An Argumentation for Embodied Plant Cognition with Parallels from Animal Cognition

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Abstract

Bordering on pseudoscience, plant cognition has long been perceived as something at the far distant border of the scientific range. In comparison to animals, plants have been grouped together with rocks as objects without cognition. At the same time, cognition as a term and phenomenon is largely undefined and arbitrary to the context and species in question. As biologists uncover more and more about plants, the claim that plants have no cognition has for some time been questioned. In light of this increased awareness of cognitive abilities in plants, it is worth updating the perspectives on cognition. One of the main current perspectives on cognition centres around the idea that it is through the body's sensorimotor experiences with the environment that cognition arises. As there is no doubt that plants have a manifested body with sensory experiences, it is reasonable to argue that even in plants, some form of cognition might take place. Within this embodied cognition paradigm, this paper looks at some of the arguments for why plants should also be considered cognitive creatures.

Keywords

Plant cognition, Embodied cognition, Animal cognition, Free will, Intelligence

1. Delusio anthropocentricae

Our interpretation of how evolution developed has painted an interesting picture of the 'living' species of the planet. On the one hand, intelligent animals, with humans at the top of the intellectual food chain. On the other hand, plants (and fungi) as automatons devoid of any cognition.

However, this is a relatively recent perspective. For a long time, it was unthinkable that animals were anything more than soulless automatons acting on deterministic instinct. This was withheld not only as part of religious doctrines but from philosophical perspectives as well. For instance, Aristotle (350 BC) proposed that animals did not have the 'agent intellect' that humans do and Descartes' (1637) idea of the *Bête-Machine* reinforced the religious perspective that only humans had a 'living experience'[1] with feelings, cognition and self-awareness due to 'man being made in God's image'[2]. Regardless of the religious motivations and the convenience it had on the morals of animal farming, the notion that animals were not thinking and feeling creatures was a long-lived myth. Today, the consensus is that animals are indeed in possession of an experience, different levels of cognition and that they 'feel.' However, it is disturbing just how long this eye-opening realisation process is taking. While Descartes' perspective that a dog with a broken paw did not feel pain was rejected rather rapidly, it was not until 2021 that crustaceans and octopuses (known to be highly intelligent) were legally considered sentient and determine to be able to feel pain[3].

Perhaps one of the most reason for why it took so long for animals to be 'enriched' with cognition is humanity's lack of understanding to that which is different. Animals, in particular our closest kins, primates and some of the by-humans-adopted mammals like dogs, are relatively similar to humans

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[1] I choose to use the expression 'living experience' instead of 'sentience' as I want it to be a bit broader interpreted with respect to a self-identify than what is possible with the discourse around sentience.

[2] Genesis 1:27-28

[3] See the Animal Welfare (Sentience) Act 2022 (UK legislation).

with respect to how they interact in the world and, thus, how their cognition materialises. It is not hard to see why their animal rights were fought for before those of the crustaceans, octopuses and even insects. Now, as crustaceans are getting 'rights', and even the complex intellect of insects like bees is illuminated [3], it appears that we have overcome the bête-machine myth and broken free from the 'delusio anthropocentricae'[4].

Simultaneously, while still 'alive' in the same way as animals, plants have been considered to be background noise in the cognitive development of the planet's inhabitants. At first glance, plants are fundamentally different in physique and behaviour to those of animals. With this in mind, it might not be so strange that it did not occur to people to consider the possibility that plants may have cognition as well. However, plants experience a much richer sensory experience of the environment than what is commonly known [4]. Not only do their cells have photoreceptor proteins that respond to light and stomatal guard cells that respond to humidity, but they also possess more or less the same neurotransmitters as animals [5].

For research on cognition, the possibility and pitfalls of plant cognition are a highly interesting domain to learn more about what cognition is and how it can be defined. While trying to avoid falling into the trap of anthropomorphising the cognition of plants (or animals), this paper discusses the topic of plant cognition and the consequences their 'living experience' has for the theory of embodied cognition.

2. Cognition in a nutshell

2.1. Attempting a definition of cognition

The reason why it is hard to find a textbook-style definition of 'cognition' is simply that there is not one. Regardless of numerous studies in intelligence, behaviour, neuroscience, psychology, with or without drug-induced medication and hallucinations, no one seems to have a concrete answer as to what cognition is, nor how it appears. Even with the most vague definition, along the lines of 'cognition is mental processing and response to stimuli', it is not obvious what physical and mental (and situational?) components should be counted to be cognitive in the first place, nor to which degree these components need to function for cognition to take place. Instead, a plethora of definitions, concepts and components are merged into a cacophony of 'we really do not know what we are talking about'[5] when it comes to what cognition is [6]. Needless to say, some of this complexity can be whiffed away as simply unnecessary terminological definition games. Yet, the problem remains: We do not have a clear idea of what the baseline for cognitive machinery is. This means that we cannot claim that plants 'do not have it,' nor, for that matter, that humans 'do have it'.

Despite such uncomfortable dilemmas, it is hard to deny that humans and other animals show clear levels of cognitive behaviour: the environment is perceived, reasoning and reactions are performed, information is exchanged between individuals, and decisions are made - typically in the form of behaviours. Thus, it is nonsensical to deny that there is an underlying cognitive machinery going on underneath the complexity of 'existence.' In order to better understand these cognitive boundaries, the hierarchical differences in the potential cognition of plants, animals and humans must be uncovered.

2.2. Embodied nature of cognition

There are many paradigms within cognitive science that try to explain how cognition emerged from a biological process and how it manifests in human intelligence. One of these paradigms is embodied cognition. The theoretical framework argues that cognition stems from the physical body's perceptions and interaction with its environment [7, 8]. As a group of theories of a similar school of thought, the main idea with embodied cognition is that all forms of thinking and conceptualisation, both low-level and higher-level cognition, can be traced back to the sensorimotor experiences.

[4]The anthropocentric delusion

[5]Creatively paraphrased.

This is highly appealing from an evolutionary perspective as it allows the development of cognitive abilities to be mapped and motivated by the stepwise adaptation from evolutionary 'survival of the fittest' and epigenetic gene manipulation to adapt to the environmental factors. From this perspective and through generational filtering, different species developed particular body parts as a way to adapt to the environment in an evolutionary beneficial way. As a consequence, these body parts required a cognitive machinery that was developed in close collaboration with the physical components. Perhaps the most obvious example of this development, in which the physical body developed alongside the cognitive abilities, is *movement*. There is consensus that most of the (human) brain was developed for movement and that much of the brain is devoted to different aspects of navigating a spatial world [9]. The first microorganisms that formed from the primordial soup needed some basic parts that could move them. Through evolutionary adaptation, prokaryotes developed flagella that allowed them to 'swim' in some random direction in the hope that this was the right way to go. The organisms that could move more were likely more successful. Today, most animals have adapted themselves to the ability to move to find food or mates; hunt or escape like cheetahs and antelopes; or, through some near gravity-defying abilities, climb rocks like the mountain goat. All of these are movement patterns that likely shape the format of how the particular cognitive processes of the species take place.

The second most important component for developing cognitive machinery was *perception*. Throughout evolution, eyes and photoreceptive cells have evolved in different species and from different evolutionary paths. In humans, vision is the most relied-on sense for navigating space, learning new things and interacting with others. However, there are many senses that humans and animals use to get a better understanding of the environment and how best to behave within it. For humans, we often talk of the five senses and their involvement in our sensoriperception [10], but in reality, the embodied experience is a plethora of physical and sensori-reactions to the physical laws of the environment.

As such, the combined sensorimotor experiences form the foundation for cognition. Typically, embodied cognition as a theory is rarely applied as a means to analyse the evolutionary path from prokaryote single-celled organisms into cognitively sophisticated creatures like humans. However, the perspective forces an interesting direction on the cognition of plants. As it argues for the sensorimotor processes to be the foundation for cognitive processes, any creature that has such experiences could, in theory, be claimed to have the basic building blocks for cognition.

2.3. The 'sort of' hierarchy of cognitive ability

The prokaryote organisms of the primordial soup likely do not have much cognition as we think of it today. But at some stage in the evolutionary pipeline, an organism was complex enough with respect to perception, movement and mental machinery to develop mental skills that we would think of as 'cognitive.' Humanity tend to think of herself as the most cognitively advanced creature on Earth. And fair enough, humans alone have devised for themselves intelligence tests (IQ test) and cognitive evaluations to confirm this hypothesis. With human intelligence as the benchmark, it is not strange that 'humanity wins.' However, many animals display different levels of intelligence with respect to their own frame of reference and the adaptation to their particular living experience.

For instance, among animals, primates are known for having the ability to reason and use tools. Yet they are not alone in having this ability; animals such as blackbirds [11] and octopuses [12] also display such abilities. Similarly, while dogs and cats have learn to communicate with humans through vocalisations, bees communicate with one another with 'dances' [3] and cetaceans, like sperm whales, communicate long distances with 'click sounds' [13]. Such behaviour show high level cognition in animals. However, many animals do not display this level of sophistication in their cognition. For instance, it would be unreasonable to place the cognitive ability of moths on the same level as that of crows. In many ways, moths have behaviours that appear more in line with automatons than conscious creatures and behaviours can be modelled with Braitenberg vehicles [14][6]. Consider how their nocturnal

[6]Braitenberg Vehicles are artificial agents that can be shown to display simple behaviours simply due to programmed rules for how to respond to basic stimuli.

‘death-dance’ into light sources is based on an instinct to have the wings perpendicular to the sun, a phenomenon known as *positive photoaxis* [15].

So, just like humans rank their internal level of intelligence, it appears that from a species-wide comparison, it is worth considering that there are different levels of cognitive sophistication in species. It is straightforward to assess that dogs are cognitively superior to worms and that dolphins are intellectually superior to jellyfish[7]. Based on analysing behaviour and perceptive systems alone, it is less obvious whether worms are superior to jellyfish, or whether dogs or dolphins are more cognitively advanced.

With these examples in mind, there must be a sort of cognitive ranking in ability. The complexity in asserting such a cognitive hierarchy stems from how humanity perceives the world from our own limited human perspective. It is easy for us humans to recognise the intelligence (or lack thereof) in dogs because they live in the same environment as us. At the same time, the physical experiences of the world’s all species are vastly different as their bodies and senses, and the environments in which they live are often worlds apart.

2.4. Not all cognition is created equal

Animals and other non-human species without a doubt see the world differently due to the rather diverse set of perceptive sensors, physical enablement and neurologically developed brain regions. In the famous article *“What it is like to be a bat”* this diversity of ‘living experience’ is emphasised by highlighting the differences of the sensorimotor experiences between humans and bats [16]. Despite both being mammals, the most obvious difference is that bats are nocturnal, fly and use echolocation as their primary sense for navigation.

Typically, humans think of the universe as a place of rigid physical laws that cannot be broken, yet different species react to these rules in various ways. Take gravity as a universally accepted phenomenon. Humans and many land-living animals will fall to the ground if their support is removed. This is a basic conceptual building block learned from the sensorimotor experiences, and many animals count on this knowledge for their survival. For instance, NASA sent thousands of jellyfish into space to see how they evolved with respect to minimal gravity [17]. Turns out, the jellyfish that were born in space did not learn how to handle gravity.

However, most animals do not get such a glorious experience and have their sensorimotor experiences locked into the state of the planet. Despite that, animals such as fish and marine mammals living in water learns a different relationship to gravity and experience another dimensionality of their environment. In water, predators can come from all six directions, and movement is not restricted to a 2D plane. Similarly, for perception, dog vision is vastly inferior to the vision of humans (or the mantis shrimp!). Yet, they have a sense of smell that is estimated to be up to 100K stronger than in humans. Comparing perception, one can say that what a human ‘see,’ a dog ‘smells.’ The difference in sensoriexperience is quite profound. For instance, smells linger, can be ‘experienced around corners’ and have an abundance of compositional depth that vision typically does not.

These differences dramatically transforms the embodied perspective of the living experience, and if embodied cognition is based on the sensorimotor processes, it is more than reasonable to assume that this also change the cognitive building blocks.

This line of thinking is not only embedded into the base premise of embodied cognition, but might also lay the foundation for the evolutionary development of intelligence. Recent findings show that animals (here birds, reptiles and mammals) use different neural pathways in cognitive tasks [18], meaning that intelligence developed in parallel through convergent evolution. This further strengthens the idea that cognitive abilities may have developed in different directions than previously assumed.

Breaking away from the anthropocentric perspective of cognition is the key to understanding the experience of other animals. Above, it was argued that there is a hierarchical ranking of cognitive maturity in different species. In this section, it becomes clear that the hierarchy is not a tower in which

[7] Adding complexity to the basis of cognition, it is worth mentioning that jellyfish typically do not have a centralised nervous system (aka a brain).

one species is more sophisticated than another, but rather a tree-like structure in which different types of cognitive behaviours may display different levels of sophistication. Meaning that for many species, it is not possible to compare which is the more cognitively superior. Acknowledging this dispersed picture of cognitive abilities, we move on to analysing the existence of cognition in plants.

3. Displays of cognition in plants

Land-living plants developed some 500 million years ago. Meaning that they lived for some 80 million years without any animals as competitors for space or resources. A lot can happen in that time.

What did not happen until very recently was that plant cognition was being seen as a legitimate research field [4]. However, today botanists and biologists are analysing different components and behaviours of plants, showcasing an underestimated complexity and sophistication. By analogously analysing how these processes relate to animal cognition as part of the embodied cognition hypothesis, some interesting perspectives on plant cognition arise[8].

3.1. Sensorimotor processes in plants

The main premise of embodied cognition is that cognition arises as a consequence of sensorimotor processes. Excluding fictive entities like Tolkien's *Ents*, there is no denying that most plants do not 'move' much in their 'living experience.' A plant is typically rooted on the spot with little possibility of moving other than through external force. Yet due to different types of sensory stimulation, plants do 'move' by shifting within the space in which they exist.

Plant movement (typically through growth) is a response to stimuli and referred to as *tropism*. The most obvious ones to consider are *phototropism* and *hydrotropism*; the movement towards light respectively water sources. But before diving into those, let us look at another tropism in how plants navigation of its space: *gravitropism*. Plants typically grow in an upward vertical fashion. This is due to gravitropism, which is the ability for plants to sense their orientation with respect to gravity. This is done through organelles called statoliths that 'fall to the bottom' of cells called statocytes. When the statoliths are no longer in the 'right place', they send chemical signals, including growth hormones, to continue to grow in a new direction based on the new orientation (For some early experiments on gravitropism, see [19, 20]). While reorienting itself might not be considered an obvious cognitive ability, it demonstrates that the plant senses its environment and that plants have a form of proprioception, which is highly important to the cognition of animals. Consider also how the physical components rely on similar functions to those of the balance organs (inside the inner ear) of humans and the components which were not properly developed in the astronaut jellyfish [17].

Also of the utmost importance to plants is how hydrotropism ensures that roots grow towards moist and particularly nutrient soils [21]. While hydrotropism is a root phenomenon, leaves can spatially react to air humidity conditions through stomatal regulation and *hydronasty*; the ability to sense humidity levels and either close or open 'the pores' on the leaves to preserve or release water.

Similarly, phototropism is movement towards light. The plants' photoreceptive abilities are much more nuanced than what is perhaps expected from an animalistic perspective, as plants have no separate organ for sight (aka eyes). Instead, they activate photoreceptive proteins embedded within their cells when exposed to different lights. Through these, they can sense lights on different spectra (e.g. blue light and red light), the directionality of light, the abundance of light, etc. As an example, *Arabidopsis thaliana*, a type of mustard, has eleven types of photoreceptors [4].

Phototropism takes place on different levels. Most commonly, it is the directed growth towards light. Consider how plants in shaded environments may have 'most' branches growing in the most beneficial direction, or, for instance, how English ivy (*Hedera helix*) rapidly expands into the sun. From an evolutionary perspective, this makes a lot of sense. Plants 'feed' on light through photosynthesis

[8]Author disclaimer: I am not a botanist and, thus, there might be grave simplifications in the way the biological phenomena are described and/or interpretated in the upcoming sections. If you identify an error, please educate me by sending an email!

and to optimise survival; more light means more fuel, more fuel means more growth. However, the movement towards light also takes place within a shorter timespan. Consider *heliotropism* in sunflowers (*Helianthus annuus*), which enables the plant to face the sun throughout the day and get more light exposure, or the common bean (*Phaseolus vulgaris*), which performs *paraheliotropism* by turning away from the sun to prevent it from overheating.

This kind of sun-seeking/avoiding behaviour is also common in animals. Mostly to save energy, lions lie in the shade of the savannah trees, humans in the garden hammock, but for many insects, the warmth of the sun is essential for their functioning. Dragonflies and butterflies, for instance, engage in *heliotaxis* by actively seeking out the sun and opening their wings for thermoregulation before they can take flight [22]. While insects such as dragonflies might not be at the top of the cognitive hierarchy and many of their behaviours can be modelled as Braitenberg vehicles, the parallel is unmistakable.

Plants also sense and react to physical stimuli, with perhaps the most notable example being the sensitive plant (*Mimosa pudica*) that folds its leaves when touched. In animals, physical touch has many purposes but is typically strongly associated with inducing emotional states (e.g. how pain leads to fear) and/or encouraging behaviours. However, plants do not have emotional states in the same way as animals do, nor do they have the same ability for reasoning about appropriate actions. This means that the physical sensations have a different purpose. For instance, vines and bean plants have the ability for *thigmotropism*, which means that when 'touching' an object, they spiral around it for support.

In [23], an experiment showed that wounding the leaf of a common tomato plant caused a plant-wide electrical 'current' that prepared other leaves that there was an ongoing attack on the plant. Further research showed that not only is the electric current similar to the neural response in animals, but the accompanied chemical composition looks very much like the animal counterparts' neurotransmitters [24, 5]. Given that it behaves on the premise of a system of electrical currents and chemical neurotransmitters, the signalling system of plants is remarkably similar in composition to that of the nervous system of animals. Research has showcased that for plants, the root system acts as a sort of neurochemical centre [25].

3.2. Communication between plants and with animals

An example of high-level intelligence in animals is the ability to communicate. (One of) the definition(s) of 'communication' according to the Cambridge dictionary read: *"the process by which messages or information is sent from one place or person to another, or the message itself"*[9]. Given this perspective, the transfer of information from one individual to another could be considered communication.

Humans have taken communication to the extreme in that we not only communicate basic information for survival such as warning screams and mating calls, but also to tell jokes, write absurdist poetry and compose science textbooks. Animals, on the other hand, typically have simpler symbol systems within their communication. For instance, the vervet monkey has three different warning calls depending on the particular predator: leopard, eagle or snake, likely due to the connective behavioural incentive: run, hide or climb.

Surprisingly, this level of sending of information to incentivise behaviour is not exclusive to animals. Plants also display a sophisticated mechanism to send information between themselves and to animals.

What we typically perceive as the 'odour' of plants is a complex chemical communication system. From a human perspective, chemical smells might not seem like a typical form of communication. However, it is a common method to share information. Consider how ants leave pheromone trails as a method to communicate optimal paths [26]. Even animals higher in the cognitive hierarchy heavily rely on scents for information. For instance, the olfactory sense in dogs has a prominent role in how dogs send information between one another; why would they otherwise 'micro urinate' all over the place?

For plants, chemical communication is done through the chemical release of what are called *Volatile Organic Compounds* (VOCs). Among others, these include terpenes and *Green Leaf Volatiles* (GLV) that, even to the limited olfactory sense of humans, have a strong odour which typically incentivise

[9] https://dictionary.cambridge.org/dictionary/english/communication, accessed: 2025-06-16

particular behaviours. Just think of the inviting smell of flowers or how the calming effect of forest smells makes you want to go mushroom foraging[10].

Through such chemical release, plants make themselves 'seen', much like why birds sing or why a midlife crisis may result in an expensive car purchase. An example of this is not only that the parasitic dodder plants (*Cuscuta*) grow in the direction of the 'scent' of other plants, but is also very selective as to which plants it targets [28]. This is an example of a predatory 'hunt-like' activity among plants that closely resembles behaviours in the animal kingdom (although on a different timescale). However, plants also display communication that benefits the other plant.

Species-beneficial communication is typically the response to damage being done to the plants. Research has found that neighbouring trees to those that are infested with insects have a higher resistance to those pests (e.g. [29]). Since there is no sharing of roots, there was no chemical/neurotransmittal signalling taking place, and the response to develop stronger defences is due to the release VOC in the infected plant.

In an experiment with beetles eating lima bean leaves (Phaseolus lunatus), [30] demonstrated just how powerful this chemical communication is. The experiment showed that not only do the leaves that are being attacked release volatile chemicals, but the flowers of the plant (which are not attacked) produce a nectar that attracts beetle-eating anthropods (!). While this is a result of co-evolutionary adaptation, it shows that plants are ready to defend themselves in remarkably sophisticated ways.

3.3. Learning and remembering in plants

Another high-level cognitive ability worth mentioning is learning and maintaining information (aka having a memory). Humans are particularly good at this, but animals such as elephants [31] and ravens [32] are known to have exceptional long-term memory. However, these are animals on the higher levels of the cognitive hierarchy, so it might not be so unexpected. More impressive is that studies show that animals such as sea slugs [33] and bees [3], with arguably significantly 'simpler' levels of cognition, show clear signs of habituated learning as well. Based on the argumentation in this paper, perhaps it is no longer surprising to learn that plants also engage in learning and storing information.

Returning to the sensitive plant (*Mimosa pudica*), a study showed that the plant learns to identify particular contact as non-treatening based on environments, and can remember this response up to a month, even when moved into a different environment [34]. Likewise, the mustard plant *Arabidopsis thaliana* undergoes epigenetic alterations as part of induced stress, which acts as a memory to enhance the plant's defences for the future [35]. Similarly, the Venus Flytrap (*Dionaea muscipula*) demonstrates short-term memory in that two separate touches are required within a short time interval for it to close (typically around a fly) [36].

Further, with respect to photoreceptors, plants store important information in order to optimise their reproduction cycle. Have you ever wondered why all the plants bloom just in time for Christmas or Mother's Day? This is due to a phenomenon referred to as *photoperiodism*, which was discovered in the mid-20th century. Botanists realised that it was possible to tweak the natural cycle of plants and get them to bloom at particular times by exposing them to a brief moment of *red* light in the middle of the night [37]. However, if you immediately after the flash of red light proceed to expose the plant with *far-red* light (corresponding to the last light of the day), the effect is reversed as though in those few seconds the plant experienced a whole day. It is clear that plants do not seem to have time perception, but they do have a memory for what part of the day it is.

These examples might seem a bit 'minimalistic' with respect to the richness of memory in animals. However, even in this minimalistic format, there are clear indications that plants too possess the ability to remember and adjust their behaviour with respect to their past 'living experience.' Exactly how much of this is to be interpreted as an actual sentience experience will be discussed next.

[10]Related is the interesting (pseudo-esque) research area "forest bathing" (Shinrin Yoku), in which, among others, the VOC of trees are thought to have a positive impact on the human psyche. For a review, see [27].

4. Consciousness and the obvious criticism of plant cognition

One of the main criticisms of why plant cognition is 'asking the wrong question' is based on the argument of consciousness [38]. As far as we can tell, they do not appear to have it. And in all honesty, the above-discussed perceived perception and proprioception of plants differ very much in terms of complexity and duration from that which exists in most animal species' 'living experience.'

Highlighting the importance of consciousness in a cognitive system, in the 1980s, Searle introduced the Chinese Room thought experiment. The idea is that a person is locked in a room with a book of transformation rules. Symbols come in from one direction, and using the book, they are to be translated and pushed out the other side of the room. What the person in the room is unaware of is that s/he is translating Chinese. Searle's argument is that, despite the success of the performed task, the person in the room does not understand Chinese.

The thought experiment was initially introduced as an argument as to how artificial intelligence will never be 'conscious' or understand the reasons for its behaviour. In many ways, the same argument can be made with respect to the arguments for plant cognition presented in this paper.

Most of the arguments are based on the premise: STIMULUS→RULE BOOK→BEHAVIOUR, much like the setup with the Chinese room. For instance, there is no denying that *tropism*, as a form of movement, is simply the result of a direct response to stimuli. To claim that there is a level of conscious awareness or even non-deterministic 'free will' within tropism would be a stretch of the concept. However, the same can be said about animals on the lower levels of the cognitive hierarchy. Insects like moths and ants, which can be almost perfectly modelled with Braitenberg vehicles and algorithms, display relatively little in terms of what we would call free will. And perhaps it is accurate to assume that they do not have free will, and that they are instead deterministic creatures responding to their environment based on stimuli and a genetic rule book.

The uncertain implications of such thoughts are twofold. On the one hand, does a deterministic existence (without free will) automatically assume that there is no cognition? And on the other hand, how can we tell that creatures higher in the cognitive hierarchy are not just deterministic creatures as well, simply with a much more complex camouflage apparatus?

5. Concluding remarks

In this short commentary, arguments on why plants are not so different from animals when it comes to displaying cognitive behaviours were presented. Basing the argumentation on the theoretical paradigm of embodied cognition meant that if a living creature displayed abilities for a sensorimotor experience, cognition could take place. Simultaneously, while plants display cognitive skills like sensory perception, communication and learning, there is no denying that the conscious experience, 'self-awareness', and (perceived) free will are questionable concepts to ascribe to plants.

One of the main contributions of the paper is the rejection of cognition to be seen from an anthropocentric angle. Based on the embodied cognition premise, the wide variety of animals 'living experiences,' neural pathways and richness in sensory perception make it impossible for all cognitive building blocks to be 'the same,' and even less that it would 'be human.' How could the sensorimotor experience of a mountain goat compare to that of a dolphin and that of a bee, to that of a waterlily? Arguably, different sensorimotor processes must result in different internal cognitive patterns and processes. At the same time, there must be a cognitive hierarchy in terms of how advanced the cognition is, and a branching with respect to the particularity of the expression of those cognitive abilities.

All in all, we either have to accept that plants have cognition and that it exists somewhere on the cognitive hierarchy, perhaps corresponding to the complexity of some insects or molluscs. Or if we reject plant cognition, we must also reject cognition in animals on the lower levels of the hierarchy that are no more advanced than plants. Only, based on the cognitive hierarchy, how do we tell when cognition starts to exist? When does the sensoriexperience morph from determinism into something other than STIMULUS→RULE BOOK→BEHAVIOUR? How do we know that we humans, arguably high in the cognitive hierarchy, are not only a complex result of our internal wiring and external stimulation?

Declaration of Generative AI

This paper has not relied on any AI tools to write, edit content or conduct research. However, as an integrated part of modern search engines, AI tools have been used to search for information and gather inspiration. Likewise, spell and grammar checkers (Grammarly), which may incorporate AI, have been used to ensure that the presented manuscript holds academic standard language.

References

[1] Aristotle, On the Soul, 350 B.C.E.
[2] R. Descartes, Discours de la méthode, 1637.
[3] L. Chittka, The mind of a bee, Princeton University Press, 2022.
[4] D. Chamovitz, What a plant knows: A field guide to the senses: Updated and expanded edition, Scientific American/Farrar, Straus and Giroux, 2020.
[5] R. Akula, S. Mukherjee, New insights on neurotransmitters signaling mechanisms in plants, Plant Signaling & Behavior 15 (2020) 1737450.
[6] C. Allen, On (not) defining cognition, Synthese 194 (2017) 4233–4249.
[7] L. Shapiro, Embodied Cognition, New problems of philosophy, Routledge, London and New York, 2011.
[8] G. Lakoff, M. Johnson, Philosophy in the Flesh, Basic Books, 1999.
[9] J. H. Kaas, The evolution of the complex sensory and motor systems of the human brain, Brain research bulletin 75 (2008) 384–390.
[10] M. M. Hedblom, Beyond space and time: An initial sketch of formal accounts to non-spatiotemporal conceptual sensory primitives, in: The Eighth Image Schema Day co-located with The 23rd International Conference of the Italian Association for Artificial Intelligence (AI* IA 2024), Bozen-Bolzano, Italy, November 27-28, 2024, CEUR-WS. org, 2024.
[11] W. C. McGrew, Is primate tool use special? chimpanzee and new caledonian crow compared, Philosophical Transactions of the Royal Society B: Biological Sciences 368 (2013) 20120422.
[12] J. K. Finn, T. Tregenza, M. D. Norman, Defensive tool use in a coconut-carrying octopus, Current biology 19 (2009) R1069–R1070.
[13] P. Tyack, Communication by sound and by visual, tactile, and chemical sensing, Ethology and behavioral ecology of odontocetes (2019) 25–50.
[14] V. Braitenberg, Vehicles: Experiments in synthetic psychology, MIT press, 1986.
[15] G. Jékely, Evolution of phototaxis, Philosophical Transactions of the Royal Society B: Biological Sciences 364 (2009) 2795–2808.
[16] T. Nagel, What is it like to be a bat?, in: The language and thought series, Harvard University Press, 1980, pp. 159–168.
[17] D. Spangenberg, T. Jernigan, C. Philput, B. Lowe, Graviceptor development in jellyfish ephyrae in space and on earth, Advances in Space Research 14 (1994) 317–325.
[18] E. Rueda-Alaña, R. Senovilla-Ganzo, M. Grillo, E. Vázquez, S. Marco-Salas, T. Gallego-Flores, A. Ordeñana-Manso, A. Ftara, L. Escobar, A. Benguría, et al., Evolutionary convergence of sensory circuits in the pallium of amniotes, Science 387 (2025) eadp3411.
[19] T. A. Knight, V. on the direction of the radicle and germen during the vegetation of seeds. by thomas andrew knight, esq. frs in a letter to the right hon. sir joseph banks, kbpr s, Philosophical Transactions of the Royal Society of London (1806) 99–108.
[20] C. Darwin, F. E. Darwin, The'power of movement in plants.'–1880. (1888).
[21] A. Hodge, The plastic plant: root responses to heterogeneous supplies of nutrients, New phytologist 162 (2004) 9–24.

[22] M. L. May, Thermoregulation and adaptation to temperature in dragonflies (odonata: Anisoptera), Ecological Monographs 46 (1976) 1–32.
[23] D. Wildon, J. Thain, P. Minchin, I. Gubb, A. Reilly, Y. Skipper, H. Doherty, P. O'donnell, D. Bowles, Electrical signalling and systemic proteinase inhibitor induction in the wounded plant, Nature 360 (1992) 62–65.
[24] S. A. Mousavi, A. Chauvin, F. Pascaud, S. Kellenberger, E. E. Farmer, GLUTAMATE RECEPTOR-LIKE genes mediate leaf-to-leaf wound signalling, Nature 500 (2013) 422–426.
[25] P. Calvo Garzón, F. Keijzer, Plants: Adaptive behavior, root-brains, and minimal cognition, Adaptive behavior 19 (2011) 155–171.
[26] W. von Thienen, D. Metzler, D.-H. Choe, V. Witte, Pheromone communication in ants: a detailed analysis of concentration-dependent decisions in three species, Behavioral ecology and sociobiology 68 (2014) 1611–1627.
[27] M. M. Hansen, R. Jones, K. Tocchini, Shinrin-yoku (forest bathing) and nature therapy: A state-of-the-art review, International journal of environmental research and public health 14 (2017) 851.
[28] J. B. Runyon, M. C. Mescher, C. M. De Moraes, Volatile chemical cues guide host location and host selection by parasitic plants, Science 313 (2006) 1964–1967.
[29] D. F. Rhoades, Responses of alder and willow to attack by tent caterpillars and webworms: evidence for pheromonal sensitivity of willows, ACS Publications, 1983.
[30] M. Heil, J. C. Silva Bueno, Within-plant signaling by volatiles leads to induction and priming of an indirect plant defense in nature, Proceedings of the National Academy of Sciences 104 (2007) 5467–5472.
[31] S. F. Hope, K. R. Willgohs, S. Dittakul, J. M. Plotnik, Do elephants really never forget? what we know about elephant memory and a call for further investigation, Learning & Behavior 53 (2025) 44–64.
[32] M. Boeckle, T. Bugnyar, Long-term memory for affiliates in ravens, Current Biology 22 (2012) 801–806.
[33] V. Castellucci, H. Pinsker, I. Kupfermann, E. R. Kandel, Neuronal mechanisms of habituation and dishabituation of the gill-withdrawal reflex in aplysia, Science 167 (1970) 1745–1748.
[34] M. Gagliano, M. Renton, M. Depczynski, S. Mancuso, Experience teaches plants to learn faster and forget slower in environments where it matters, Oecologia 175 (2014) 63–72.
[35] P. A. Crisp, D. Ganguly, S. R. Eichten, J. O. Borevitz, B. J. Pogson, Reconsidering plant memory: Intersections between stress recovery, rna turnover, and epigenetics, Science advances 2 (2016) e1501340.
[36] A. G. Volkov, H. Carrell, A. Baldwin, V. S. Markin, Electrical memory in venus flytrap, Bioelectrochemistry 75 (2009) 142–147.
[37] H. A. Borthwick, S. B. Hendricks, M. W. Parker, The reaction controlling floral initiation, Proceedings of the National Academy of Sciences 38 (1952) 929–934.
[38] L. Taiz, D. Alkon, A. Draguhn, A. Murphy, M. Blatt, C. Hawes, G. Thiel, D. G. Robinson, Plants neither possess nor require consciousness, Trends in plant science 24 (2019) 677–687.
[39] J. R. Searle, Minds, brains, and programs, Behavioral and Brain Sciences 3 (1980) 417–457.