as extended. Indeed, we have observed that some plants behavior involves not only the plant itself, but also the manipulation of environmental circumstances. This adaptation is necessary for the plant′s nourishment and for making predictions that help it in its growth process. Furthermore, we presented an experiment in which pea plants show behavior corresponding to Pavlov′s canon of conditioning.
I can conclude that there are examples of minimal cognition in plants, but also that the question of cognition in plants merits further investigation. Much research is underway to study this fascinating world, but this is related to the specificity of plants, namely the fact that their reaction times are much slower than those of human and non-human animals. Above all, what prevents most researchers talking about cognition in the case of plants is precisely the absence of movement.
However, what I propose with this paper is to articulate a different paradigm for understanding the plant world. Plants constitute a completely different system from human and non-human animals, and it would be reductive to crush their difference in an anthropocentric sense.

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«La vita come mezzo della conoscenza» – con questo principio nel cuore si può non soltanto valorosamente, ma perfino gioiosamente vivere e gioiosamente ridere

(Friedrich Nietzsche, *La gaia scienza*, aforisma 324)

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