« 13 » We believe that taking this road might save some forms of EP from some troublesome worries. For example, in order to avoid falling back on some "impoverished stimulus"-type of psychology, some ecological psychologists, such as Michael Turvey, have swayed in the opposite direction, postulating an ultra-information-richness of the media (light, air, etc.) around us (cf. Chemero 2009: 106f). Here, the structure of the optical array determines completely the (behavioral) meaning of the object: there is no ambiguity possible. However, Rob Withagen and Anthony Chemero (2009) have challenged this view on evolutionary grounds. If we think of the information in the optical array not in a semantic way but as a certain correlation, which can be very strong or only moderate, between that structure and the meaning of the object then we can move away from the idea that the array-structure determines (or as ecological psychologists say "specifies") meaning (i.e., the correlation between the two is one).

« 14 » This is not to say that the stimulus is impoverished and needs to be worked on to be enriched. It merely allows for information available through the optic array to specify affordances not fully. That does not imply a need for it to be supplemented through some type of mental construction. The organism can find out the affordances of the object by interacting with it. When the available (optic) invariant co-varies only moderately with the affordances, so to say, the history of interaction, in this case learning history, explains the organism's improved adjustment to its situation. No semantic information or enrichment is implied, because the sedimentation of the historical interactions, as we called it, is characterized as a bodily change, and not as an informational process.

« 15 » To conclude, let us try to answer our question in the title with respect to the two points discussed in this commentary. Firstly, with respect to the question of neural structures, we suspect that, despite the pronouncements made in the target article, neural structure is important in the explanation of at least some perceptual phenomena. That Fultot et al. deny that, so we have argued, is due to the fact that they are not primarily concerned with these aspects. If this interpretation is correct, then EP and REC are complementary. With respect to the use of semantic notions, we have argued that these can be banned from EP without loss of explanatory power. If our interpretation is correct, EP and REC are not incompatible.

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Learning of New Percept-Action Mappings Is a Constructive Process of Goal-Directed Self-Modification

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> Upshot • In my view, the clash between ecological psychology, enactivism, and constructivism in general has more to do with irreconcilable metaphysical and theoretical incommensurabilities (ontologies, epistemologies, modes of explanation) than disagreements about specific mechanisms or processes of perception. Even with mutual enabling of action and perception, some internal process of self-modification (neural construction, learning) is still needed if novel behavior is to be adequately explained.

« 1 » In their target article, Martin Fultot, Lin Nie, and Claudia Carello present a critique of enactivism and constructivism from the perspective of the Gibsonian ecological theory of direct perception.

« 2 » Ecological psychology focuses on animal–environment relations that permit animals to directly perceive those structures of their environments that are directly related to their goals. In contrast to indirect perception, in which the external world is inferred from elaborate operations on meaningless, atomic sensory elements, direct perception is thought to occur by selecting appropriate observables and sets of dynamical constraints that solve the problem at hand. The mechanisms of direct perception exploit the richness of the sensory flux and action space, which permit percepts and actions to be coordinated and realized with a minimum of internal complexity. A paragon of such a process is the "smart machine," a simple analog device that can perform seemingly complex operations in an elegant manner (Michaels & Carello 1981). Generally speaking, the ontological framework of ecological psychology is materialist, direct realist, and physics-reductive, tending towards a eliminativist-materialist attitude with respect to mental and conscious states. Ecological psy-

chologists reject representational and computational theories of mind based on symbolic representations and algorithms that operate on them (Carello et al. 1984). Rather than assuming "the poverty of the stimulus," a tenet of symbolic cognitivism, Gibsonians point to the richness of the sensory flux, its highly structured nature and tight coupling to action, and the availability of a wide range of observables that permit reliable, effective control and straightforward, uncomplicated realizations of action-goals. Action reveals new percepts, and new percepts reveal new actions. This is what I take to be meant by "percept-action mutuality."

« 3 » The core concept of constructivism entails agents that modify themselves, thereby changing their relationship to their environments. In Piagetian psychological constructivism, new mental structures (concepts) are formed through ongoing learning processes that take place amidst iterated sensorimotor transactions with an external environment. In my view, all learning is goal-directed self-construction (self-modification), in which neural systems are reorganized in response to experience. One can envision this reorganization in terms of relatively simple changes, such as establishment of new neural linkages, that need not necessarily involve complex, elaborated mental structures of the symbols-and-rules variety.[1] The radical constructivism of Ernst von Glasersfeld is an epistemology of self-constructing, but limited, observers. Enactivism holds that action is primary, but also that meaning is constructed by an actor (who enacts a world). Enactivism is therefore a constructivist psychological theory, albeit with a different, more externalized, emphasis than Piagetian constructivism. Francisco Varela, Evan Thompson and Eleanor Rosch (1991; Thompson & Varela 2001) proposed an enactivist theory based on Buddhist ontology that includes a neurophenomenological component that attempts to link the structure and contents of first-person subjective awareness with patterns of neural activity.

« 4 » Both ecological psychology and enactivism are opposed to the theories of mind based on symbols-and-rules that pervaded symbolic AI, analytic philosophy, linguistics, and many sectors of cognitive science in the last half of the twentieth century. These theories drew heavily on disembodied, Platonic possible-world ontologies and digital computer metaphors, asserting the primacy of logic and reason, internal symbolic representations, and algorithmic operations to the exclusion of interactions with external, non-symbolic environments. Ecological psychology, on the other hand, entirely rejected the computer metaphor, the poverty-of-the-stimulus dogma, and most notions of internalist, mental structures and instead focused on interactions between animal and environment within iterated percept-action cycles. The turn towards embodied and embedded cognition, which considers how brain, body, and world interact to codetermine behavior, are moves toward externally-directed action and away from the Platonic solipsism of disembodied symbolic representational structures. Enactivism can be seen in similar terms, as a middle-ground attempt to incorporate both internalist, constructed mental structures and externalized perception and action.

« 5 » Much of the disagreement is that ecological psychologists want to keep all of the processes and variables as part of a unified animal–environment system (or ontology), whereas the enactivists are interested in internal mental and phenomenal processes in addition to action (behavior). This leads the enactivists to accuse the Gibsonians of leaving the goals and internal deliberations of the animal out of the picture (§20), and the latter to protest that these are already incorporated into their concept of affordance in their universal animal–environment description (e.g., §13).

« 6 » What is at stake is whether to describe perception and action in universal terms of general animal–environment situations or in terms of specific semi-autonomous, goal-seeking agents operating in complex, ill-defined, and partially-accessed environments. I find the language of cybernetics, i.e., of purposive, goal-seeking percept-action systems, much more intuitive and straightforward (Cariani 2011, 2015). Purposes (system-goals) are at the root of affordances. Embedded in the Gibsonian concept of affordance is the function or purpose or end-state that a given action-possibility affords. "They define what the environment *affords* the animal; affordances are what the environment means to the animal" (§10). To be explicit, they, affordances, are what the environment means in terms of fulfilling the animal's goals. Actions are not pursued for the sake of themselves, they are pursued for the sake of realizing some desired end state. Translating into cybernetic terms, an affordance is a goal-attaining action-alternative. Animals have embedded goal-states of different immediacies that range from maintaining physiological homeostasis (oxygenation, hydration, nutrition) to avoiding harm to mating to exploring their surrounds. These goals are in constant competition with each other to determine which actions will be taken at any given moment.

« 7 » If one regards these goal states as internal mental states, which seems reasonable enough if one ascribes to the animal some degree of autonomy and self-direction, then the affordances pursued in a given situation depend in great part on the internal state of the animal-actor. A thirsty animal searches for water, a hungry animal for food, a ruttish animal for a mate, a curious animal for novelty. In my view, the actual behavior of the animal in a given situation is contingent on

- which internal goals currently predominate,
- which action-alternatives are available in the situation itself, and
- which affordances with their associated action-alternatives are recognized by the animal to be available in the immediate situation.

« 8 » My suspicion is that these are the same sets of contingencies that are already utilized in Gibsonian theory, albeit wrapped up in different, more indirect, terms (§13) such as situations, activities, occasions, and dimensions of relevance.

« 9 » An animal acts when there is a motive and when actions that are perceived as likely to fulfill the motive present themselves. If the animal fails to recognize that there is a means available of achieving its

1| Part of the problem is that despite its title, "mental construction" and "percept-action mutuality" are not ever clearly defined in the target article. The apparent assumption made in §18 is that constructive processes are necessarily complex and involve elaboration rather than selection. Even in the discussion of constitutive construction (§§30–34), no concrete psychological or neural examples are entertained.

current goals, then in effect that possible action-alternative is not actualized – the animal will very likely not pursue that behavior. In cybernetic terms, James Gibson's *effective stimulus* (§11) satisfies an internal goal that is currently salient such that it drives behavior, whereas a *potential stimulus* is not goal-driven and is therefore ineffective in changing behavior.

« 10 » Gibsonians, because they desire one physical description of the animal–environment system and because they scrupulously avoid appeal to internal "mentalist" mechanisms, would still want to locate these goals in the environment and not in the internal mental state of the animal-actor. Perhaps most of the objections that the authors lodge against the enactivists here involve whether to differentiate animal and environment (vs. properties of the animal–environment whole) and whether to locate attributes in the animal itself or in the animal–environment situation (§13). In order to locate these attributes in the animal–environment whole, I think one would need to define an affordance in a given situation in terms of perceived availability of action-alternatives for a particular animal that fulfill particular goals (§13).

« 11 » The ecological psychologists see little or no value in theories of mental process or neural action (§§16f), let alone phenomenology (§52).[2] They argue (and I wholeheartedly agree with them) that there can be theories of purposive, end-directed action that do not depend on neural systems, and that general, systems-theoretic conceptions of purpose, intentionality, agency, and goal-seeking behavior are desirable. However, the point of this assertion (with which I strongly disagree) seems to be that there is no specific reason to study nervous systems as paradigms for goal-directed behavior, and that there is nothing to be learned from doing so.

« 12 » Purposive systems need not be neurally-embodied (e.g., plants, §17), but the appearance of nervous systems was a major leap forward in the evolution of animals with complex behaviors. Where would we be without brains? In cybernetic terms, a purposive system is a control system with embedded goal states and means of altering internal organization so as to create behavior patterns that more reliably attain system-goals. In purposive, percept-action systems, changes in internal organization link particular percepts to particular actions. In natural settings, food sources and tactics for finding food or hunting prey can change rapidly, and experimental psychology is replete with countless conditioning-extinction-conditioning demonstrations in which animals flexibly change their mappings of percepts to actions to adapt to new stimulus-reward contingencies. Neural coordination of behavior permits rapid learning that exploits the richness of possible percept-action combinations.

« 13 » Both constructivist and ecological psychology theories need to explicitly incorporate concrete processes of learning alongside what is or can be learned. Mental construction itself is learning. Affordances can become perceptually accessible to an organism by means of learning processes, and new action-alternatives can be created via acquisition of new motor skills. This is the whole point of learning, to create newly accessible avenues for action that realize goals. An animal can learn to perceive affordances, by trial-and-error actions or by observation. In trial-and-error learning, the affordance is not perceived initially, but the animal by happenstance behaves in a manner that brings reward (goal satisfaction) such that the action-reward connection comes to be perceived. In the case of learning through observation, the action-reward connection is made visible and explicit. Recent wildlife footage provides a very good example of this process.[3] Here, a moose calf observes its mother feeding and learns the affordance that plants with essential nutrients can be found on lake bottoms, hidden below the water's surface. The calf eventually learns to venture into the water, and then to dive down to reach plants on the bottom. Learning through observation of successful behaviors can occur whether the mother moose cow intends to demonstrate the affordance to the calf or whether she unintentionally provides an example of the tactic in the course of her own foraging.

« 14 » This process of learning to perceive affordances is a process of construction in which effective sensory observables are linked to specific goal-signals and appropriate actions (a new percept-action linkage has been formed that enables new behaviors). Without incorporation of (even hypothetical) mechanisms of neural construction in which new linkages between existing percepts and actions can be fixed, ecological psychology theories cannot explain how new behaviors arise, such that access to additional affordances can be added to existing behavioral repertoires.

« 15 » To conclude, in my opinion, much of the divide between ecological psychologists and enactivists is created and maintained by deep, probably irreconcilable, differences of a philosophical (direct realist vs. perspectivist ontologies, meaning in the environment vs. meaning in the head) and theoretical nature (internalist-constructivist vs. externalist-direct perception theories of behavior). Despite these barriers, and in spite of some of the criticisms levelled here, I think that the enactivists have incorporated in their thinking many Gibsonian insights regarding the processes by which goal-relevant information can be elegantly extracted from sensory environments rich in percept-action possibilities.

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2| I think every theory needs to be able to demarcate its own scope, and like Watsonian behaviorism a century ago, ecological psychology has every right to restrict itself to explaining overt behavior and to avoid consideration of internal mental processes. However, considerable lasting damage, in the form of foreclosed avenues of investigation, can be caused when whole general areas of scientific study are dismissed out of hand for the wrong reasons.

3| See PBS documentary "Moose: Life of a twig eater." by Susan Fleming, 2016, http://www.pbs.org/wnet/nature/moose-life-of-a-twig-eater-full-episode/13815, segment 16:39–20:30.