Biosemiotics. Commentary to the target article by Terrence Deacon

Does autogenic semiosis underpin minimal cognition?

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Abstract

Minimal cognition is an emerging field of research in the context of the life-mind continuity thesis. It stems from the idea that life and mind are strongly continuous, involving the same basic set of organisational principles. Minimal cognition has been sometimes regarded as the analysis of the minimum requirements for the emergence of cognitive phenomena. In the target article, Deacon describes the emergence of the autogenic system as an interpreting system that displays the simplest form of interpretive competence, its most critical function being the capacity to re-present itself in ever new substrates and to interpret environmental conditions with respect to system self-maintenance. Since Deacon describes the autogen in cognitive terms, this article examines whether the autogen model can embody the critical disposition that underpins the emergence of minimal cognition. It finds that it does so, but argues that the autogenic system itself fails to be cognitive because it lacks the displacement of constraints that enable the semiotic scaffolding exhibited by life processes. The article then discusses the implications of the idea that autogenic processes underpin the emergence of minimal cognition for the life-mind continuity thesis.

Keywords

minimal cognition, life-mind continuity thesis, origin of life, self-organisation, teleology, teleodynamics

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How can a physical property be about any other physical property? This is a daunting question whose answer many believe to fall beyond the boundaries of science. To many, physicochemical structures are in and of themselves devoid of significance and can only be significant to a mind. Usually, aboutness—a.k.a. intentionality, or the property to be about something—has been debated in contexts that assume the prior existence of a cognitive entity defined as a conscious subject or, at least, as a living being. But how the inert structures of matter could have given rise to cognitive phenomena is a question that has rarely been addressed, and even less so in the context of origin-of-life chemistry.

This article discusses minimal cognition, the analysis of the paradigmatic capacities and behaviours at the origin of mentality. Specifically, it addresses these questions: Is Deacon claiming that autogenic semiosis is a form of cognitive semiosis? Does the autogenic system involve not just the possibility that some molecules can be about other molecules, but that they can equally distinguish between opposite tendencies (self-destructive, self-regenerating)? If some form of minimal mentality can be attributed to the autogenic system, how further down could semiotic competence be extended into the physical reality? And finally, what implication does this have for the so-called "life-mind continuity thesis"—the idea that mind is lifelike, and life is mindlike (Thompson 2007: 128)—which has been central to autopoietic and embodied approaches to minimal cognition?

Minimal cognition models

In his article, Deacon describes the autogenic system using cognitive vocabulary. The autogen is said to be an "interpreting system" that displays "the simplest form of interpretive competence" by which the autogenic system can be self-re-presented in ever new substrates **(p. 4).** The system has the capacity to re-present itself, that is, to offload its basic constraints onto new substrates that maintain its boundary conditions despite its constant internal instability. This semiotic competence is described as the ability to interpret or analyse environmental conditions with respect to their contribution to system self-maintenance **(p. 10).** In this context, it is argued that the reference and significance of a semiotic relationship is "interpreted" by the system of constraints **(p. 15)** that creates the autogen. And yet, at no point is it implied that the interpreting act that enables the continuity of the autogenic system is or amounts to a cognitive function, even if it is of the simplest or most minimal kind, and that there is an interpreter of these functions.

Is there any such cognitive interpreter? This is no minor issue. From the turn of the last century a number of theorists attempted to identify the critical threshold that marks the transition from non-cognitive to cognitive phenomena. Although there is no agreement on where this threshold is, "minimal cognition" has been defined as the "the minimum requirements for the generation of cognitive phenomena" in actual organisms (Van Duijn et al. 2006: 158), and such requirements have been interpreted in very different ways. In the "autopoietic model" these consist in the recursive network of co-dependent processes that characterises minimal autopoietic systems. These systems are claimed to give rise to a "surplus of significance" that is absent from non-normative chemical reactions.

Maturana and Varela were the first to identity the intrinsic relation between the biological and cognitive domains and to articulate the idea that life and mind are continuous. Their view provided inspiration for the "life-mind continuity thesis", endorsed by many embodied and dynamical theorists, which says that the mind and its features are prefigured in life phenomena, and that they emerge from features like self-organisation, autopoiesis, or adaptation, while being both qualitatively different from and irreducible to these features. The life-mind continuity thesis is additionally supported by the fact that all prokaryotic organisms exhibit an internal disposition to sense and react to external objects (Lyon 2015; Godfrey-Smith 2016), although, in and of itself, this is not a guarantee that the signal processing of prokaryotes can be interpreted in cognitive terms (Sharov 2018).

A growing body of literature analyses the justification for this claim of continuity. Consider Escherichia coli (E. coli), a rod-shaped, single-celled, motile bacteria that has no nuclei and lives in environments considered too hostile for other multicellular organisms. E. coli uses its flagella to propel itself, tumble, rotate across liquid channels, and select the best orientation for reaching areas of higher sucrose concentration where nutrients abound. There are many possible ways to describe the behaviour of E. coli. In Thompson's view, the local molecular effects of sucrose permeating the membrane of E. coli are insufficient for understanding what is happening at the global level. While the local effects of sucrose may be critical for understanding molecular interactions, the global picture remains unclear unless it is acknowledged that E. coli is interpreting the sucrose gradient as a nutrient. Without this critical assumption, all possible molecular interactions remain without "meaning and value as food" (Thompson 2007: 74). This is how the milieu or *Umwelt* of E. coli becomes significant, and life is distinguished from basic chemistry.

More recent approaches inspired by the life-mind continuity thesis attempt to identify the simplest possible form of mentality in features like self-movement, coordinated action or problem-solving in bacteria (Van Duijn et al. 2006), plants (Garzón & Keijzer 2009) and slime moulds (Vallverdú et al. 2018). In particular, Van Duijn et al. emphasise the role of second-order properties that emerge with bacterial chemotaxis. While they agree that a E. coli provides a prime example of minimal cognition, the reason is not that the bacterium can interpret sucrose gradients as potential nutrients and act so as to benefit from them. This may always be explained as a case of adaptation. Consider the metabolic processes of the "lac operon" in E. coli, the system regulating the metabolism of lactose. The "lac operon" is a case of metabolic adaptation that is triggered by environmental conditions. The production of a particular enzyme in proximity to food is part of the organism's metabolic organisation—what could be interpreted as a change in its set of chemical reactions. Accordingly, by itself the lac operon system fails to display anything that resembles a cognitive disposition. In contrast, chemotaxis is a process caused by "physical changes in the position of the bacterium with respect to its environment" (Van Duijn et al. 2006: 164), rather than a chemical reaction. Following Van Duijn et al., unlike metabolism, chemotaxis has a "second order" character. Through chemotaxis, an organism "reacts to the environmental dispersal of metabolic requirements, rather than these requirements themselves" (Van Duijn et al. 2006: 164). If this is so, it could be said that chemotaxis constitutes a primitive version of sensorimotor coordination, and that this capacity seems—unlike the lac operon system—a more likely candidate for minimal cognition.

Other organisational approaches locate the origin of mentality in the nervous system itself (Arnellos and Moreno 2015; 2016). Moreno describes the cognitive domain as a sub-domain of life phenomena that emerges as an evolutionary by-product of the interaction between the nervous system and the rest of the organism. For cognition to appear, the system must first "decouple" from metabolic processes and the kind of movements induced by it to reach a "meta-metabolic domain" or second-order domain of unexpected behavioural possibilities. On the face of it, it may be assumed that cognition involves not just the capacity to sustain metabolically induced behaviour, or perceptually guided behaviour, but a world of meaningful interactions for the animal (Moreno & Mossio 2015).

Autonomy and embodiment theories alike depart from the idea that cognition could only have emerged as a function of living systems. Non-biological systems or other lifelike systems fail to exhibit it. And yet, this is not a unanimous view. Consider active materials like oil droplets, systems allegedly capable of displaying autonomous, self-driven movement. Could they be compared to the movement of bacteria? Lagzi et al. (2010) argue that the introduction of a pH gradient to a maze environment shows how chemotactic oil droplets "solve" the maze test without errors, that is, by selecting the shortest route from a limited range of options (McGivern 2019). McGivern argues that the behaviour of active materials like oil droplets or self-propelling nanoparticles calls for a wider notion of minimal cognition to include non-living systems. Inasmuch as oil droplets engage in emergent behavioural patterns that are highly sensitive and context-dependent, they might be seen as minimal models of "cognition" (McGivern 2019: 442).

Where does the autogenic system stand among these approaches? Can the so-called "interpretive competence" of the autogenic system be understood without a cognitive analogue? Is not the iconic interpretation of self-destructive tendencies and the capacity of reconstitution after damage an implicit recognition that the system establishes a cognitive rapport with its environment? And does this so-called "zeroth" level semiotic process entail a "zeroth" level cognitive process in simple lifelike systems?

Re-presentation: the most basic form of semiosis

Of course, the answer to this slew of questions depends on how the term "cognition" is defined. And here our problems begin. Authors have pointed out that "there are no sufficiently agreed concepts of cognition, biological or otherwise, that would enable us to identify the phenomenon in the natural world" (Lyon 2020). Van Duijn's definition, quoted above, does not help us either because it seems to be circular. I see then two alternative courses of argument. If the definition of cognition depends on biological features like metabolism and sensorimotor coordination, not to mention the development of a nervous system, higher-order consciousness and subjectivity, then re-presenting features of the autogen must fall short of cognition. If cognition is defined by these features, the autogenic system fails to provide any kind of cognitive analogue. However, if cognition is straightforwardly characterised as mere "re-presentation", that is, as the ability to map the world in ways that are functionally useful for the system, autogenic re-presentation may embody the kind of dynamics that any minimally cognitive system is supposed to exhibit, while not being itself cognitive for the lack of sufficient displacement of constraints to enable semiotic scaffolding. This displacement paves the way for the recursive iteration of increasingly complex semiotic relationships that build on previous iterations of the same process to create nested interpretive hierarchies. As a result, the most basic form of autogenic semiosis simply reflects the emergence of the dynamics that grounds minimal cognition, rather than minimal cognition itself. I will elaborate on this in the final section.

Deacon introduces re-presentation as the most basic semiotic relation. It is defined by the autogenic tendency to select some features and ignore others in its molecular environment. In other words, while there may be unlimited kinds of similarity, in the autogenic environment most of these are ignored and just a few are selected. The ones that are selected are precisely those that support the continued existence of the whole, while other deleterious, non-functional, or indifferent alternatives are side-tracked. Another way to express this idea is to say that because the autogenic system reacts to different environmental conditions in ways that take into account their possible contribution to self-maintenance **(p. 10)** and self-similarity, its interpreting acts do play a functional role.

Of course, reasonable objections may be raised against the idea that the selective disposition of autogenic dynamics underpins minimal cognition. Dissipative systems and other non-living systems like active materials might also display the same selective capacity and exhibit a self-stabilising tendency. On the face of it, could not these other processes be regarded as functionally semiotic in the manner of the autogen? And if these systems are granted some kind of functionality, how far down into the physical domain could this semiotic competence be extended?

This issue has been canvassed in contrasting ways. From a perspective inspired by autopoiesis, "[b]elow the level of complexity of autopoiesis—for example, the level of self-organizing, physical dissipative structures—we find no analogue of the phenomenological notion of the disclosure of the world" (Thompson 2007: 159). Thus, only systems that display the self-producing and co-dependent features of autopoiesis constitute a valid cognitive analogue. As is known, the theory of autopoiesis identifies the living cell and the metabolic network that creates its membrane as the first autopoietic system. Below the cell level, no molecular structure builds its own boundary in the manner of a cell.

So, according to autopoietic theory, smaller-than-the-cell structures fall short of providing the desired cognitive analogue to ground a theory of minimal cognition. Thus, the question may be asked: how does the autogenic environment compare with the *Umwelt* of E. coli? Significantly simpler than bacteria, the autogen lacks metabolism, chemotaxis, and a semi-permeable membrane. Autogenic processes result from the synergistic coupling of two self-organising processes that cancel out each other's self-destructive entropic tendencies and might even be considered to be made up of them. This coupling creates a partially contained system that tends to stabilise despite the continuous threat of degradation imposed by equilibrium dynamics. In this context, self-organising processes like those at work in the autogenic environment can only avoid dissolution if gradients are abundantly supplied to sustain reciprocal catalysis. But as is known, dissipative structures tend to deplete the material gradients that sustain them, eventually undermining their own basis.

While dissipative structures may exhibit spatiotemporally stable processes, they are neither intrinsically individuated nor do they perform work to support their continued existence. A similar consideration applies to the selective behaviour of active materials like oil droplets. Even if these processes could distinguish themselves as self-organising, temporally stable wholes, they would inexorably succumb to entropy. If efficient, their selective behaviour would simply tend to maximise entropy production, thereby accelerating the rate at which their system would be driven towards equilibrium. For this reason, it seems that by their own, dissipative structures cannot provide the desired cognitive analogue.

Functions are more than chemical reactions

Deacon assigns autonomy, individuality, normativity, and interpretive or semiotic competence to the autogenic system. Its non-normative chemistry is claimed to be the result of the emergence of dispositions that are irreducible to their underlying chemical processes while entirely dependent on them. In Deacon's view, these dispositions "are not reducible to the physical-chemical properties of its components and are emergent from the intrinsic dispositions of the whole integrated system" **(p. 8)**. Although it remains implicit, this change involves a radical phase transition in dynamical organisation by which new causal dispositions inaugurate a new higher-order logic of dynamical relations.

If features like autonomy, individuality, normativity, and interpretive competence can be predicated on the autogenic system, it seems inevitable to concede that smaller-than-the-cell processes can create semiotic relationships that are about something else, while at the same time denying that self-organising processes can be about anything[1]. Probably the best way to test this hypothesis is to consider autocatalytic processes, complex chemical reactions where the catalyst and its product coincide, spontaneously forming spatiotemporal units. The autogen is constituted by these processes, but because autocatalytic processes fail to withstand their own entropic tendencies, and thus tend towards their own dissolution, the features that are attributed to the autogen cannot be based only on autocatalysis or be reduced to its far-from-equilibrium dynamics. Further reasons why these sets cannot form individuals have been given elsewhere (Deacon 2013: 295; García-Valdecasas 2021).

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[1] This is not to say that self-organising processes cannot be sign vehicles or provide semiotic affordances. In addition, note that I am not using "being about something" to mean "phenomenally conscious" or even "subjective" or "first-person" for reasons given above. Molecular intentionality should be simply interpreted as the ability to be about something else in the way in which Deacon describes autogenic semiosis.

In my view, the threshold that marks the emergence of semiosis in the simplest autogen is the constitution of an individual beneficiary. If the autogenic system can be said to perform work that sustains self-maintaining and self-regenerating structures for the sake of an ultimate beneficiary, and this beneficiary is the constraint system, I see no compelling argument to deny that the sign vehicle properties present in the autogenic environment can provide affordances for an agent's interpretive competence **(p. 9)**. The processes taking place in the autogenic environment "are functions, not merely chemical reactions, because they exist to produce specific self-promoting physical consequences" (Deacon 2012: 273). These consequences amount to the characteristics listed above (autonomy, individuality, normativity, and interpretive competence) and may well include the emergence of the dynamics that underpins minimal cognition, while not sufficing to constitute minimal cognition itself. Certainly, the simplicity of the autogenic system might entail that the first semiosis is limited to the detection of disruptive and self-reconstituting tendencies, for which a set of disruptive possibilities were iconically interpreted as equivalent. But crucially, the system could distinguish between entropic and far-from-equilibrium tendencies, and disrupting and self-regenerating tendencies in a way that no other previously existing processes could. It is suggested that this disposition provides the underlying dynamics for minimal cognition.

Conclusion

The outcome of this discussion is that the autogenic system, despite lacking an internal metabolism and being only lifelike, represents a semiotic process capable of resisting hostile rejoinders based on the life-mind continuity thesis. And in fact, Deacon's teleodynamics may have important implications for this thesis. If by "continuous" it is understood "made up of incremental steps" from life to mentality features, both the rise of autogenic semiosis and the emergence of minimally cognitive systems may have been the result of dynamical transitions that recursively built on the displacement of constraints exhibited by the creation of ever more powerful semiotic relationships. Because this tendency is sustained at each step by teleodynamics, and this dynamics is inherently discontinuous—and ratchet-like, as Deacon describes it—it is questionable that the life-mind continuity thesis can entirely capture the complexity of the semiotic scaffolding that supports cognition.

This scheme might provide Deacon with a basis for articulating his position within the minimal cognition debate, even if that debate is not the main focus of his paper.

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