Causation and Information: Where Is Biological Meaning to Be Found?

Mark Pharoah¹

Received: 5 May 2020 / Accepted: 4 November 2020 / Published online: 13 November 2020
© The Author(s) 2020

Abstract

The term ‘information’ is used extensively in biology, cognitive science and the philosophy of consciousness in relation to the concepts of ‘meaning’ and ‘causation’. While ‘information’ is a term that serves a useful purpose in specific disciplines, there is much to the concept that is problematic. Part 1 is a critique of the stance that information is an independently existing entity. On this view, and in biological contexts, systems transmit, acquire, assimilate, decode and manipulate it, and in so doing, generate meaning. I provide a detailed proposal in Part 2 that supports the claim that it is the dynamic form of a system that qualifies the informational nature of meaningful interactive engagement, that is, that information is dependent on dynamic form rather than that it exists independently. In Part 3, I reflect on the importance of the distinction between the independent and dependent stances by looking specifically at the implications for how we might better interpret causation and emergence.

Keywords Information · Enactivism · Embodiment · Causation · Correspondence · Emergence · Semiosis · Biological meaning

In relation to causation, Hume (1748) talks of a power or force that is entirely concealed from us, describing this power as ‘the secret connexion’ which induces one causal impetus to follow another in an uninterrupted succession:

We only learn the influence of our will from experience. And experience only teaches us, how one event constantly follows another, without instructing us in

✉ Mark Pharoah

¹ London, UK

the secret connexion, which binds them together, and renders them inseparable. (Hume 1748, Section 7, part 1: 108)¹

That the secret connexion is entirely concealed should be a cautionary note: is it not the case that the concept of information has found its way into that very role? Information has become a metaphor for this secret connexion.² As such, it is the unseen ‘commodity’³ which connects one causal agent to the next, ensuring the determination of one event to another in an inexorable chain of informational events.⁴ Much of this way of thinking is implied, but Johansson (2009: 84) is explicit: ‘we can’t get any information from a system without interacting causally with it ... information is a causal process’. Fresco et al. (2018: 547) provide another example: ‘functional information is a special type of causal information’. So, too, does Jablonka (2002: 582), who details the consistent *causal role* that she says information plays in contributing to functional, goal-oriented behaviours. From this conception, it is but a small step to have this informational commodity appear to bear a correspondence with, and to become a carrier of, meaning.⁵ It seems that the adoption of information as the secret connexion in causal process has, in general, underscored a creeping bias which has granted causation its *volitional* character in virtue of the transmission of an informational (read, ‘meaningful’) directive.⁶ This stance has greatly influenced thinking in the fields of biology, cognitive science and philosophy of consciousness.

I am broadly in agreement with Levy (2011) whose ‘fiction-based’ explanation concerning the application of the concept of information in biology indicates the fallacy in treating information as a concrete physical entity: ‘Informational notions have theoretical significance, but this should not lead us to reify them’ (p. 653). Levy argues that applying an informational schema is a pretence for qualifying the causal facts.⁷ In this paper, I reconsider the causal–informational relation and explore in what way it makes sense to connect information with meaning. Firstly, in Part 1, I explore and critique the unqualified assumption that information is a commodity that meaningfully informs causal process. In Part 2, I defend the claim that information, in relation to biology and mental content, can make sense only in reference to any given Entity’s, Agency’s, System’s, or Observer’s (EASO) particular meaningful categorisation of interactive events, and that this ultimately depends on the EASO’s own dynamic form. In Part 3, I will indicate how these two opposing positions on information have a bearing on emergence and on the metaphysics of causation.

¹ See also Russell (1912: 189) concerning the intelligible nexus between cause and effect and Roth (1985) on Peirce’s contribution.

² On information as metaphor in biology consider Sarkar (1996), Emmeche (1999), Griffiths (2001), Levy (2011) and Longo et al. (2012).

³ Here, ‘commodity’ is defined as some kind of physicality that is substantively qualitative and/or quantitative.

⁴ Consider Francis (2003) on genetic determinism.

⁵ See Jordan and Day (2015) on the differences between the coherence- and correspondence-driven approaches to reality; see also Ingold (2001: 143).

⁶ Consider Stegmann’s (2005) view of information as ‘an instruction’, for instance.

⁷ See also Godfrey-Smith and Sterelny (2008) for an overview, and Hoffmeyer’s (2002) criticism of the ontological presuppositions in the fields of biology such as in the notion of digital information as a causative agent.

Part 1. Information as EASO-Independent

Information as a Commodity

The use of the acronym EASO is in itself a statement of intent, for it encompasses a very broad range of views, definitions and disciplines. But it also reflects the tendency for an overlap in the use of terminology; many of these terms are used interchangeably. A more encompassing term that I might use instead of EASO is ‘construct’. But for the purposes of this paper I will use the acronym because each of the terms that the acronym encompasses has a unifying connection to the concept of information: they all are said, in one form or another, to use it, process it, transmit it, decode it and so forth. In other words, they are all terms that support the premise that information is a property or commodity that can be ‘moulded’ in a meaningful way. It is due to this manner of thinking—through the use of the terms which make up the acronym—that the concept of information has become the metaphor in place of Hume’s secret connexion.

This notion of information as a substantive property is ubiquitous in the fields of biology, cognitive science and philosophy of consciousness where researchers typically have come to speak of information as being acquired, used, detected, read, processed, transmitted, received, extracted, converted, utilised, exchanged, coded and stored. As such, it is passed on from one instantiation to the next, from environment to agent, from one system to another, or from object to observer or interpreter. It is then the task of the EASO to assimilate it, and it is in this capacity, usually, that meaning is said to be constructed (later I will question the veracity of this syntax to semantic order; see Section 1.4).⁸ Subsequently, I refer to this stance, which treats information as a causally efficacious commodity, as the EASO-independent stance.⁹ This is the view that information exists independently of any class of EASO that might register and assimilate it. For most researchers, information informs the processes of physical, biological and mental coherence.¹⁰

Information and the Construction of Biological Meaning

In their treatment of information as a commodity researchers typically say, for instance, that plants and animals make practical use of environmental information; genes and cells carry semantic information; phenotypic traits are coded for by genes which contain information; cell processes execute a program of information stored in genes; information flows from one generation to the next; mind content is constructed from information; mental representations may consist of analogue or digital information; information enters into our perceptual world through our senses where processes of cognition convert syntactical information into semantical meaning, and so on.¹¹ In this capacity, information is something that endures until it is read and processed by an EASO. This reading and processing is considered possible only if the EASO (be it

⁸ A special issue on information in biosemiotics sees this stance typified (Brier and Joslyn 2013: 6–7).

⁹ See von Foerster (1981: 140 and 237) on information being taken as a substance; and Zoglauer (1996).

¹⁰ Notwithstanding the distinctions drawn by process philosophers (notably Bickhard 2008: 252; see also Bickhard 2011; Seibt 2018; Campbell 2009; Dupré 2014; Dupré and Nicholson 2018)

¹¹ See Godfrey-Smith (2007) on the extended applications of the concept of information in biology.

natural or artificial—noting Dennett 1987) possesses the necessary ‘functional complexities’ to facilitate the construction of the counterfactual aspects of meaningful information. This objectification of information, that is, the tendency to view information as a substantive thing, is reaffirmed by the idea that information can be reduced quantitatively into smaller ‘bits’.¹² Inevitably where information is thought to consist of incremental bits, somewhere along an arbitrary line of assimilating complexity—which for many entails decoding or computation¹³—certain organisational mechanisms, it is assumed, must also be capable of constructing meaning from it.¹⁴ For many in biology, it is convenient and expedient to utilise information in this manner and assume that somewhere along the line ‘meaning just happens’—courtesy perhaps of ‘Mother Nature’ (noting Fodor’s 1996 critique).

Of course, biological meaning comes in many forms. I am not sure how contentious it would be if one were to try to make a tentative list of these forms. For instance, I consider biological meaning to include such things as function, quality, quantity, process, structure, temporality (e.g. ‘memory’) and spatial differentiation. But the point is not whether these forms should be included in a list of what might or might not constitute meaning in biological contexts. The point is that there is always the temptation to equivocate between the concept of information and the forms of meaning to which it might be affiliated. This equivocation then allows certain assumptions about information to be left unchallenged.

Jablonka (2002) presents an interesting example (see also Fresco et al. 2018). On Jablonka’s functional account, a source in the environment becomes information only when the interpretative system of a receiver facilitates functional reaction—a source is not information otherwise. This represents an observer-dependent stance on information. But if we take her shortened definition from the abstract, ‘a source becomes an informational input when an interpreting receiver can react to the form of the source (and variations in this form) in a functional manner,’ we find that it can be written alternatively without recourse to the concept of information, as follows, ‘a source is meaningful when a receiver reacts to the form of the source in a functional manner’. In other words, Jablonka’s definition, as I have put it, is about biological meaning specifically as goal-oriented function. As such, it is not clear what the concept of information serves in the original untampered definition. If we say that the phenomenal experience, for example, to 484 THz in two different species is qualified in virtue of their contrasting ontogenetic and phylogenetic ancestry, in what way does it make sense to say that the source (484 THz) ‘has information’ unique to each creature? Are we not merely talking about an environmental source ‘meaning’ different things to different organisms? One might seek to incorporate information into Jablonka’s thesis concerning function and its relation to biological meaning by drawing a distinction

¹² See Peters’s (1988) historical overview.

¹³ Concerning computation, Piccinini and Scarantino (2010) argue that the cybernetic movement (see McCulloch and Pitts 1943; Rosenblueth et al. 1943; von Neumann 1945; Ashby 1952) influentially contributed to the conflation of the concept of information with its computational treatment in many disciplines, including cognitive science.

¹⁴ See Bergstrom and Rosvall (2011) on information flow and the many commentaries on their work; consider Hoffmeyer’s (2002) critique of the notion of information flow and transmission, and on the fallacy that ‘instructions’ are passed from DNA to protein; and Bickhard (2009: 575) who argues that ‘the information flow model of perception, cognition, and language is wrong from top to bottom’.

between functional, syntactic and semantic information. Clearly though, to do this, is to introduce distinct conceptual versions of information which, in effect, ends up leading to an equivocation between both EASO-independent and EASO-dependent positions.

Information and the Construction of Mental Content

In regard to philosophy of consciousness, Akins (1996: 337–8) argues that attempts at the naturalisation of mental content typically rest upon an intuitive view of what the senses do, namely, that they function to inform the brain of what is going on ‘out there’ in the external world. This orthodoxy regards the human mind as an information processing system with storage and processing capabilities that operate on internal representations. Importantly, Akins (1996: 350) cites empirical studies to reinforce her point. This evidence indicates that sensory signals do not correspond with some property in the world: sensory signals clearly and evidentially do not encode external properties.¹⁵ In essence, Akins is questioning the veracity of the view that the sensory or mental states to which we ascribe meaning to the world bear a correspondence with an informational world.¹⁶ Prakash et al. (2020) apply ‘interface games’ (a class of evolutionary game) to indicate that perceptions never faithfully report the structures of the observer-independent world: natural selection, they argue, shapes perceptual systems not in order to provide veridical perceptions, but to serve as species-specific ‘interfaces’ that guide adaptive behaviour. Steward (1997, 2012) also criticises the standard conception of perception and agency, proposing instead that we view agency as a special form of downward causation (see Part 3). Other advocates of Akins’ position include Cohen and Nichols (2010) who make the case that ‘colour’ perception is a construct of the perceiver rather than that colour is EASO-independent, and Bickhard (2009: 573–5) who questions the classic notion of ‘information flow’ from perception to cognition by arguing that perception is not a matter of sensory encoding.

There are a number of reasons why the EASO-independent position has gained traction in recent history. For instance, there has been the influence of the cognitive revolution of the 1960/1970s (see Gardner 1985) and of cybernetics and computer science. There was also the potent idea of genes as information bearing following the discovery of the double helix. They all seemed to point to an information bearing world. The task was then about how ‘complex systems’ constructed meaning from it. Simon (1978: 3) expresses unreserved confidence when adopting this position: ‘The human brain encodes, modifies, and stores information that is received through its various sense organs, transforms that information by the processes that are called ‘thinking’, and produces motor and verbal outputs of various kinds based on the stored information. So much is noncontroversial.’ Dretske (1981: 194) echoes Simon’s stance: ‘In teaching someone the concept *red* ... we exhibit the colored objects under conditions in which *information* about their color is transmitted, received, and (hopefully) perceptually encoded. ... it is the information that the object is red that is needed to shape the internal structure that will eventually qualify as the subject’s concept *red*’ (emphasis in original). Other examples that illustrate the EASO-independent stance on information are numerous, but note Tye’s (1995: 145) unquestioning observance of the

¹⁵ Compare Maturana and Varela (1980: xiv).

¹⁶ See Jordan and Day (2015) regarding the correspondence stance.

orthodoxy: ‘*The obvious view*, suggested by our color experiences (and compatible with my position), is that the colors we see objects and surfaces to have are simply intrinsic, observer-independent properties of those objects and surfaces’ (emphasis added). Clearly Akins was against the significant tide of opinion at the time that Lycan (1996: 54–5) also declared: ‘When real human beings regard a physical object from different visual points of view, they take in different and all highly selective bunches of information about that object.’

In each of these quoted examples, some kind of informational property is assumed to be existing out there in the world independently of the observer. To take this view prompts those who are interested in naturalisation to consider the great mystery of where and how meaning comes about; how and why does information from the objective informational world get re-expressed as biological, phenomenal or conceptual meaning? This prompting inevitably leads many to consider the role of representation and/or computation in the biological, phenomenal and conceptual processing of environmental information: ‘Many representational models hold that representation is constituted in some special ... relationship between the representation and the represented. Typically, this special relation is thought to be causal, nomological, or informational’ (Bickhard 2009: 559). Representational and computational theories typically begin, then, from the problematic premise that there is such a thing as a physical entity that possesses the ‘know-how’ to qualify informational differences and, subsequently, to instruct a meaningful and comparable measurement of those differences (noting Bateson 1970; Dennett 1998: 142–9; Stoffregen 2000).

Information: The Aether and the Meaning-Maker

It is evident that the EASO-independent view of information performs an ideological alchemy which is deeply problematic. How does this ideological alchemy work? Well, consider ‘aether’. It was once thought by the greats, such as Newton, Maxwell, Lorentz and Kelvin, that there was an all-pervasive aether—a field or space-filling medium throughout the Universe—that facilitated the propagation of electromagnetic and gravitational forces. The concept of information serves a very similar function: information is typically viewed as an all-pervasive entity that exists everywhere. In this capacity, information is given the status of a medium that occupies every corner of existence (note Wiener 1948: 155; Günter 1963; Stonier 1990: 21, Stonier 1991, Stonier 1996) and that facilitates the transmission, storage and measurement of ‘value-laden’ properties across the broadest possible range of interactions, be they physical, biological or mental. Unfortunately, in its capacity as a kind of aether, information has become the realist’s prop for the ‘intrinsic property of reality’.

In tandem with this conceptualisation, the term ‘system’ has found its place in the lexicon of academia to refer to any complex process that is deemed to have access to, to read, and to interpret this ‘information-aether’. In this manner, and across a very broad range of disciplines, the term ‘system’ has become a metaphor for that which organises complexity (or ‘makes sense of it’) or that turns information into meaning. For illustration, consider these examples from three prominent philosophers. The first is from Dretske’s influential book, *Knowledge and the flow of information* (Dretske 1981):

a semantic structure may be viewed as a system's interpretation of incoming, information-bearing signals. (p. 181)

the system making the conversion necessarily *abstracts* and *generalizes*. It *categorizes* and *classifies*. (p. 182; emphasis in original)

the system has interpreted the signal as meaning ... The system has *seen* a red square. (Dretske 1981: 181; emphasis in original)

Similarly, Chalmers (1995; see also Chalmers 2011), whose intention in his seminal paper is to define and classify the problem of consciousness, utilises the term 'system' as the entity or process that derives meaning from a world full of informational properties:

Sometimes a system is said to be conscious of some information when it has the ability to react on the basis of that information, or, more strongly, when it attends to that information, or when it can integrate that information and exploit it in the sophisticated control of behavior. (p. 201)

A third example is taken from the transcription of an interview between Warburton and Dennett (2013) concerning Searle's (1980) much debated Chinese Room argument and illustrates how the EASO-independent stance influences the conception of the argument:

Dennett: Imagine the capital letter *D*. Now turn it 90 degrees counterclockwise. Now, perch *that* on top of a letter *J*. What kind of weather does that remind you of?

Nigel Warburton: The weather today, raining . . .

Dennett: That's right; it's an umbrella. Now notice that the way you did that is by forming a mental image. You know that coz you are actually manipulating these mental images ... Now, that would be a perfectly legitimate question to ask; in the Chinese Room scenario, and ... if Searle—in the backroom—actually followed the program, without his knowing it, the program would be going through those exercises of imagination: it would be manipulating mental images. He would be none the wiser coz he's down there in the CPU opening and closing registers, so he would be completely clueless about the actual structure of the system that was doing the work. Now, *everybody* in computer science, with few exceptions, they understand this because they understand how computers work, and they realize that the understanding isn't in the CPU, it's in the *system* ... that's where all the competence, all the understanding lies. (09:14; emphasis in original)

In each of these three examples, we see the authors referring to 'systems' as doing the hard work of creating meaning. The last quotation in particular from Dennett is illustrative of the way in which the term 'system' is so readily used in its role as a

meaning creator (the system, in this particular example, being a computer) and indicates how it is so effectively accepted as an explanation.

In relation to mental content, the conceptual basis underpinning the term ‘system’, which has also become central to the predominant expository language, perpetuates the notion of a syntactic–semantic dichotomy. This dichotomy must exist in such cases because the concept ‘system’ assumes the role of a facilitator through which an external syntactical information-aether gets re-presented as content that is meaningful; the concept ‘system’, as meaning creator, is the necessary term that provides the convenient bridging concept that plugs the syntactic–semantic gap. Without that plug, the concept of information becomes virtually redundant.

Now, the reader might interject that this criticism is all very well, but what is the alternative? In Part 2, I propose inverting the syntactic–semantic order by putting meaning first and positioning information as an EASO-dependent construct. To understand this view, it is perhaps easiest to consider it in relation to human written or spoken language. An individual human, for instance, may possess a meaningful subjective perspective about the world and their place within it. They then might articulate part of that perspective through a syntactic digitised socioculturally adapted linguistic code. A second individual might then read that coded text. While doing so, this reader, I suggest, does not upload or convert that code’s meaning from author to reader: ‘A book itself cannot transmit or “install” information (clues, ideas, and images) into readers’ minds’ (Sukhoverkhov 2010: 164). Rather, the reader moderates their own existing world-view: they reconstruct a new meaning about the world that incorporates some of the ideas implied in the text. This new meaning, like all fingerprints, will be slightly different from all others. What I suggest is that there is no meaning in the text itself whose substance, as ‘information,’ is transmitted or relayed from author to reader—information is not a vehicle that carries meaning via some causal correspondence from one medium to another. Rather, any sense of information from the author that is established by the reader is an appraisal of the reader’s re-evaluated world-view—their is a new constructed meaning that bears a relation to that of the compositor due to a multitude of equivalent cultural, social and experiential references and definitions. For the reader to talk of this new meaning in informational terms is for them to attempt to standardise by digitising and conceptualising their meaningful world-view, that is, to seek to make it relational.¹⁷ My position is a broad metaphysical one that states that this is the case in all instances and for all EASOs.

Part 2. Information as an EASO-Dependent Construct

Information: An Expansive Metaphysical Proposition

Searle (2013) adopts the position that information is EASO-dependent in expressing the view that ‘Information is only information relative to some consciousness that assigns the informational status’ (sec. 6). But I advocate a more expansive metaphysical

¹⁷ Rescher (1982) similarly talks of human knowledge as being about creating theories and concepts to formalise our meaningful relation to the world in a way that systematises what we *then establish* as the ‘data of objectivity’.

proposition that relates this view—namely that information is EASO-dependent—to include any kind of EASO, be it mental, biological or even purely physical. This view reflects those of Josephson (2017) who has proposed the incorporation of meaning into fundamental physics, drawing specifically on the insights of biosemiotics. It is also inferred by Pharoah's (2018) hierarchical model, which proposes distinct ontological levels of interactive discourse that might be extrapolated into the realm of quantum mechanics¹⁸ (see also Barad 2006). One of the consequences of this expansionist EASO-dependent stance is that it allows for the possibility that a host of distinctive categories of EASO possess differing categories of informational relations to their environment. Nevertheless, for the purposes of this paper the focus is only on the biological and mental aspects of information and meaning.

In these areas, the proposal outlined in this paper aligns with Bateson (1972: 453) when he expresses the view that the informational status of an object, such as a piece of chalk, is dependent on the subject observing it, and therefore, is dependent on the nature of that subject's dynamic construct. It is also consistent with Jordan and Vinson (2012: 9) who take the embodiment position that 'organisms do not need to be "informed" by environments in order to be about environments because they are necessarily 'about' the contexts they embody'. In other respects, the paper advocates the enactivist view that meaningful information necessitates a description in terms of the locus or characterisation of engagement. 'For the enactivist, sense is not an invariant present in the environment that must be retrieved by direct (or indirect) means. Invariants are instead the outcome of the dialog between the active principle of organisms in action and the dynamics of the environment' (Di Paolo et al. 2010: 39).¹⁹ Consider also Akins (1996, discussed above) and Thelen and Smith (1994) who propose that systems do not store information acquired from the world but that multimodal systems structures categorise the world informationally. Similarly, for Merleau-Ponty (1962, 1963), biological reactions are not reducible to structural parts within the organism or to localised bits of stimuli but rather to the interacting relation of an agency's entire dynamic form with its environment (bearing in mind that an environment may be, for some interactive agents, the internal world of a single cell and for others, such as a species, the transgenerational environment).

Dynamic Internal Adjustment and Meaning as a Construct of the Whole

Merleau-Ponty expresses the view that biological reactions are an embodied interacting relation between an agency's entire dynamic form and its environment: 'It can happen that, submitted to external forces which increase and decrease in a continuous manner, the system [comprising 'the individual'], beyond a certain threshold, redistributes its own forces in a qualitatively different order' (Merleau-Ponty 1963: 137, 'Structure in

¹⁸ Notably Fuchs (2010), who argues for the subjective nature of quantum information, emphasises that supporters of the informational point of view about quantum states have tried to have it both ways: on the one hand that quantum states are not real physical properties, yet on the other that there is a right quantum state that is agent independent.

¹⁹ Also consider Torrance and Froese (2011).

Physics'²⁰). One can interpret this in relation to the evolutionary and processual nature of biology, adaptation and mental engagement: what Merleau-Ponty is saying is that individual bodies maintain a balance in virtue of internal adjustments that influence the whole. Interestingly, on his account the system redistributes its own forces *qualitatively*. Merleau-Ponty qualifies this with the following:

physical stimuli act upon the organism only by eliciting a global response which will vary qualitatively when the stimuli vary quantitatively; with respect to the organism they play the role of occasions *rather than of cause*; the reaction depends on their vital significance *rather than on the material properties of the stimuli*. Hence, between the variables upon which conduct actually depends and this conduct itself there appears a relation of meaning, an intrinsic relation. One cannot assign a moment in which the world acts on the organism, since the very effect of this 'action' expresses the internal law of the organism. (Merleau-Ponty 1963: 161; emphasis added)²¹

Clearly, Merleau-Ponty subscribes to the view that information does not exist out there in the environment (these passages indicate that he would also subscribe to Levy's 2011 bifold distinction): that which would otherwise be bland causal mechanics become qualified (informationally), notably, not by 'the material properties of the stimuli,' but rather by the 'internal law of the organism' in virtue of the adjustment of its internal dynamics. Vehkavaara's (1998: 210) view that 'The interaction between a living system and its surroundings is not considered as causal chains of the necessary causes and effects, but as sign processes' echoes Merleau-Ponty's position where 'the sign process' equates, for Merleau-Ponty, to the 'internal law of the organism' (see below concerning the sign process). For Merleau-Ponty, meaning is a construct of the whole, where the whole, I suggest may be an organism, a cell, an organelle, even a replicating lineage or a consciousness.

But what is this 'internal law' of which he speaks? Well, we can confidently say that the internal law must be that which ensures the maintenance of a dynamic stability following interaction because a dynamic stability is what persists: when any given EASO responds to an interaction through an adjustment of its internal dynamics, we can note that it is adjusting to this end. Whatever else it could be, this end, in all its complex and diverse incantations, must be the observance of its internal law (until such time as the maintenance of stability undermines structural and/or functional integrity, or when a system reaches 'beyond a certain threshold').

The Dynamic Whole that Qualifies Meaning as Informational

Insofar as there is a dynamic stability at any given instance in observance of its internal law, we can say that an EASO's dynamic construct itself must be that which qualifies the nature of its response to interactive impulses.

²⁰ Compare Emmet (1992: 35): 'processes are changes with an internal order which distinguishes what is happening within the process from forces acting on it from outside'. Consider also Hulswit (2001) on Peircean processes and events.

²¹ See also pp. 145–7. And in relation to Part 3 note 'they [stimuli] play the role of occasions rather than of cause'.

Additionally, if we say of an EASO's dynamic state that it responds differently to a variety of interactive impulses in subtle pursuance of its particular internal law, we can surmise that *all its responses* are due to the nature of its own particular dynamic state. It is the internal law that generates significance and meaning via a dynamic coupling with the environment. Thus we can extend Ingold's (1990: 216) notion that 'enfolded within the organism itself is the entire history of its environmental conditions' by suggesting that the construct of the organism, namely, its ancestral history and its changing environment, as well as its experiences and thinking, constitute the informational integrity of its entire 'form' (a viewed shared in Jablonka 2002). This 'form' is what informs its embedded and meaningful relation to the world. Without that form, there is no meaning, there is no information (consider here Cao's 2012 teleosemantic approach to information). We should note, therefore, that there must be an ongoing informational relation between an EASO's dynamic stability and its environment as it adjusts to interactions.

Furthermore, it is an EASO's changing dynamic form itself which qualifies the ongoing informational relationship that it has with its environment. Consequently, the argument supporting the key claim is made, namely, that if there exists an informational character or status to physical interaction, it is not a commodity that is transmitted by a direct causal correspondence from one instantiation to another, but rather, is a reflection of the specifics of the internal dynamics of any given EASO: in other words, information is EASO-dependent, not EASO-independent.

As a physical principle, we have good reason to claim that this is true of any given EASO, whether it be mental, biological or even physical in nature. This conclusion undermines the view that the mind is principally a computational module and that the body is an information processing device: 'the body is not a puppet controlled by the brain but a whole animate system with many autonomous layers of self-constitution, self-coordination, and self-organisation and varying degrees of openness to the world that create its sense-making activity' (Di Paolo et al. 2010: 42).

Semiosis and Information as EASO-Dependent

Peircean semiotics has greatly influenced biosemioticians in their desire to interpret biological meaning and clarify the nature of its origins in informational and transactional terms. But, I suggest, biosemiotics should not focus on studying living organisms in terms of their ability to generate and to interpret information; life is not intrinsically related to *information processing* and its *communication* (Sharov 2010: 1051). Indeed, the term 'interpretant' can be misleading.²² This is not to say that the triadic object–sign–interpretant model is incorrect but that it readily suggests an information processing interpretative agent; this is clearly problematic from the EASO-dependent standpoint. What the EASO-dependent stance requires instead is an emphasis on the role of the *dynamic interpretant* in the final analysis. Thus, the EASO-dependent stance might be considered to incorporate semiosis as a triadic process whereby a construct mediates objects as sign relations in virtue of their meaningful relevance—be that relevance functional, qualitative, quantitative, processual, objective, temporal or spatial: these being aspects or modes of biological meaning. This stance is evident in Sukhoverkhov

²² Savan (1988) express the view that interpretants need to be understood as 'translations'.

(2010) in his analysis of temporal consistency in biological, mental and social contexts: ‘A sign is a *heteronomous* phenomenon whose being depends on subjects . . . Signs as material objects or “sign vehicles” have no special semiotic (representative) essence—only material existence. The semiotic essence is assigned to them. . .’ (p. 162 emphasis in original). The EASO, as a construct, generates its own interpretant as a unique translation of interactive experience. This reconfigures the Peircean stance where semiosis is often interpreted as a process of *communication* of a form, *from* the object, *to* the interpretant through sign mediation.

Part 3 Emergence and Causation

Is the EASO-Dependence -Independence Distinction Worth Examining?

Hoffmeyer (2002: 9) emphasises that in recent years ‘quite a few biologists and philosophers have claimed that efficient (Aristotelian) causation cannot exhaustively account for the dynamics of living natural systems (Juarrero 1999; Riedl 1997; Rosen 1991; Salthe 1993; Ulanowicz 1997)’. Hoffmeyer goes on to say that this change towards a richer concept of causation makes the idea of information flow look a little like the antiquated notion of phlogiston. But many still persist with the view that the dependent–independent distinction is unimportant or that the viewpoints amount to the same thing. They might say, for example, that an aeroplane they see flying across the sky exists independently of their seeing it, and therefore, so too must exist the informational properties by which they and others identify it as an aeroplane: the information, they claim, is obviously not dependent on the perceiving subject because the object exists irrespective of the subject’s observation of it. But to clarify, the view that information is EASO-dependent is not a denial of realism. Rather, all it says is that information is not a commodity that is extracted from the environment and from which meaning is then constructed, re-presented or computed. Instead, the EASO-dependent stance holds that the nature of an EASO’s meaningful relation to the world is a function of its existing dynamic construct. This meaningful construct can only then be viewed in informational terms.

The importance of this distinction is best examined in relation to emergence, for in the biological disciplines the idea of emergence is widely accepted (Korn 2005; Rothschild 2006; Okasha 2011). In the next section, however, what I intend to do is show that emergence fits uncomfortably with the view that information is EASO-independent. This is not the case if one adopts the EASO-dependent stance on information.

Emergence and the Upward–Downward Causation Paradox

Kim’s (1999, 2006a) argument against emergentism is under-appreciated in biological contexts (note Bickhard 2009: 550–1; O’Connor and Wong 2020). Kim states that downward causation is the emergentist’s most problematic issue; how is it that lower-level processes cause higher-level processes which in turn exercise downward causal influences on lower-level processes? Kim (2006b) presents the following argument to support the view that emergentism faces a problematic overdetermination:

I would like to give an idea of the difficulties that confront anyone who wants causal efficacy for emergent properties. Suppose a claim is made to the effect that an emergent property, M , is a cause of another emergent property, M^* (this is short for saying that an *instance* of M causes an *instance* of M^*). As an emergent property, M^* is instantiated on this occasion because, and only because, its basal condition, call it P^* , is present on this occasion. It is clear that if M is to cause M^* , then it must cause P^* . The only way to cause an emergent property is to bring about an appropriate basal condition; there is no other way. So the M – M^* causation implies a downward causal relation, M to P^* . But M itself is an emergent property and its presence on this occasion is due to the presence of its basal condition, call it P . When one considers this picture, one sees that P has an excellent claim to be a cause of P^* , displacing M as a cause of P^* . The deep problem for emergent causal powers arises from the closed character of the physical domain, which can be stated as follows:

... If a physical event has a cause, it has a physical cause. And if a physical event has an explanation, it has a physical explanation. (p. 199)

To summarise:

Emergent property M has basal properties P .
 Emergent property M^* has basal properties P^* .
 If M causes M^* , it does so in virtue of causing M^* 's basal properties, P^* .
 But P also has claim to cause P^* , displacing M 's claim to causing P^* .²³

My view, however, is that the Kim paradox relies on the assumption that a causal entity determines an effect through some direct instructional correspondence.²⁴ The causal impetus, it is assumed, provides the *information* to the system to act in a particular way courtesy of that impetus's causal properties. The Kim paradox, therefore, aligns with the EASO-independent standpoint—it is from this standpoint that he undermines the emergentist position. Is it not possible, therefore, to disarm Kim's argument of overdetermination by undermining his EASO-independent standpoint?

For instance, if we say of a certain environmental impetus C , that it corresponds with a certain kind of action E_1 by a system S_1 , one might assume with Kim that C causes S_1 to E_1 . Furthermore, if we say that C corresponds with an alternative kind of action E_2 by an alternative system S_2 , we have reason to assume that C also causes S_2 to E_2 (noting comparable arguments in Alexander 1920: 43; van Cleve 1990: 221; O'Connor and Wong 2005: 665–70). Consequently, we might justifiably deduce of C that it could, conceivably, correspond to E_n in virtue of the possibility of S_n (where n is an integer). But this plurality of possible actions, E_n , I suggest is nonsensical for we can conclude nothing substantive from any given observation concerning the informational properties pertaining to C . This indicates that the observer-independent position on information is an idealised one. When it is said that an entity has causal properties, the term

²³ See Macdonald and Macdonald's (2010: 154) appraisal and critique, which in essence calls to task its substance ontological standpoint; consider also Bishop (2012) and Bitbol (2012).

²⁴ Note Hulsmit (2001) and Santaella-Braga's (1999) general account of Peirce's concept of final causality.

‘property’ implies the existence of an informational commodity that can be transmitted *up* the causal chain. The problem with Kim’s stance relates, therefore, to the assumed determination of action by causal entities courtesy of their informational properties; hence his claim that there is a paradox of overdetermination for the emergentist.

What I propose instead, is that the nature of any given action *E*, following an impetus from a property *C*, is indicative not of *C* being the cause of *E* at all, but rather of the respective *S* effecting a particular action courtesy of its particular structure and mechanism of interactive engagement, or, as Bickhard (2009: 553) puts it, that it is internal organisation that is the locus of causal power.²⁵ The nominal appearance, then, is that *C* causes *E*, that is, that there is a direct mechanistic informed correspondence from any given *C* to *E* (a point emphasised by Merleau-Ponty), but this appearance is a deception.

Kim’s argument holds only when one maintains the orthodox position that information exists as a EASO-independent entity. Under this formulation, the secret connexion is ‘information’. And in this idealised role, information just is what it is; determines what it determines; is the difference which causes the difference; and is that which allows for the possible construction, representation, decoding and computation of meaning by EASOs. This position holds that information is the aether of our modern era that fills every space of existence and facilitates the required conceptual bridge, from interaction without meaning—in physics, chemistry and biology—to meaningfulness in biology and mental content.

Alternatively, if one takes the position that information is not a commodity that exists and, therefore, that information is not passed along the causal chain, then it forces a revision of such things as meaning and its characterisation. How might this revision look?

Meaningful information is a dynamic construct of any given EASO. It is expressed through the requirement of the whole in the maintenance of a dynamic stability. In this capacity EASOs exert their influence through meaningful action following interactive engagement. How do we resolve this with the notion that there is upward influence? This is a difficult question to address, but I suggest that the physical, biological and mental operate at ontologically distinct levels of meaningful engagement. As such, they can all operate in parallel, each effecting meaningful engagement at distinct levels. This view implies that there is no ‘upward’ causation.

Summary

I hope this paper gives some foundational ideas on how to revisit the concept of information in the context of biological meaning and mental content. The primary objective in Part 1 has been to provoke a critical appraisal of the orthodox view and, in Part 2, to make a case for an alternative stance. This stance indicates that biological meaning takes form as spatiotemporal, functional, structural and qualitative extension. In this regard, it can be interpreted as an informational construct *of* the world. Environmental interaction leads to modifications to these constructs, which is to say

²⁵ Note Ingthorsson (2002) who expresses the view that causal process should be seen, not as a causal agent acting upon a recipient, but as a mutual and reciprocal interactive process; see also Laland et al. (2013).

that biological meaning evolves. Notably, then, meaning is not constructed from information. Information is not something that moves from one space or from one time to another. Structures are not made of it. An informational world is not represented meaningfully. There is no causal correspondence or power in the transmission of information in biology.

In Part 3, my intention was to show that the distinction is important by indicating that it has profound implications for how we might interpret such things as emergence and causation.

Funding Not applicable.

Compliance with Ethical Standards

Conflict of Interest Not applicable.

Open Access This article is licensed under a Creative Commons Attribution 4.0 International License, which permits use, sharing, adaptation, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if changes were made. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit <http://creativecommons.org/licenses/by/4.0/>.

References

- Akins, K. (1996). Of sensory systems and the 'aboutness' of mental states. *Journal of Philosophy*, 93(7), 337–372.
- Alexander, S. (1920). *Space, time, and deity* (2 vols). London: Macmillan.
- Ashby, W. R. (1952). *Design for a brain*. London: Chapman and Hall.
- Barad, K. (2006). *Meeting the universe halfway: Quantum physics and the entanglement of matter and meaning*. Durham: Duke University Press.
- Bateson, G. (1970). Form, substance, and difference. *General Semantic Bulletin*, 37, 5–13. The nineteenth annual Alfred Korzybski memorial lecture, delivered at New York, January 9, 1970; reprinted in *Steps to an ecology of mind, Part V: Epistemology and ecology* (pp. 454–471).
- Bateson, G. (1972). *Steps to an ecology of mind*. New York: Ballantine.
- Bergstrom, C. T., & Rosvall, M. (2011). The transmission sense of information. *Biology and Philosophy*, 26, 159–176.
- Bickhard, M. (2008). Issues in process metaphysics. *Ecological Psychology*, 20(3), 252–256.
- Bickhard, M. (2009). The interactivist model. *Synthese*, 166, 547–591.
- Bickhard, M. (2011). Some consequences (and enablings) of process metaphysics. *Axiomathes*, 21(1), 3–32.
- Bishop, R. C. (2012). Excluding the causal exclusion argument against non-reductive physicalism. *Journal of Consciousness Studies*, 19(5/6), 57–74.
- Bitbol, M. (2012). Downward causation without foundations. *Synthese*, 185(2), 233–255.
- Brier, S., & Joslyn, C. (2013). Information in biosemiotics: Introduction to the special issue. *Biosemiotics*, 6, 1–7.
- Campbell, R. (2009). A process-based model for an interactive ontology. *Synthese*, 166(3), 453–477.
- Cao, R. (2012). A teleosemantic approach to information in the brain. *Biology and Philosophy*, 27, 49–71.
- Chalmers, D. (1995). Facing up to the problem of consciousness. *Journal of Consciousness Studies*, 2(3), 200–219.
- Chalmers, D. (2011). A computational foundation for the study of cognition. *Journal of Cognitive Science*, 12, 323–357.

- Cohen, J., & Nichols, S. (2010). Colours, colour relationalism and the deliverances of introspection. *Analysis*, 70(2), 218–228.
- Dennett, D. C. (1987). *The intentional stance*. Cambridge: MIT Press.
- Dennett, D. C. (1998). *Brainchildren*. Cambridge: MIT Press.
- Di Paolo, E. A., Rohde, M., & De Jaegher, H. (2010). Horizons for the enactive mind. In J. Steward, O. Gapenne, A. Ezequiel, & Di Paolo (Eds.) *Enaction: Toward a new paradigm for cognitive science* (pp. 33–88). Cambridge, MA: MIT press.
- Dretske, F. (1981). *Knowledge and the flow of information*. Cambridge: MIT Press.
- Dupré, J. A. (2014). A process ontology for biology. *The Philosophers' Magazine*, 67, 81–88.
- Dupré, J. A., & Nicholson, D. (2018). A manifesto for a processual philosophy of biology. In D. Nicholson & J. Dupré (Eds.), *Everything flows: Towards a processual philosophy of biology* (pp. 3–45). Oxford: Oxford University Press.
- Emmeche, C. (1999). The Sarkar challenge to biosemiotics: Is there any information in a cell? *Semiotica*, 127(1), 273–293.
- Emmet, D. (1992). *The passage of nature*. Basingstoke: Macmillan.
- Fodor, J. (1996). Deconstructing Dennett's Darwin. *Mind and Language*, 11(3), 246–262.
- Francis, R. (2003). *Why men won't ask for directions: The seductions of sociobiology*. Princeton: Princeton University Press.
- Fresco, N., Ginsburg, S., & Jablonka, E. (2018). Functional information: A graded taxonomy of difference makers. *Review of Philosophy and Psychology*, 11, 547–567.
- Fuchs, C. (2010). QBism, the perimeter of quantum Bayesianism. *arXiv: Quantum Physics*.
- Gardner, H. (1985). *The mind's new science*. New York: Basic Books.
- Godfrey-Smith, P. (2007). Information in biology. In D. Hull & M. Ruse (Eds.), *The Cambridge companion to the philosophy of biology* (pp. 103–119). Cambridge: Cambridge University Press.
- Godfrey-Smith, P. & Sterelny, K. (2008). Biological information. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*, <http://plato.stanford.edu/entries/information-biological/>. Accessed 28 April 2020.
- Griffiths, P. E. (2001). Genetic information: A metaphor in search of a theory. *Philosophy of Science*, 68, 394–412.
- Günter, G. (1963). *Das Bewusstsein der Maschinen: Eine Metaphysik der Kybernetik [the consciousness of machines: A metaphysics of cybernetics]*. Krefeld: Agis-Verlag.
- Hoffmeyer, J. (2002). The central dogma: A joke that became real. *Semiotica*, 138(1), 1–13.
- Hulswit, M. (2001). Peirce on causality and causation. In M. Bergman & J. Queiroz (Eds.), *The commens encyclopedia: The digital encyclopedia of Peirce studies. New edition*. <http://www.commens.org/encyclopedia/article/hulswit-menno-peirce-causality-and-causation>. Accessed 28 April 2020.
- Hume, D. (1748). *Philosophical essays concerning human understanding*. London: A. Miller.
- Ingthorsson, R. D. (2002). Causal production as interaction. *Metaphysica*, 3(1), 87–119.
- Ingold, T. (1990). An anthropologist looks at biology. *Man, New Series*, 25(2), 208–229.
- Ingold, T. (2001). From the transmission of representations to the education of attention. In H. Whitehouse (Ed.), *The debated mind: Evolutionary psychology versus ethnography* (pp. 113–153). Oxford: Berg.
- Jablonka, E. (2002). Information: Its interpretation, its inheritance, and its sharing. *Philosophy of Science*, 69, 578–605.
- Johansson, L. G. (2009). Causation: A synthesis of three approaches. In S. Alice, J. Stuart, & G. D. Crnkovic (Eds.), *Computation, information, cognition: The nexus and the liminal* (pp. 75–86). Newcastle: Cambridge Scholars Publishing.
- Jordan, J. S. & Day, B. (2015). Wild systems theory as a 21st century coherence framework for cognitive science. In T. Metzinger & J. M. Windt (Eds.), *Open MIND: 21(T)*. Frankfurt am Main: MIND group.
- Jordan, J. S., & Vinson, D. (2012). After nature: On bodies, consciousness, and causality. *Journal of Consciousness Studies*, 19(5/6), 229–250.
- Josephson, B. (2017). Incorporating meaning into fundamental physics. Lecture given at the Frontiers of fundamental physics 15, Miguel Hernández University, Spain. <https://sms.cam.ac.uk/media/2657924>. Accessed 28 April 2020.
- Juarrero, A. (1999). *Dynamics in action. Intentional behavior as a complex system*. Cambridge: MIT Press.
- Kim, J. (1999). Making sense of emergence. *Philosophical Studies*, 95, 3–36.
- Kim, J. (2006a). Emergence: Core ideas and issues. *Synthese*, 151, 547–559.
- Kim, J. (2006b). Being realistic about emergence. In P. Clayton & P. Davies (Eds.), *The re-emergence of emergence* (pp. 189–202). New York: Oxford University Press.
- Korn, R. W. (2005). The emergence principle in biological hierarchies. *Biology and Philosophy*, 20, 137–151.

- Laland, K. N., Odling-Smee, J., Hoppitt, W., & Uller, T. (2013). More on how and why: Cause and effect in biology revisited. *Biology and Philosophy*, 28, 719–745.
- Levy, A. (2011). Information in biology: A fictionalist account. *Noûs*, 45(4), 640–657.
- Longo, G., Miquel, P. A., Sonnenschein, C., & Soto, A. M. (2012). Is information a proper observable for biological organization? *Progress in Biophysics and Molecular Biology*, 109(3), 108–114.
- Lycan, W. G. (1996). *Consciousness and experience*. Cambridge: MIT Press.
- Macdonald, C., & Macdonald, G. (2010). Emergence and downward causation. In C. Macdonald & G. MacDonald (Eds.), *Emergence in mind* (pp. 139–168). Oxford: Oxford University Press.
- Maturana, H. R., & Varela, F. J. (1980). *Autopoiesis and cognition: The realization of the living*. Dordrecht: D. Reidel.
- McCulloch, W., & Pitts, W. (1943). A logical calculus of the ideas immanent in nervous activity. *Bulletin of Mathematical Biophysics*, 7, 115–133.
- Merleau-Ponty, M. (1962). *The phenomenology of perception*. C. Smith (trans.). New York: Routledge.
- Merleau-Ponty, M. (1963). *The structure of behavior*. A. L. Fisher (trans.). Boston: Beacon press.
- O'Connor, T., & Wong, H. Y. (2005). The metaphysics of emergence. *Noûs*, 39, 658–678.
- O'Connor, T., & Wong, H. Y. (2020). Emergent properties. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*, <https://plato.stanford.edu/archives/spr2020/entries/properties-emergent/>. Accessed 28 April 2020.
- Okasha, S. (2011). Emergence, hierarchy and top-down causation in evolutionary biology. *Interface Focus*, 2, 49–54.
- Peters, J. D. (1988). Information: Notes toward a critical history. *Journal of Communication Inquiry*, 12(9), 9–23.
- Pharoah, M. C. (2018). Qualitative attribution, phenomenal experience and being. *Biosemitotics*, 11, 427–446.
- Piccinini, G., & Scarantino, A. (2010). Computation vs. information processing: Why their difference matters to cognitive science. *Studies in History and Philosophy of Biological and Biomedical Science*, 41, 237–246.
- Prakash, C., Fields, C., Hoffman, D. D., Prentner, R., & Singh, M. (2020). Fact, fiction, and fitness. *Entropy*, 22, 514.
- Rescher, N. (1982). *A coherence theory of truth*. Lanham: University Press of America.
- Riedl, R. (1997). From four forces back to four causes. *Evolution and Cognition*, 3(2), 148–158.
- Rothschild, L. J. (2006). The role of emergence in biology. In P. Clayton & P. Davies (Eds.), *The re-emergence of emergence* (pp. 189–202). New York: Oxford University Press.
- Rosen, R. (1991). *Life itself: A comprehensive inquiry into the nature, origin and fabrication of life*. New York: Columbia University Press.
- Rosenblueth, A., Wiener, N., & Bigelow, J. (1943). Behavior, purpose and teleology. *Philosophy of Science*, 10(1), 18–24.
- Roth, R. J. (1985). Did Peirce answer Hume on necessary connection? *Review of Metaphysics*, 38(4), 867–880.
- Russell, B. (1912). *The problems of philosophy*. London: Williams & Norgate.
- Salthe, S. (1993). *Development and evolution: Complexity and change in biology*. Cambridge: MIT Press.
- Santaella-Braga, L. (1999). A new causality for the understanding of the living. *Semiotica*, 127(1/4), 497–519.
- Sarkar, S. (1996). Biological information: A skeptical look at some central dogmas of molecular biology. In S. Sarkar (Ed.), *The philosophy and history of molecular biology* (pp. 187–231). Dordrecht: Kluwer Academic Publishers.
- Savan, D. (1988). *An introduction to C.S. Peirce's full system of semeiotic*. Toronto: Toronto Semiotic Circle.
- Searle, J. (1980). Minds, brains, and programs. *Behavioral and Brain Sciences*, 3, 417–424.
- Searle, J. (2013). Can information theory explain consciousness? *New York review of books*, January 10. <https://www.nybooks.com/articles/2013/01/10/can-information-theory-explain-consciousness/>. Accessed 28 April 2020.
- Seibt, J. (2018). Process philosophy. In E. N. Zalta (Ed.), *The Stanford encyclopedia of philosophy*, <https://plato.stanford.edu/archives/win2018/entries/process-philosophy/>. Accessed 28 April 2020.
- Sharov, A. A. (2010). Functional information: Towards synthesis of biosemiotics and cybernetics. *Entropy*, 12(5), 1050–1070.
- Simon, H. A. (1978). On the forms of mental representation. In C. W. Savage (Ed.), *Perception and cognition: Issues in the foundations of psychology* (pp. 3–18). Minneapolis: University of Minnesota Press.
- Stegmann, U. E. (2005). Genetic information as instructional content. *Philosophy of Science*, 72, 425–443.
- Steward, H. (1997). *The ontology of mind: Events, processes, and states*. Oxford: Oxford University Press.
- Steward, H. (2012). Actions and processes. *Philosophical Perspectives*, 26, 373–388.
- Stoffregen, T. (2000). Affordances and events. *Ecological Psychology*, 12, 1–28.

- Stonier, T. (1990). *Information and the internal structure of the universe: An exploration into information physics*. London: Springer.
- Stonier, T. (1991). Towards a new theory of information. *Journal of Information Science*, 17, 257–263.
- Stonier, T. (1996). Information as a basic property of the universe. *Biosystems*, 38(2/3), 135–140.
- Sukhoverkhov, A. (2010). Memory, sign systems, and self-reproductive processes. *Biological Theory*, 5(2), 161–166.
- Thelen, E., & Smith, L. B. (1994). *A dynamic systems approach to the development of cognition and action*. Cambridge: MIT Press.
- Torrance, S., & Froese, T. (2011). An inter-enactive approach to agency: Participatory sense-making, dynamics, and sociality. *Humanamente*, 15, 21–53.
- Tye, M. (1995). *Ten problems of consciousness: A representational theory of the phenomenal mind*. Cambridge: MIT Press.
- Ulanowicz, R. E. (1997). *Ecology, the ascendent perspective*. New York: Columbia University Press.
- van Cleve, J. (1990). Mind-dust or magic? Panpsychism versus emergence. *Philosophical Perspectives*, 4, 215–226.
- Vehkavaara, T. (1998). Extended concept of knowledge for evolutionary epistemology and for biosemiotics: Hierarchies of storage and subject of knowledge. In G. L. Farré & T. Oksala (Eds.), *Emergence, complexity, hierarchy, organization* (pp. 207–216). Espoo: Finnish Academy of Technology.
- von Foerster, H. (1981). *Observing systems*. Seaside: Intersystems Publications.
- von Neumann, J. (1945). *First draft of a report on the EDVAC*. Moore School of Electrical Engineering, Philadelphia, University of Pennsylvania. https://www.wiley.com/legacy/wileychi/wang_archi/supp/appendix_a.pdf. Accessed 28 April 2020.
- Warburton, N., & Dennett, D.C. (2013). Daniel Dennett on the Chinese room. *Philosophy Bites*. <http://philosophybites.com/2013/06/daniel-dennett-on-the-chinese-room.html>. Accessed 28 April 2020.
- Wiener, N. (1948). *Cybernetics, or control and communication in the animal and the machine*. Cambridge: MIT Press.
- Zoglauer, T. (1996). Can information be naturalized? In K. Kornwachs & K. Jacoby (Eds.), *Information: New questions to a multidisciplinary concept* (pp. 187–207). Berlin: Akademie-Verlag.

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.