Authors' Response

Complementarity of Symmetry and Asymmetry

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> Upshot • Gibsonian and enactivist thinkers appear to diverge primarily with respect to the emphasis placed on the contributions of the organism to perception-action. Enactivists claim that a fundamental asymmetry in the organism-environment relationship should be credited for the existence of meaning in the world. Gibsonians counter that theory must reckon with both the asymmetry and symmetry between organism and environment as well as with the role of specificational information in underwriting their coordination.

Introduction

« 1 » In the past decades, both ecological psychology and enactivism have grown and ramified to the point where it can be difficult to compare the approaches given their diversification and re-appropriation by researchers in disparate fields. But this does not imply that either approach has lost its solid theoretical foundations. Not surprisingly, perhaps, core principles have been sharpened in the face of what might be seen as peripheral adulteration. In this sense, it is correct, as **Dobromir Dotov** claims, that we assume (as do Mace 1977; Michaels & Palatinus 2014; Richardson et al. 2008; Shaw, Turvey & Mace 1982; Turvey & Carello 1981, 2012; Turvey et al. 1981) the position of "ambassadors" from an ecological "fortress." Judging by the commentaries, proponents of the enactive account show similar resolve. This strikes us as a positive circumstance, since the two approaches show commensurable conceptual depth. Our target article was intended to highlight the rigorous development of perception–action and organism-environment mutuality in James Gibson's ecological approach and, further, the centrality of specificational information to that development. Whereas the mutualities are embraced by enactivists, specificational information is not. We argued that this reluctance leads to enactivists' constructivist orientation, an orientation that seems at odds with their claim to be non-computational.

« 2 » While most commentators seem to defend a complementarity between the two approaches, their varied reactions press points more or less related to either

- the *asymmetry of organism and environment*,
- the *origin of meaning*, or
- the *nature of affordances*.

Although these three points are linked, we have separated them for better clarity in our response.

Asymmetry of organism and environment

« 3 » Our target article insists on the mutuality of organism and environment, a mutuality that raises the level of analysis to the ecosystem. It is safe to say that there is a very strong consensus in the commentaries regarding that fact. However, it has been repeatedly argued that our position fails to acknowledge important *asymmetries* between organism and environment that need to be accounted for. Namely, it is argued that organisms present some particular and special properties that deserve attention and that enaction might just be the right kind of (non-cognitivist) theory to account for those properties. Different commentaries see these organismic properties as sheer facts that require explanation, and thus they take the special attributes of organisms as an *explanandum*. Other commentaries use these special properties to explain some facts of perception, and as such they advance the asymmetrical attributes of perceivers as an *explanans*.

Organismic attributes as explanandum

« 4 » In his commentary, **Manuel Heras-Escribano** expresses his worry that ecological psychology is "rejecting subjectivity instead of naturalizing it." Subjectivity is indeed a proverbial property of individuals and not of larger complexes such as ecosystems. As **Marek McGann** notes, what is crucial about subjectivity is that it refers to the *singularity* of every perceptual happening from a first-person perspective. For instance, every individual perceives whether a door affords passing through from a singular perspective and contextual setting. **Andrea Schiavio** and **Konrad Werner** recast this idea in phenomenological terms. According to them, phenomenology shows that the world is never perceived as "a brute fact detachable from our conceptual framework." Philosophically, this is known as "intensionality" (with an "s"), viz. the fact that we perceive the world *as*, that is, in one way rather than another. It has already been claimed that intensionality constitutes an insurmountable challenge to direct perception because it entails the existence of intermediate stages of perception (Fodor & Pylyshyn 1981). **Schiavio** and **Werner**'s points are different, though. **Werner** sees in Edmund Husserl's concept of "noema" a way out of dualism that is compatible at the same time with individual perspective. The noema is not a classical conceptual framework constituted by representations, but rather a mental structure that shapes and invites the world into our perception in particular ways. **Schiavio** does not explicitly appeal to representations of the world to account for intensionality either, but rather to active engagements, which of course depend on the singular properties of each organism's metabolism, neural structure, and thermodynamic constraints. Nevertheless, **Schiavio** insists that meaning is a dynamic act of construction mostly due to the organism-asymmetric properties, whereas **McGann**, for instance, states that acknowledging the individual histories is enough to account for singular perceptual relations, and that "no mental construction is needed." Yet history-dependent interactions require some kind of memory according to some commentators, which points to the process of learning as another asymmetrical feature of organisms. Thus, **Karim Zahidi** and **Jan Van Eemeren** see a point of divergence between ecological psychology and enactivism in the weight the latter assigns to neural processes of learning and of conscious experience. In this vein, **Heras-Escribano** argues for a complementarity of the two approaches. Thanks to the study of (asymmetric) neurodynamic realization of the sub-personal mechanisms of perception, enactivism can provide a naturalization of the subjectivity that ecological psychology takes for granted at the ecosystem level.

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Organismic attributes as explanans

« 5 » Perhaps an even stronger argument from the commentaries points to the *necessity* of the asymmetry to explain facts of perception that seem to challenge ecological psychology. **Peter Cariani**, for instance, remarks that perception of possibilities for action is never neutral but happens for the sake of realizing goal states of the individual. He thus proposes a cybernetic treatment of goal-directed activity. Insofar as the goal states are realized as mental states, they add more weight to the side of the organism, so to speak, thus enhancing the asymmetry. Similarly, **Dotov** claims that ecological psychology needs to bring in the asymmetry in order to account for the purposeful behavior of organisms. Therefore, emergent properties resulting from the action of organisms may as well be called sense-making, and without the ontological consequence of dualism that is denounced in the target article. **Mog Stapleton** appeals to the concept of *relevance*, namely the fact that organisms unilaterally decide which information is relevant. That process depends on agency, that is, an asymmetrical property of the organism. In short, as **Dotov** and **McGann** hold, there is a problem of *selection* from an otherwise overabundant source of information. In line with **Stapleton, McGann** and **Dotov**, **Ezequiel Di Paolo** proposes a way of interpreting the problem of relevance as that of "massive reduction of the inexhaustible potential sources of influence that can impinge on an agent to a rather limited set." This, he argues, requires a theory of agency and autonomy that enactivism seems to provide.

« 6 » All of these commentaries elucidate the enactive-ecological divide and deserve a more thorough treatment. However, we can only briefly suggest our conviction that some commentators have overstated or misunderstood the asymmetry between organism and environment. Importantly, the concept of ecosystem is defined in terms of the symmetry (mutuality) as well as the asymmetry (reciprocity) of organism and environment. Thus "the relationship between organism and environment must reflect their different functions in the ecosystem – a bipolar dimension over which they act and react in reciprocal but distinct ways that nevertheless fulfill one another" (Turvey & Shaw 1995: 153). The critical challenge lies in keeping the balance that allows asymmetrical properties to be articulated so as to ensure the symmetry that makes possible the existence of perception and action at the ecological scale.

« 7 » There is a body of research in ecological psychology that meets the challenge while addressing the asymmetries of organisms. Typically, the concept of affordance is complemented by that of *effectivity* (see below). More specifically, ecological psychology has paid considerable attention to the issue of motor coordination. Following Nikolai Bernstein's tradition, motor coordination has been approached from the perspective of the problem of degrees of freedom – very crudely, that the same behavioral outcome can be obtained through an immense, virtually open-ended number of different neuromuscular patterns and configurations (Turvey, Shaw & Mace 1978; Latash 2008). This problem has drawn ecological psychologists to the study of *synergies* (Turvey 2007), i.e., heterarchical neuromuscular assemblies that exploit interconnectedness and concinnity.[1] Synergies require the modulation of fewer parameters than degrees of freedom in order to bring about coordinated movement. The concept of synergy is directly linked to dynamical systems theory, which also models the way in which complex systems compress immense numbers of degrees of freedom into enslaving global parameters, as well as to thermodynamics since synergies are dissipative structures (Kelso 2009; Kugler, Kelso & Turvey 1980). Notice how these issues map onto what some commentators refer to as the problem of affordance selection. Affordance, however, deals with perception, whereas Bernstein's problem regards action. Turvey has suggested that these are in fact *dual*, that is, the problem of degrees of freedom is mirrored by that of degrees of constraint. Indeed, he has studied some compelling examples of how the perceptual system can contribute to the required reduction of degrees of freedom without having to appeal to computational or representational processes (Turvey 2007; Turvey & Fonseca 2014). Similarly, Robert Shaw has worked unrelentingly on an operationalization of the concept of effectivity as the physical control process that realizes an intention under the guidance of affordance-specific information (Shaw 2001; Shaw & Kinsella-Shaw 1988; Shaw & Turvey 1999; Turvey & Shaw 1995).

« 8 » The upshot is that from research on the dynamical coordination of movement emerges a conceptual framework that allows us to articulate concepts pertaining to both the environment and organism sides of the asymmetry as *commensurate* and thus at the same time *symmetrical*, as the ecosystem approach requires. That conceptual framework recasts the problem of putative selection as that of *constraining* energy flows. It does not ask "which mental entities allow a system to become autonomous in order to select those external features that are of interest to it," rather it asks "what dynamical constraints, embodied physically and asymmetrically over the ecosystem, modulate the emergence of such and such behavioral pattern?" For this purpose, the XYZO formalism (identified in the target article, originating with Turvey & Shaw 1979, and articulated most recently in Turvey 2015) also introduced an *occasion variable*, to refer generally to the set of critical contextual to "constraints. The occasion variable also contributes to the reduction of degrees of freedom during action-perception. Finally, degrees of freedom are fully constrained to produce a single behavioral outcome by generic thermodynamical principles that act as a "physical selection principle," as **Tehran Davis and Michael Turvey** state. This illustrates how **Cariani**'s objection that ecological psychologists prefer to locate explanatory factors in the environment to avoid mental entities is misplaced. We do not divide organism and environment into mental and physical respectively! Moreover, ecological psychology does not ignore "subpersonal" processes as **Heras-Escribano** claims, but the problem of dimensionality reduction is a formidable one and not every theory is able to meet the ecosystem challenge, which is why progress appears slow in that area of research. For instance, it is not clear why we should follow **Dotov** in adding the label "sense-making" to the process of dimensionality reduction unless we are already operating in a theory, such as enactivism, that overstates the asymmetry of organism and environment.

1 | "[T]he adaptive fit of parts of a system to each other and to the system as a whole" (Turvey & Fonseca 2014: 152)

« 9 » Learning constitutes, precisely, an appropriate example to see how constraints operate at the level of the ecosystem. Schiavio claims that "each cognitive system identifies a range of environmental constraints to be (en)acted upon and within. In doing so, it provides affordative (sic) structures to a world that would otherwise show up as meaningless." But what makes a system pick this instead of that constraint? Presumably, as Zahidi and Eemeren hold, we need to appeal to learning. However, learning is *not* a fully autonomous process where each agent chooses what to learn and what not. Learning is constrained by the environment. Interestingly, Cariani argues that learning constitutes a proof of perceptual construction because "neural systems are reorganized in response to *experience*" (emphasis added). For him, neural reorganization is causally implicated in its associated capacities. We agree that neural reorganization is certainly in the service of experience but it alone is not evidence for the existence of or an explanatory role for construction. Without the common basis provided by specificational information, for example, the convergence of joint perception and action would not be possible, as Davis & Turvey rightly point out?

« 10 » The idea is precisely that in learning, there is a process of *adaptation*. It is interesting that enactivism has a rather conflicted relationship with that concept, as Heras-Escribano and Manuel Pinedo remind us. Schiavio seems to make room for adaptation in a way that should meet the ecosystem challenge, e.g., as a property of the agent–environment closed loop. Yet it is telling that neither Schiavio, nor Di Paolo wish to make more of adaptation than a gradual anticipatory response to "perturbations." Indeed, Di Paolo's (2005) and subsequent enactivist treatments (e.g., Barandiaran & Moreno 2009; Froese & Stewart 2010) refer to the latter process as "adaptivity," since "adaptation" presupposes a pre-given world into which the agent fits. But then again, reducing environmental factors to a mere "perturbation" does not do justice to the fact that such factors are *structured* and *specifically* constraining.

« 11 » In short, we find the insistence on learning being a brain-bound process to be unjustified. A poplar leaf, for example, engages in defensive behavior when attacked by a caterpillar, and does so more quickly for a subsequent attack (Dicke, van Loon & Soler 2009). Learning seems not to require a nervous system. And far from being ignored by ecological psychology, learning is part and parcel of the approach, from the intuitions provided by James Gibson (1966) about the *education of attention* to the more formal *theory of direct learning* (Jacobs & Michaels 2007), whose development is very much grounded in the notion of specificational information. "[T]he overarching theme is that information alters and improves the fit of situations and actions at many timescales" (Michaels & Palatinus 2014: 27).

« 12 » What about autonomy and subjectivity? Is it possible to identify such properties at the ecosystem scale? Does an ecosystem have subjectivity and autonomy? If the concepts are to have any explanatory usefulness in perception, it must be (however counter-intuitive it sounds). The fact that organism and environment contribute asymmetrical constraints to the global, *end-directed* processes of perception-action does not entail that only organisms by themselves are autonomous. Both pieces of the puzzle contribute asymmetrically to the end-directed process of, in Davis & Turvey's words, "energy quality reduction." In response to questions concerning subjective attributes such as first-person perspectives and intensionality, there is reason to believe that the language of constraints can provide insight. For instance, it has been hypothesized that intensionality is a property of *non-holonomic* constraints (Kugler & Turvey, 1987), that is, constraints that are history-dependent with integrals that cannot be computed. Interestingly, these constraints are at the same time variant and invariant (cf. McGann). They are invariant in that they can be expressed by fixed equations of constraint, yet they are variant in that they emerge from the system's trajectory. We do not know if this response is enough to convince Dotov that ecological psychology has enough resources to tackle dimensionality reduction without sense-making, but it surely shows that the problem has not been ignored, contrary to his claims. In this vein, we suggest that Werner's rapprochement between Husserl's concept of noema and affordance be understood as constraints on perceptual information. Yet noema must also depend on environmental constraints. Possibly, Werner's suggestion that "things presenting themselves *make offers to subjects*" is in agreement with that last statement.

« 13 » Thus it seems to us that proposing ecological psychology and enactivism as complementary research programs focusing on different levels or parts of ecosystems is mistaken. As we insist in the target article, ecological psychology does not ignore the asymmetry of reciprocity and strives to articulate it with the symmetry of mutuality; enaction, in contrast, tends to downplay symmetry.

Origins of meaning

« 14 » A number of commentaries argue that ecological psychology cannot make sense of meaning without acknowledging the special sense-making properties of organisms. In other words, they argue that the origin of meaning is fundamentally unidirectional and, therefore, does not reflect the organism-environment (O–E) symmetry requirement of the ecosystem. But in so doing, they belie their own distaste for a pre-given, animal-neutral world. Again, we appeal to Gibson:

> "The world of physical reality does not consist of meaningful things. The world of ecological reality, as I have been trying to describe it, does." (Gibson 1979: 33)

Organisms across all phyla exhibit functionally specific variability; they perceive meaningful distinctions (Turvey & Carello 2012). Questions of origins – whether of meaning or intention or agency – must be grounded in first principles. Some ecological psychologists have argued that we need to develop a new field, intentional thermodynamics (Shaw & Kinsella-Shaw 2012), to do this justice. For present purposes, the organism does not add something that is outside of the O–E system to a situation or occasion. To be sure, the organism's personal history is part of the O–E system. Di Paolo agrees with this assertion in the sense that he posits no dedicated computational mechanism. But he ultimately disagrees with the ecological understanding of meaning by saying it

comes from the organism's intrinsic way of being, a view that reinforces the grave asymmetry.

« 15 » Similarly to Di Paolo, Stapleton holds that sense-making is the result of something "*intrinsic*" (emphasis added) to organisms. Thus Stapleton asks, for instance, what makes foraging behavior count as *foraging* rather than merely behaving as if it was foraging. There has to be something intrinsic to "genuine" foraging behavior, and that is a "need," Stapleton concludes. The ecological approach answers that foraging is genuine when it characterizes an ecosystem's dynamics, that is, when the behavior is embedded in an ecosystem. However, McGann is not satisfied by this answer as it merely pushes back the question from behavior to the ecosystem: "how it could be that a purely physical world could become an ecosystem, how a world without concerns can come to have them." As stated here, this question is circular. Indeed, McGann is already assuming that "concern" is what defines ecosystems in order to prove that purely physical worlds cannot be ecosystems because they lack concern. Yet a non-circular account of concern and how it introduces meaning is presumed to be available in considerable detail in the enactive framework. Di Paolo reminds us that sense-making is the result of autonomy and autonomy is an intrinsic property of a specific class of systems, namely adaptive autopoietic systems (Di Paolo 2005). By definition, autonomy is accompanied by *precariousness* and *viability*. Indeed, autonomous organisms are defined in terms of the active maintenance of their integrity. This implies semantically that they are concerned about their structural integrity and thus experience every interaction with the environment in a value-laden way, that is, as a function of whether the interaction contributes or not to the maintenance of their structural integrity. It is that value-referential way of interacting that "provides affordative (sic) structures to a world that would otherwise show up as meaningless" as Schiavio claims.

« 16 » In contrast to the autopoiesis-based enactive theory and in line with Davis & Turvey, we have defended the idea that ecosystems are intrinsically meaningful because they are grounded in thermodynamics (see also, and especially Swenson & Turvey 1991). However, what is offered as a crucial point against our thermodynamic approach to the origin of meaning is that, according to Di Paolo, dynamical descriptions cannot grasp the finitude and precariousness of material properties, but only approximate them. Similarly, McGann expresses his doubt that thermodynamics may suffice to provide a theory of the origin of meaning without "a defensible explanation of what makes agency agency, and how it can emerge from a world without it" (§21). Such emergence is precisely the point of "thermodynamic reasons for perception-action cycles" (Swenson & Turvey 1991).

« 17 » The problem, we think, is that some commentators – notably, not Davis & Turvey – underestimate the richness of modern thermodynamics. The commentators insist that meaning is made possible only thanks to agency. Yet agency in turn is impossible without the physical capacity to do work, that is, free energy. Free energy *per se* would count as no more than fuel if it were not for the fact that it is *end-directed* and *adaptive*, and that these are *intrinsic* properties. Lest this sound like ancient teleology or extreme anthropomorphism, free energy is not a creature with desires and beliefs figuring out how to make its way in the world. Nevertheless, the second law of thermodynamics states that free energy is *end-directed*, that is, it has the *intrinsic* property of tending to be dissipated along potentials (e.g., from a hotter body to a colder one) and the Law of Maximum Entropy Production (Swenson & Turvey 1991) states that it does so, intrinsically, in an adaptive way, that is, towards the paths that facilitate dissipation at the fastest rate given the constraints and compensating for departures from optimal dissipative regimes (see references in Davis & Turvey).

« 18 » Can we claim that free energy degradation is an autonomous process? In a sense it is, since its properties are not dictated from outside but intrinsic. However, this is not needed for our point. Autonomous systems add a further level of organization that facilitates energy degradation. Indeed, living autocatakinetic systems rely on an internal source of free energy in order to follow low-energy gradients, which in turn allow access to new, more distal, higher-order paths to dissipation (Swenson & Turvey 1991). From this point of view, the emergence of order and autonomy is paradoxically primary *and* secondary. It is primary in that it is necessary to ensure higher levels of energy degradation, yet secondary in that the main overarching goal is *not* the maintenance of autonomous integrity but precisely that of energy degradation. Even for the autopoiesis theory, perturbations become meaningful by virtue of the *goals* of the system, and not of its autonomous material integrity. In other words, the system could happen, by contingent reasons, to keep a material integrity, yet if it is not an intrinsic goal of the system to *stay* that way, adaptively (Di Paolo 2005), then no meaning emerges.

« 19 » So we claim that end-directedness is the more fundamental property responsible for the origin of meaning. For instance, some female octopuses renounce integrity once they lay their eggs. Their sole goal is to care for the eggs at the expense of their own integrity, in other words, they degrade their own free energy. Anything that conspires against that egg-caring is meaningful relative to that end state. Moreover, the notion of viability presupposes the need to maintain integrity, but the notion of precariousness does not – any end-directed process can fail. Following enactivists, thus, we could describe free energy as having a "concern" to be degraded, and to proceed adaptively so as to respond to perturbations that deviate that process from the optimal paths to its end state. As a consequence, self-sustaining systems are not concerned with their own integrity, which is a conservative principle, but with helping free energy be degraded at the fastest possible rate, which explains evolution and the increasing complexification and diversification of life forms on Earth (Swenson & Turvey 1991). To answer Stapleton, then, foraging behavior is "genuine" when it is functional to free energy degradation. Furthermore, the contributions of brains and/or nervous systems are to be understood in this context as well, not as contributors of meaning but as enhancing opportunities for maximizing the rate of entropy production.

« 20 » Therefore, because of their intrinsic directionality and adaptivity, ecosystems as special cases of thermodynamic systems, are meaningful; free energy is diversified and transformed thereby losing

progressively its capacity to do work. In ecosystems, far-from-equilibrium, autocatakinetic entities exploit low-energy patterns that are specific to structures that, in time, lead to more free energy degradation (Swenson & Turvey 1991). This fact addresses Zahidi & Van Eemeren's concern about meaningful information. Information, as low-energy structured patterns, is meaningful not because it is semantically contentful as in symbolic approaches, but because it specifies affordances that are opportunities for action *directed* ultimately towards faster degradation of free energy. Indeed, the notion of specificational information is missed, dismissed, or mischaracterized by a number of commentators. Specificational information is the linchpin for ecological psychology. With it, no loans of intelligence are needed, the organism is linked to the environment, and perception is mutually compatible with action. Missing specificational information is to miss the point.

« 21 » The problem for some commentators is that they see specificational information in an old stimulus–response framework, lamenting it as something the animal responds to (Stapleton); or that information is an "input," or is "processed" (Di Paolo); or that behavior is determined by information (Zahidi & Van Eemeren). Or commentators lose sight of the ecological insight that perception does not happen at an instant nor is it in the habit of producing percepts that then get clarified, or that information is complete at an instant (Zahidi & Van Eemeren). All of these are taken by enactivists as motivations for supplementing or supplanting ecological psychology with enactivism. But specificational information is none of these things. It is the invariant structure of (low) energy distributions lawfully structured by an animal–environment relation that, because of that lawfulness, specifies that animal–environment relation. As Davis & Turvey point out, this invariant structure is what allows joint action.

The nature of affordances

« 22 » So where does this leave the discussion regarding the pivotal Gibsonian concept of affordance? Can it serve as the bridge that brings ecological psychology and enactivism together? The answer to this question depends on whether the meaning of affordances is taken to be *intrinsic* or organism-dependent. There does not seem to be a consensus on this among commentators, though. Pinedo and Werner are more sympathetic to the idea that the meaning of affordances is intrinsic (i.e., dispositional) and observer-independent, although with some reservations. Dotov and Stapleton seem to hold an intermediate position and argue that affordances are emergent from organism-environment transactions yet they do not subscribe to the hard constructivist position that the *agent* makes all the sense. Di Paolo is more inclined to the idea that sense-making is a feature of the organism and thus meaning is derived from the latter. How do the considerations regarding symmetry/asymmetry and thermodynamics bear on issue of affordances?

« 23 » Consider once more the sucrose example. Di Paolo holds that our position about sucrose being *intrinsically* a nutrient is untenable because we cannot know in advance all the complex, open-ended ways in which potential organisms with different structures could exploit sucrose as a nutrient. Although we agree completely that *knowing* in advance the possible ways sucrose could afford being consumed is intractable, we must signal Di Paolo's mistake in conflating an *epistemic* limitation with an *ontological* one. The fact that we cannot know how sucrose can operate as a nutrient is entirely independent from its capacity to do so. For all we know, there might be strange microbes many light years from here consuming sucrose in very strange ways. Werner suspects that there are limiting cases where affordances could not exist, such as the Big Bang, and he doubts that sucrose would still be a nutrient when no extant creature would be there to consume it. The "distance," so to speak, between the potential event and its realization matters, and the larger the distance, the smaller the potentiality. The trouble with this is that it seems to conflate possibility with probability. It is akin to the objection that everything can potentially do anything, given enough time to reunite the adequate conditions. But sucrose as a nutrient depends in particular on the amount of work it can do, and there is a boundary to that. In a similar way, Stapleton defends Anthony Chemero's (2009) interpretation of affordance as similar to the property of "being lovely." This property depends on there being at least one extant individual *able* to perceive the affordance. But this definition, too, runs into trouble when we consider a continuum in the ability to perceive. What if the perceiving individual has bad sight? Or if she does not exist yet but some other individual or process has plans to create her? And so on.

« 24 » Pinedo agrees that affordances are better seen as observer-independent properties, yet he warns against some ontological pitfalls concerning *possibilia*. In particular, if sucrose is a nutrient, it is a nutrient to an open-ended number of "possible" beings. If being a nutrient is defined in relation to those *possibilia* then apparently our ontology is all of a sudden inflated with infinite elements. But the ecological position is simpler than that. Consider a concave lens. The concave shape of its surface exists here and now. Now it may be the only lens in the universe, yet the concavity, as a shape, in some way implies its complementary shape, namely the convex shape. The concave lens is complementary to a convex lens even if the latter never existed nor would exist. The digestion of sucrose is performed precisely thanks to a convex/concave complementarity. Enzymes such as suc*rase* are used to catalyze sucrose hydrolysis by exploiting the complementary shape and polarity of the enzyme's active site, which binds to sucrose thereby exposing the oxygen bond between glucose and fructose to the lytic action of H2O (Malone & Dolter 2008). Given sucrose's free energy content and its geometry, a restricted subset of potential digesters is implied by complementarity, even if they do not exist. Perhaps another way to express this is that sucrose "invites" a suitable digester even though there is none available to receive the invitation.

« 25 » Sucrose, under the ecological formalism, can be seen as an organism-referential nutrient. However, the symmetrical view also holds: the organism is a sucrose-referential digester. The meaning of affordances, we have argued, is grounded in the ultimately thermodynamical significance of O–E mutuality: An ecosystem is a far-from-equilibrium system, where the offerings of the environment dynamically constrain and are constrained by the capacities of the organism so as to, ultimately,

increase the overall rate of entropy production. The enactive account of meaning fails to express this symmetry: the organism makes sense of sucrose as a nutrient from its first-person experience, yet nothing can be said to make sense of the organism, not even natural selection since adaptation is rejected by enactivism. Our challenge to enactivism thus consists of highlighting this incompleteness in their account of the origin of meaning and emphasizing the end-directedness and adaptivity of the ecosystem as a whole.

Conclusion: Towards detente?

« 26 » A major disquieting feature of ecological psychology for enactivists seems to center around our downplaying of phenomenal experience. It should be noted, however, that much of what was insightful in Gibson was, in fact, based on thorough, rather hard-headed phenomenology – flow fields, surfaces, surface arrangements and, especially, occlusion, all abide by a first-person perspective. Nonetheless, our broad-based approach to perception-action for all organisms encourages a de-emphasis of conscious experience. But in no way does this downplay the significance of the animal, including its history at all time scales. The concepts of *effectivity* and the *occasion variable* (in the XYZO formalisms) are two theoretical terms that some ecological psychologists introduced to address the role of the animal. As already mentioned, Shaw (Shaw & Kinsella-Shaw, 1988; Shaw & Turvey, 1999; Shaw 2001; Turvey & Shaw, 1995) has been developing the concept of effectivity as an "actualizing process" of affordance goals. Along the way of multiple realizations of an affordance goal lies the discovery of effectivities. In this sense, effectivities are not dispositions, but are completely in line with the notion of constraints discussed above. Until the appropriate conceptual and technical tools are available, ecological psychologists are loath to wade in headlong. Nonetheless, relevant theoretical elaborations of these notions may be found in developments of the concept of smart perceptual instrument (Runeson 1977; Turvey & Carello 2011). Effectivity has had appeal in the domain of developmental research (e.g., Rochat, Goubetb & Senders 1999; Zukow-Goldring & Arbib 2007). And recent experimental forays can be found in research on intentional exploratory dynamics (Riley et al. 2002), affordance transitions (e.g., Lopresti-Goodman, Turvey & Frank 2009), and tool use in dynamic touch (Wagman & Carello 2003). With respect to tool use, for example, we might say "on the occasion that I need to pound something, I alter my relation to an object so as to effect pounding."

« 27 » We are being drawn to the conclusion that effectivities and the occasion on which they are manifest may hold the key to a better understanding between ecological psychology and enactivism. Indeed, as highlighted by some commentators, phenomenological research may offer important insights into concepts that have been underdeveloped in the ecological camp. In effect, we are suggesting that enactivism has already been directed at an aspect of the ecological approach, viz., the effectivity complement of the XYZO formalism:

> "Organism Z *effects* activity *Y* in situation *X* on occasion *O* if and only if *Z* and *X* are mutually compatible on dimensions of relevance to *Y*." (Turvey 2015: 29)

« 28 » Enactivists see occasions and the particular effectivities they encourage as necessary but missing from ecological psychology. Ecological psychologists see occasions and effectivities as necessary and present in ecological psychology. But they also see them as in need of fuller *principled* development. A number of commentators emphatically suggest that such a principled development is already going on in enactivist theory yet, as we have argued, there are good reasons for keeping our distance from the enactive principles of autopoiesis (see **Davis & Turvey**) and sense-making. For us, a principled development cannot undermine ecological realism (for which we appeal to delineations of our "fortress" found in, for example, Michaels & Palatinus 2014; Richardson et al. 2008; Turvey & Carello 1981), and must rest on thermodynamic principles. We are willing to be patient and would welcome the efforts of those who are similarly committed to perception–action mutuality by organism-environment systems.

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