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Two open questions in the reformist agenda of the philosophy of cognitive science

Aurora Alegiani,[α] Massimo Marraffa[α] & Tiziana Vistarini[β]

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Abstract In this paper we carve out a *reformist* agenda within the debate on the foundations of cognitive science, incorporating some important ideas from the 4E cognition literature into the computational-representational framework. We are deeply sympathetic to this reformist program since we think that, despite strong criticism of the concept of computation and the related notion of representation, computational models should still be at the core of the study of mind. At the same time, we recognize the need for a liberalization of the computational and representational framework that can address deep dissatisfaction with the anti-biologism and radical internalism of classical cognitive science. However, reform is a difficult task, so in this article we focus on two open questions within the reformist agenda. The first concerns the possibility of combining mechanistic-computational and dynamical explanations. The second concerns related changes in the notion of representation and its use (with special attention to Andy Clark's radical predictive processing).
KEYWORDS: Continuum of Representational Genera; Enactivism; Predictive Processing; Radical Embodied Cognition Thesis; Representationalism

Riassunto *Due problemi aperti nell'agenda riformista della filosofia della scienza cognitiva* – In questo lavoro identifichiamo un'agenda *riformista* nel dibattito sui fondamenti della scienza cognitiva che incorpora alcune idee centrali provenienti dalla letteratura sulla cognizione 4E all'interno di una cornice computazionalista e rappresentazionalista. Tale agenda considera il quadro computazionalista e rappresentazionalista ancora imprescindibile ai fini dello studio integrato della mente e del cervello, ma ne persegue una liberalizzazione nell'intento di renderlo idoneo ad accogliere alcuni importanti spunti emersi dalla letteratura sulla cognizione delle 4E. Tuttavia, riformare è un compito difficile. In questo articolo ci concentriamo su due problemi aperti nell'agenda riformista. Il primo riguarda la possibilità di mettere assieme le spiegazioni meccaniciste e computazionaliste con quelle dinamiche. Il secondo riguarda i cambiamenti relativi alla nozione di rappresentazione e al suo impiego (con particolare attenzione all'elaborazione predittiva radicale di Andy Clark).
PAROLE CHIAVE: Continuum dei generi rappresentazionali; Elaborazione predittiva; Enattivismo; Tesi della cognizione incarnata radicale; Rappresentazionalismo

[α]Dipartimento di Filosofia, Comunicazione e Spettacolo, Università di Roma Tre, via Ostiense, 234/236 - 00146 Roma (IT)

[β]Dipartimento di Scienze Filosofiche, Pedagogiche ed Economico-Quantitative, Università degli Studi di Chieti-Pescara "G. D'Annunzio", via dei Vestini, 31 - 66100 Chieti (IT)

E-Mail: aurora.alegiani@uniroma3.it; massimo.marraffa@uniroma3.it (✉); tvista3@gmail.com

1 The radical embodied cognition thesis

BETWEEN THE 1950S AND 70S, cognitive science took on the intellectual and institutional structure that we today define as "classical". This occurred, however, at the cost of narrowing the disciplinary scope that characterized its gestation period. In fact, while this early phase was characterized by the dense interweaving of contributions from various fields of research (studies on artificial neural networks, symbolic artificial intelligence, Chomskyan linguistics, neuroscience, and psychology), in classical cognitive science, symbolic artificial intelligence established hegemony. Nevertheless, starting from the mid-eighties, cognitive science began to regain – and indeed expand – its original scope, extending in two directions.[1] On the one hand, it expanded *vertically*, toward the brain, leading cognitive neuroscience to assume the centrality that artificial intelligence had previously held. As part of this downward expansion, the emergence of subsymbolic connectionism was hailed by many as a paradigm shift.[2]

On the other hand, cognitive science has also expanded *horizontally*, toward the environment. This expansion resulted in a critical review of both the methodological individualism of classical cognitive science (it is not possible to study the mind by putting the physical and social environment in which it operates in brackets), and the metaphysical thesis according to which the mind depends only on the brain (mental processes are in the first instance control systems of a *body* that moves, acts and, by moving, retroacts on the brain and mind). Accordingly, a number of highly diverse research programs have adopted an *externalist* conception of explanation that is organically linked to a conception of cognition as embodied, embedded, enacted and extended – so-called "4E cognition".[3] This conception can be more or less radical.

A first form of externalism consists in the methodological thesis that an adequate understanding of cognitive processes requires study of the environment in which these processes take place.[4] This thesis is fully compatible with evolutionary computational psychology, which assumes that cognitive processes have been "designed" (by evolution or learning) for specific physical or social environments.[5]

A second form of externalism is the so-called "sensorimotor paradigm", a family of theories that share a critical stance towards computational theories of perception and classical computationalism in general. This paradigm also informs sensorimotor *enactivism*, a research program that can be characterized as today's updated version of the ecological perspective introduced by James J. Gibson. It takes the form of *radical* enactivism when it follows Gibson's ecologism not only in considering perception to be *constituted by* (not only dependent on) the possession of sensorimotor competence,[6] but also in subscribing to his critique of the concept of mental representation.[7]

This radicalization is certainly not mandatory. Sensorimotor enactivism can accord, within an ecological theoretical framework, some role to computational models, more or less consistently revised to make them congruent with the ecological point of view. But there have also been attempts to synthesize computationalism and ecologism in a different way, i.e., by trying to account, within the computational paradigm, for some theses from the Gibsonian school.

The idea of an integration of the computationalist and ecological theoretical frameworks is only of course possible if Gibson's ban on the notions of representation and computation is overturned. The first attempt in this direction was made by Ulrich Neisser, whose notion of *anticipatory schema* is much closer to the concept of representation in cognitive science than to the Gibsonian idea of direct extraction of invariants.[8]

On this track, Pierre Jacob and Marc Jeannerod's dual theory of vision tried to account for some aspects of ecologism within the computational paradigm.[9] The authors believe that a clear distinction should be made between vision-for-action and vision-for-perception, both characterized in terms of computations and representations. Vision-for-perception is realized in the ventral pathway and is conceived, in broad terms, according to Marr's framework. Vision-for-action is realized in the dorsal pathway; and it is here that some of Gibson's theses are computationally reinterpreted. For example, the viewing of affordances is reconceptualized as a modular computational process in which a visuomotor representation is constructed to function as a kind of anticipatory schema.

In this way, the computationalist can capitalize on an important point emphasized by Gibson's ecological psychology. The perceptual process can be understood as both that which allows us to control motor behavior and that which allows us to recognize objects; to neglect either aspect is to forego offering a complete account of perceptual activity. In particular, while it is true that we have historically favored the use of "perception" to denote the process that culminates in the formation of an empirical belief, it should be clear by now that this traditional linguistic usage inappropriately neglects the fact that perception is also a system of action control.

However, as already mentioned, sensorimotor enactivism claims to go far beyond the conclusion that perception is *also* an action control system, advancing the thesis that visual perception is a form of action that does not require construction of mental representations. This is the *radical* strand of enactivism; and when joined with that form of externalism that denies or tends to deny the existence of *a clear boundary between agent and environment*, it corresponds to what Clark has called "the radical embodied cognition thesis".[10]

The radical embodied cognition thesis is the outcome of a Kuhnian interpretation of the dynamical approach to cognition (sometimes referred to simply as "dynamicism"). The application of tools of dynamical systems theory to psychological phenomena has been presented as the advent of "a third contender" in the debate on the foundations of cognitive science.[11] In this connection, a standard reference is van Gelder and Port's *Mind as Motion*, a collective volume that was the first major presentation of the dynamical approach to cognition. According to the editors, «to see that there is a dynamical approach is to see a new way of conceptually reorganizing cognitive science as it is currently practiced».[12] Such reorganization takes a stand against not only classical but also connectionist computationalism – and this despite the fact that the connectionists were the first to apply dynamical systems theory to the study of cognition.[13] However, van Gelder and Port argue, the limit of connectionism lies in the use of dynamical systems tools within a paradigm that is still computationalist and representationalist, though in a brain-like variant. This is not enough for the dynamicists.

First, the dynamicist dissolves the boundary between the cognitive system and the system's environment. Coupling between the equations describing a cognizing system and those describing the environment gives rise to complex "total system" behaviors.[14] In this perspective, «the cognitive system is not just the encapsulated brain; rather, since the nervous system, body, and environment are all constantly changing and simultaneously influencing each other, the true cognitive system is a single unified system embracing all three».[15]

Second, the dynamicist cuts ties with mechanistic and computationalist explanations. The dynamicist expansion into the environment implies a very different explanatory model from the mechanistic one underlying vertical expansion. In the 1950s the early cognitivists' appeal to mechanistic explanatory strategy was the logical conclusion of the battle waged against behaviorism and mathematical psychology, which conceived of psychological explanation as the discovery of laws or mathematical regularities in behavior.[16] The dynamical approach, however, relaunches the covering law conception of explanation.[17] The dynamical analysis identifies the critical variables characterizing the state of a system and attempts to construct laws (a set of differential equations) to account for the system's trajectory through state space. The system can no longer be decomposed into subsystems (modules) that involve computations on representations. Consequently, the dynamical explanation is seen as incompatible with the explanatory style of the computationalist mechanism.[18]

So we have arrived at the radical embodied cognition thesis: to understand the complex interplay of brain, body, and environment we do not need either the concepts of internal representation and computation or the mechanistic decomposition of a cognitive system into a multiplicity of inner neuronal or functional subsystems; all we need are the analytic tools and methods of dynamical systems theory.[19] We think, however, that in this form the dynamicist project is not a third contender in the controversy on the foundations of cognitive science but, rather, the denial of the possibility of such a science. In other words, it is not "radical embodied cognitive science" but, rather, the confirmation of the current relevance of some *behavioristic* metaphysical and methodological challenges.[20]

Fortunately, this obituary for cognitive science has been opposed by a "reformist" perspective, according to which the computational and representational paradigm can be reconstructed making due allowances for «the environmental embedded, corporeally embodied, and neurally "embrained" character of natural cognition»,[21] without collapsing into the radical embodied cognition thesis.

2 A continuum of representational genera: An early continuist take

In pursuit of this reformist program, Andy Clark grafted the computational and representational framework onto a three-tiered explanatory strategy: (a) a *dynamical* explanation of the gross behavior of the agent-environment system; (b) a *mechanistic* account, describing how the components of the agent-environment system interact to produce the collective properties described in (a); and (c) a *representational* and *computational* explanation of the components identified in (b).[22]

This tripartite strategy (*minimal representationalism*) is then situated within the larger framework of *active externalism*. Unlike *semantic* externalism, where the mental contents of a subject depend on aspects of the environment which are clearly external to the subject's cognitive processes, active externalism asserts that the environment can play an active role in constituting and driving cognitive processes.[23]

In the wake of Gibson's ecologism, this environment is conceived by Clark as a complex of affordances, which are however the source of a particular variety of internal states, namely, *action-oriented representations*. Unlike the symbols of classical computationalism (prototypically, language-of-thought symbols), action-oriented representations are *personal* (in that they are related to the agent's needs and the skills that it has), *local* (in that they relate to the circumstances currently surrounding the agent) and *computationally cheap* (compared with David Marr's rich inner models of the visual scene).[24] Thus, Clark affirms, when the agent represents the environment as a complex of affordances, the type of internal states that are generated are representations that describe partial aspects of the world and prescribe possible actions and interventions.[25]

However, action-oriented representations are only one *genus* of representations. The concept of inner representations was introduced in cognitive science to account for cases in which a cognitive system must coordinate its behaviors with environmental features that are not always present and manifest to the system.[26] In such cases the cognitive system is able to decouple from the external environment and act in an offline fashion by creating some kind of inner item that stands in for the absent phenomena. These *inner stand-ins* are what cognitive scientists have termed "inner representations". Such cases of environmentally decoupled cognition are really a tough nut for the anti-representationalists to crack, since they are exclusively concerned with cases of "adaptive hookup", i.e., cases in which the inner states of a system must coordinate behaviors with specific environmental contingencies.[27] Such cases, however, cannot ground a *general* anti-representationalist argument since they are not sufficiently "representation hungry".[28]

In view of this, Clark replaces the classical notion of mental representation with *a continuum of representational genera*. At one end of the spectrum are inner states that border on simple causal correlation and environmental control. At the other end of the spectrum, we find the type of inner stand-in that allows us to deal with the representation-hungry problems. Between these two poles are the action-oriented representations.

According to Clark, therefore, depending on the coupling or decoupling between agent and environment, one must respectively appeal to the dynamical non-representational or the representational explanation. It can be objected, however, that this implies a division of labor between the two styles of explanation, and not their complementarity; as a result, they cannot be tiers (i) and (iii) of a single explanatory strategy, as Clark would like.

This ambiguity echoes in Clark's most recent proposal, which appeals to predictive processing to refine the reformist agenda. We return to this point in Section 4.

3 Integrating mechanistic and dynamical explanations

Clark's active externalism leaves another thorny question open: what role is there for the "highest" dynamical level, if we have already a mechanistic explanation of the interactions between the components of the global system? We understand that one can say that a certain type of system does not lend itself to mechanistic description, and so a dynamical model must be used; but we do not understand why, as Clark seems to suggest, we should (1) describe the global agent-environment system as a dynamical system and (2) describe the interactions between the components of the system with a mechanistic model: if the interactions between the components are describable in mechanistic terms, the reason for thinking of the global system in dynamical terms falls away.

The philosopher who has worked most on the prospects for the integration of dynamical modeling with mechanistic analysis has been William Bechtel.

In the ground-breaking *Discovering Complexity*, Bechtel and Richardson note that in the early stage of the process of developing mechanistic models scientists often assume that the processes they are considering are performed serially.[29] But when it is not possible for scientists to develop a linear model that is adequate for a phenomenon, they start to introduce feedback loops and other non-linearities in their attempts to develop adequate models. The outcome is what the authors define as "functionally integrated systems".

Again, as in the case of Clark's representationalism, a continuum emerges. At one end of the spectrum, we have *fully decomposable* (or *highly modular*) systems, which are composed of subsystems that are completely independent except for the mutual exchange of outputs.[30] If the interactions among the subsystems are weak but not negligible, the system is *nearly* decomposable. As the complexities of the interactions among parts increase, the explanatory burden shifts from the parts (or, more precisely, the interactions *within* subsystems) to their organization (i.e., the interactions *between* subsystems). Thus, we reach the other end of the spectrum, where we find *holistic* systems, whose components are functionally equivalent and hence interchangeable. In between the nearly decomposable systems and the holistic ones, there are the integrated systems. In these systems, unlike the holistic systems, it is possible to isolate different parts that make distinctive contributions but also give rise to a complex set of interactions that are nonlinear, and hence much stronger than those of a nearly decomposable system.

Now, Bechtel believes that psychobiological cognition occupies the intermediate space between near decomposability and holism, namely that of integrated systems.[31] This allows him to denounce as spurious the opposition between an ultra-modularist conception of the parts of biological mechanisms as totally isolated and a radically holistic view that rejects the very possibility of decomposing the mind-brain.[32]

Indeed, Bechtel considers the collection of studies by David van Essen and his collaborators – which provide an almost complete map of the areas of the Macaque monkey visual system – to be an exemplar of a *mechanistic* analysis of how the brain performs a cognitive function.[33] The researchers have identified over 30 different areas in the macaque visual cortex and more than 300 connections between these areas; and the tool-kit of dynamical analysis can be very useful for modeling this vast number of feedforward, feedback, and collateral connections. However, although these regions are highly interconnected, we can still determine what each area contributes to visual information processing. That is, it is not a holistic system, but an integrated one; and in an integrated system, mechanistic analysis «provides the foundation for dynamical analysis»[34] since the latter has explanatory force only insofar as it describes «the operations of the underlying mechanism»,[35] only to the extent that it reveals «aspects of the causal structure of a mechanism».[36] In this vein, Bechtel and Abrahamsen coined the phrase "mechanistic-dynamic explanations" for those explanations that integrate the mechanistic decomposition of systems into parts and operations with the quantitative tools offered by dynamical systems theory.[37]

Mechanistic-dynamic explanations, however, require a reconceptualization of the notions of part and operation:

> Dynamic mechanistic explanations are still mechanistic, and so make reference to operations localized within parts, but respect the dynamic processes that require characterizing both parts and operations relationally in terms of how they are situated in endogenously active dynamic networks.[38]

In this perspective, then, individual brain regions are "endogenously" active and as a result of this activity organize themselves into specialized processing components. And yet, even as brain regions specialize, they remain integrated with other regions according to a form of organization known as "the small-world network". In such an organization, local clustering gives rise to specialized regions, but long-range connections link processing in these regions with activity taking place in other parts of the system, allowing activity in these other parts to modulate the behavior of local clusters.

Do Bechtel's dynamic mechanistic explanations succeed in harmonizing mechanistic-computational with dynamical explanations as Clark's three-tiered explanatory strategy requires? It is unclear. The appeal to dynamical models is invoked for integrated systems which are very *weakly* modular, since each of their parts is influenced by the activity in some other parts of the system. Is this degree of modularity sufficient for the standard required by a mechanistic model including computational explanations? Certainly not for those cognitive scientists who argue that a mechanistic-computational explanation requires constraints on the concept of part far more demanding than what is required for the notion of integrated system, namely, some form of informational encapsulation and massive modularity.

An example is provided by Peter Carruthers who, in dealing with Fodor's problem of the computational intractability of holistic central cognition, distinguishes a "narrow-scope" form of encapsulation from a "wide-scope" variety.[39] Influenced by the "simple heuristics" research program, he argues that such computational tractability does not require Fodor's "narrow-scope" form of encapsulation in which the encapsulated system cannot draw on any information held outside of it during the course of processing but only that, on any given occasion, it draws only on a subset of the "exogenous" information – a property that Carruthers calls "frugality" or "wide-scope encapsulation".

Now, within this modularist framework, Carruthers suggests an account of central cognition based on a functional architecture known as the "Global Workspace" (GW). Initially proposed by Bernard Baars based on hypotheses made by Tim Shallice and Michael Posner, this architecture was later developed by Stanislas Dehaene (2014) as the "Global Neural Workspace" (GNW) hypothesis.[40]

Analyses of functional connectivity patterns in the human brain, Carruthers notes, have demonstrated just the sort of neural architecture necessary to realize the main elements of a GW model.[41] More specifically, these studies show the existence of two main neurocomputational spaces within the brain, each characterized by a distinct pattern of connectivity. The first space is a processing network, composed of a set of parallel, distributed, and functionally specialized processors or *modular* subsystems subsumed by topologically distinct cortical domains with highly specific local or medium-range connections that encapsulate information relevant to its function. The subsystems compete with each other to access the GNW, which is implemented by long-range cortico-cortical connections, mostly originating from the pyramidal cells of layers 2 and 3 that are particularly dense in prefrontal, parieto-temporal and cingulate associative cortices, together with their thalamo-cortical loops. This GNW breaks the modularity of the nervous system. When one of these subsystems accesses the GNW, its outputs are broadcast to an array of specialized executive, conceptual, and affective consumer systems – e.g., systems that "consume" the perceptual input to form judgments or make decisions. Moreover, GNW makes possible the development and subsequent benefits of a working memory system which exploits the mechanisms of global broadcast to subserve a wide variety of central-cognitive purposes.[42]

Thus, a GNW architecture arranges parallel specialized conceptual systems around the global broadcast of attended perceptual information and thus enforces competitive entry into a general-purpose working memory system. Such design features seem to enable us to circumvent many aspects of Fodor's scepticism about holistic central cognition being amenable to computational modeling.[43]

Hohwy proposed an account of conscious access that integrates the GNW into the framework of the Predictive Processing framework, a view that Whyte terms "the predictive global neuronal workspace".[44] This reference makes it particularly interesting for the purposes of our reflection on reformism in philosophy of cognitive science Andy Clark's attempt to develop the explanatory framework of active externalism by adding to the resources of connectionist and dynamical psychology those of the Predictive Processing (henceforth, PP).

4 Radical predictive processing and 4E cognition

PP is a renowned and highly articulated framework that has emerged as one of the prominent alternatives for a reformist program. PP, it appears, is capable of pursuing many notable objectives: above all, that of conjugating the "pragmatic turn" taking place in the cognitive sciences with the more "conservative" desire to preserve a representational outlook on cognition.

Some ambiguities in the project still remain, though. These involve the employment of the concept of representation. Indeed, it seems, and understandably so, that when it comes to representations, the middle ground can easily lead to fuzziness. A further look at this unwelcome consequence may not only point to open questions in the reformist agenda but also to strategies we could employ in its future development.

In this respect, Clark's recent integrative proposal is a leading example. If it is true that the notion of representation has undergone several changes, his approach pushes these modifications to their limit. The development of Clark's methodology reflects the rationale of the three-tiered scheme presented in Section 3. The "continuist" approach adopted there is now cast within the popular framework of PP. Before looking at Clark's stance, we highlight a few key points of PP.

4.1 A nod at predictive processing (PP)

In PP, organisms proceed by trial and error in an uncertain world. They have access to the sensory consequences of environmental causes exclusively and, based on the former, must reconstruct the latter. To do so, in light of the models they acquire through experience (generative models), systems proceed inferentially to predict the causes of the effects they receive. Upon failure, error signals ensue. The minimization of these signals is the fundamental goal of cognition, for all its processes («perception and action and everything mental in between») can be traced back to the overarching principle of prediction error minimization.

Error minimization calls for a complex balancing game between "model intervention" and "world intervention". When an error ensues, a system must decide whether to correct the model upon which the predictions were made or to change the world to conform to the model. This decision is not straightforward and requires further harmonizing between the reliability of the models on the one hand and the errors on the other. The tradeoff between such reliabilities is modulated by precision.

A crucial aspect of this theory lies in its hierarchical nature. While there are different approaches to how they should be algorithmically sorted and implemented, the general idea is that a predictive architecture is made of different levels, each comprising different units: predictions and prediction errors. At any level predictions are sent downstream in the hierarchy while prediction errors are sent upstream; each level is in turn constrained by predictions coming from higher and errors coming from lower levels. The hierarchical matrix of PP is mirrored in the generative models it proposes. The highly structured data they contain (the interactions between hidden causes and their effects) require, in fact, a multilevel kind of organization that tracks different interactions at different spatial and temporal scales. In this way, the causal-probabilistic relationships standing between causes and expected outcomes trace the environmental variables as closely as possible.

4.2 Clark's radical synthesis

Based on these premises, Clark has developed what he himself dubbed "*radical* predictive processing" (rPP), opposing it to the contrasting "conservative" view (cPP).[45]

His reasoning can be summarized schematically: PP is compatible with 4E approaches; PP is (in some shape or form) representational;[46] hence, PP affords a strategy to integrate the two perspectives on cognition. Importantly, PP is not just another version of the "traditional" computational-representational view of cognition (as "conservative" proponents, seemingly, claim), but is a paradigm that enables a virtuous synthesis between apparently opposing tendencies. In this sense, Clark contends, PP allows us to "predict peace" in the long-standing "representational wars" raging in the cognitive sciences. But before such peace can be stipulated, it seems that a few dangling threads must be tied together.

Clark provides a captivating option for the reformist agenda. However, noting a few matters can provide an indication as to how a reformist proposal must evolve to be more robust. Clark's alternative is convincing from a general perspective. By this, we mean that his reformist proposal compellingly points to the compatibility of PP and 4E, leveraging key points that are consistent with the "pragmatic turn" of PP. This aspect of the integrative proposal, though, is also supported by proponents of cPP:[47] the fact that the brain's objective is not *plainly* "reconstructive"[48] is part and parcel of PP's program. If both parties are in general agreement as to the compatibility of PP and 4E, then the crux of the dispute lies in singling out exactly what *features* of such representations significantly differ from those of the "conservative" camp. This should further enable rPP to distinguish the types of processes and levels at play in the synthetic framework.[49] Given that cPP already undertakes a shift in the understanding of representational activities, a further refinement of this shift puts the "radical" reformist in dire straits, as shall become clear below.

Clark's two-faced account reveals a risk that looms large on reformist approaches when they try their hand at changing the features of the representations they postulate while still resorting to a computational-representational gloss. This problem acquires the form of a question: *how far can we take these modifications?*

It seems, in fact, that while the stricter claims coming from the conservative camp provide more rigorous criteria for representations,[50] Clark's deflationary[51] proposal has some unfinished business. We emphasize that this article does not intend to unravel these complex knots. Rather, it intends to point out, in light of Clark's proposal for rPP, the risks lurking in the reformist agenda.

4.3 The background and development of the radical synthesis

As anticipated, various aspects of the proposed compatibility between PP and 4E are endorsed by both rPP and cPP.

In Clark's work, this compatibility has immediate repercussions on the descriptions of the representations at play in cognition. As illustrated in the previous Sections, it is important to note that his view harkens back to both embodied[52] and enactive projects,[53] as well as to the suggestions coming from behavior-based robotics[54] and Beer's dynamical approach.[55] Upon this reading, in outlining cognitive processes, we should not consider the slavish reconstruction of the world to be their prerogative. On the contrary, cognitive science must be in the business of sketching «the common principles or lawful linkages between sensory and motor systems that explain how action can be perceptually-guided in a perceiver-dependent world».[56] In this sense, cognition is modulated by "scaffolding" and "productively lazy" processes. According to the latter, cognitive systems operate strategically to reduce the load of their enterprises; in line with the former, systems exploit the environment and their bodies to minimize cognitive costs. One interesting instance is that of infants in category learning and concept formation processes: here, «self-generated motor activity, such work suggests, acts as a "complement to neural information-processing"».[57] In sum, by poking, sucking, and grasping, infants balance out the cognitive load of "information structuring" and "information processing" across their brains, bodies, and the environment.

Clark makes the case that PP is compatible with these standards. Two of the major points he leverages fall under the balancing game mentioned above (sect. 4.1). For one, in model selection, we opt *for less complex* alternatives. As famously claimed by Clark: «the goodness of a predictive model is determined by accuracy minus complexity» (this is pointed out by Hohwy himself).[58] To this end, our model choices will tend to be less costly in computational terms. Second, precision calls for frugality. Its *context-sensitive* precision assignments – based on which we select our cognitive strategies – both consist of the alteration of «patterns of "effective neuronal connectivity"» and rest on an impending situation on which we must get a quick grip.

In sum, it is not coincidental that the two terms "fast" and "frugal" stick together. Keeping up with the requirements of the environment requires us to be "fast". But being fast is only possible through frugality.

Another example related to "scaffolding" illustrates the link between "fast" and the "frugal". The case is Optical Acceleration Cancellation (OAC). When running to catch a fly ball, we do not resort to detached representations to determine where it will land to *thereafter* run to reach the expected spot. Rather, as long as we move so as to cancel any «apparent changes in the ball's optical acceleration»,[59] we will reach the point where the ball strikes the ground.

Instead of relying exclusively on independent structures to successfully interact with it, we harness the world itself to achieve this very same goal. In the case above, "throwing away the world" would amount to doing all the cognitive work on representations before acting. To live up to this function, such representations would be complex and articulated. In short, the lack of representational frugality comes with slowness.

On cPP, Clark notes, «the model-rich cognizer is able to "throw away the world" and select her actions and responses by manipulating the inner model instead».[60] Just like Clark, Hohwy promotes his stance based on the very motives of PP. It is the uncertainty we navigate in our experiences that calls for rich and (p)reconstructive models. In this view, PP subscribes to a more canonical understanding of the computationalist-representationalist perspective.

Two points carry weight, though. The appeal cPP proponents make to the reconstructive aspects of representations should not have us thinking that they argue that the pragmatic traits of cognition are a drop in the bucket. On the contrary, they oftentimes emphasize that the rejection of the idea of «representation for representation's sake»[61] is not at odds with the preservation of «internal representation *as such*». In short, claiming that representations "copy" does not equate to saying that the reconstruction they impart does not bolster "coping".[62] Hence, cPP proponents do not negate the relevance of action or coping. Rather, they claim that pursuing such cognitive goals does not require dispense with the reconstructive and detachable traits of representations altogether.

Another conviction we should let go of as far as cPP is concerned is that the "more canonical" representations we have been mentioning thus far are the traditional, "*linguaformal*" structures of Fodorean inspiration.[63] PP's representationalism, in fact, comes with a whole different wealth of representations, one that exhibits substantial differences from the "traditional" understanding of the concept. This is even more evident when we pause on the fact that *generative models* are the standard of mental representation on PP. Much more should be specified here, for the implications of this transition are immense. But we will limit ourselves to note that the "recapitulative" function performed by these kinds of representations is starkly different from the linguistic alternative. Here, the neocortex does not explicitly represent the parameters indicating the causal-probabilistic relations between the represented environmental variables; rather, just like a graph or a map, it *acquires* the form, the structure, of the reciprocal relationships between these variables.[64] As Daniel Williams has noted, the implication is that «[i]n doing so, [these relationships] effectively realize a dynamical model (albeit a causal-probabilistic one) of the body and environment» and, further, «brains deploy the very kind of representation that advocates of dynamical systems theory argue *we* should use to model the brain».[65] Importantly, this seems to imply compatibility between the deployment of representational structures and dynamical approaches to cognition.

This conclusion gives hope to the reformist program. If cPP already provides substance to this integration, what does rPP add to the picture?

4.4 rPP representations

Clark's talk of representations gains shape while he is in the affair of distancing them from the rich, reconstructive, and detached models of cPP. This is a thorny issue, as it seems that the key features of Clark's representational paradigm must be taken up by those very traits that are intended to distinguish them from what we generally consider representational. This is further complicated by the fact that both these "paradigmatic" structures and the processes that tap into them combine with other structures and operations, thus making the term difficult to outline and understand straightforwardly.[66] Some points can be drawn, though.

First, to be genuinely "pragmatic" and pursue the control-theoretic goal cognition performs, representations must be fast, frugal (that is, "quick-and-dirty"), and "attached" (in the sense of "non-detached"), as well as observer-dependent.[67] To be a structure of this kind is to be an action-oriented representation.

Second, such structures are intermingled with other "styles" of processing, that go from higher-order, rich modeling, to reflex-like processes. The relations between these kinds of processing, as well as those between the structures handled (or not handled) in each case, lie on a *continuum* and combine with one another based on the system's needs (these observations recall section 2). In this, Clark explicitly draws on computational neuroscience, such as the correlation between "model-free" and "model-based" styles of processing.[68] In general, these two types of processing are considered two extremes of the cognitive spectrum. Model-free processing resembles the non-representational end, while the model-based end traces higher-level cognition. Both these extremes and what is in between combine in varied and dynamic ways.

Third, action-oriented representations, to exert their effects, lean on rich models. It is such models that make the default patterns of action-oriented representation possible, Clark claims when he observes that «slower processes of learning and adaptive plasticity have already sculpted patterns of neural connectivity in ways that make the low-cost strategy available».[69]

To recapitulate then: The "pragmatic turn" pervades the representational agenda. Cognition is *not* in the business of reconstructing rich, slow, and abstract models. While the concept of representation is preserved, unlike in cPP, the notion is (mainly) action-oriented. Representations are frugal, fast, and observer-dependent. However, they are not all there is to cognition, which is made up of different styles of processing that variously combine, spanning from higher, abstract levels down to heuristic, reflex-like processing. The possibility of engaging in action-oriented representations itself "rests" on high-level knowledge.[70]

4.5 A glimpse into the issues

The picture indeed exhibits ambiguities. Clark's insistence that representations be fast and frugal leads to surprise when he alludes to the presence of rich models. This sensation is as pronounced as ever when he claims that action-oriented representations (which are central in rPP, if only because of Clark's insistence) are *made available* by rich models (thus granting the latter a key role after having largely downsized their benefits). Further, it is not very clear why action-oriented representations should still be deemed as such: what are the genuinely representational traits they impart? Last, it is not uncontroversial that these different styles of processing can all be maintained in PP.[71]

We shall group these uncertainties into three main issues: first, the representational status of action-oriented representations; second, the possibility of intermingling between model-based and model-free approaches; third, the role of high-level models.

All of this aims at highlighting possible flaws of the reformist program. We will not by any means resolve these issues but leverage them to provide food for thought for the future development of the reformist agenda.

Clark's description poses issues as to the representational status of the structures he proposes. As mentioned above, his favored strategy in describing action-oriented representations is to distinguish them from PP's commonplace understanding of the notion (that of cPP). The general impression is that he does not systematically explain in what capacity they still are, for all intents and purposes, representations. If, on the one hand, Clark tells us why we should shy away from the canonical understanding of the notion in PP, he does not rigorously indicate why we should still consider action-oriented structures to have representational status.

This sounds even more dissonant if we think that cPP does indeed propose structures that are both representational and, ultimately, action-guiding (see above). It would be misleading to suggest that the representations at play in PP are action neutral. In cPP, the process of construction of a structural representation of the environment «is not an end in itself, but a tool for self-maintenance».[72] Further, «what is "reconstructed" in internal models of prediction-error-minimizing-agents are those aspects of the environment which constitute the organism's *Umwelt*, i.e., the ones which the organism depends on in its practical engagements with the environment».[73] Suffice it to say that it is not sufficient for a state to be "structurally similar" to its domain for it to qualify as representational. To acquire this status, the relation of structural similarity must be *exploitable*.[74]

In light of these general observations, it might seem that the hybrid structures put forward by Clark add complication. cPP poses entities that, in reconstructing the environment, do not aim at mirroring it, but rather at acting in it, in this way fully embracing the pragmatic turn and the 4E approach. Concurrently, cPP allows us to endorse this option while at the same time providing a structured way of motivating the representational status of the structures at play.[75] It seems that, as long as there is an option that allows us to get "the best of both worlds" by aptly justifying both endorsements (that is, the computational-representational stance on the one hand and the pragmatic role of cognition on the other), it makes less sense to endorse a two-faced notion[76] such as action-oriented representations. This consideration is bolstered by the concurrent need, on Clark's end, for the postulation of a non-representational end on the one hand and of a "canonically" representational one on the other, as well as for the "fully" representational structures to be the condition for availability of the action-oriented representations.

Related to this haziness about the representational weight that action-oriented representations may bear, is the fact that they often appear to be compatible with the notion of "affordance". Even more so, the representations postulated by Clark aptly correlate with Shepard's[77] development of Gibson's theory. This reference of Barrett is on point: Shepard, in fact, proposes a model where selection and learning provide the basis for apt 'resonation' to the environment. Thus, we are «tuned to resonate» to patterns that are meaningful to us. Such a "resonating system" imparts higher levels that resonate to a «wider class of objects and events». Very interestingly, systems are calibrated to reduce the complexity of these resonances. Higher levels are invoked when things get complicated. If not, systems deploy simpler resonation, which, at the lowest level, is "direct perception" in a Gibsonian sense[78]. The similarity between this program and Clark is evident. Thus, it seems Clark could set up a very similar project even without the notion of representation.

This issue, as anticipated, cannot be solved here. But it points to a major risk looming on the reformist agenda. *If, in adopting a reformist approach, we change the notion of representation to fit 4E, then we must be careful to provide a more robust account of the terms by which it should still genuinely be "representational"*. The absence of this clarification, in fact, might make the postulated structures compatible with approaches that do not ratify representationalism, thus making its endorsement appear trivial.

This leads us to the second point. Clark admits to the possibility of coexistence and cooperation between representational and nonrepresentational processes. This point is further argued for by casting the findings of computational neuroscience[79] into the PP framework. Model-based and model-free cognitive styles coopt one another and dynamically combine based on our current needs. This point puts pressure on the endorsement of the representational jargon, though. PP, in fact, promotes an overarching view in which cognition is constructed in a fractal-like manner. If lower levels of cognition operate in a model-free, non-representational way, then how can higher levels operate so differently? This claim necessitates for instance the adoption of "double standards", or of a "double gloss": as Anderson and Chemero[80] have argued, for example, the notion of prediction at low levels is used differently from that at high levels. They frame this operation as an arbitrary one: «it is a theoretical choice not necessitated by evidence».[81] The conclusion they draw is, in short, that since PP can be framed in a non-representational gloss,[82] we could settle things once and for all by excluding the notion of representation altogether. Thus, the presence itself of model-free processing puts pressure on the persistence of the notion of representation[83] from *two perspectives* (from both the representational and the non-representational readings of PP). On the one hand, assuming that PP is representational, PP's hierarchical, overarching view is at odds with this stark distinction, as generative models are supposed to be at work everywhere throughout cognition; on the other, the fact that we encounter non-representational processes, conjoined with PP's overarching framework, might lead us to think that the notion of representation is ultimately uninformative.

This second point emphasizes the risks of a hybrid architecture in promoting the reformist agenda. Not only are the required double standards at odds with the general rationale of PP (leading to objections from proponents of both camps), but the difference between model-based and model-free processing seems to be too radical to grant, as Clark would wish, the possibility of seeing these processing styles as the two ends of a continuum.

A similar argument has been made by Hohwy with regard to the relationship that is supposed to stand between action-oriented representations and higher levels of the generative model. Recall, the latter make low-cost strategies *available*. This is a strong statement, for it argues that the action-oriented representations' operations are made possible by rich representations. Not only is this a strong statement, but a confusing one too, since Clark devotes much ink to rescaling the role of the latter. This point is well argued by Hohwy: «there is [...] a potential tension [...] between allowing and withholding a role for rich models».[84]

This tension is especially highlighted by the following considerations. Clark "withholds" a role for rich models in two main ways. Firstly, he extends the non-reconstructive prerogative to include higher levels of elaboration. The latter do not aim at *depicting* the world, but at *ensuring an adequate grip on it*. The pragmatic rationale goes all the way up to high-level cognition. Secondly, the use we make of the latter is avoided as much as possible.

However, not only does he concurrently preserve the jargon of richness (for example, he claims that higher levels are "more *abstract*", thus implying some form of detachment),[85] but he also ascribes an important role to them. For instance, he argues:

> [...] high-level states (of the generative model) target large-scale, increasingly invariant patterns in space and time. Such states help us to keep track of specific individuals, properties, and events despite large moment-by-moment variations in the stream of sensory stimulation.[86]

This seems to point to slow and definitely richer, as well as detached levels of elaboration. This is where Clark "allows" a role for rich models.

This ambiguity provides food for thought for reformists: we who are sympathetic to this camp should be careful not to superimpose the *features* of the representations on the nature of their *use*. This oscillation is present in rPP: when Clark argues that higher levels of the generative model exert an "active" role what he means, most probably, is that in their *use* they are fundamentally pragmatic. In short, when we put them into use, we do not deploy them *as rich reproductive models as such*, but we use them to highlight what is meaningful to us in that context. In principle, however, Clark does agree that we have an «immense storage of causal knowledge».[87] Thus, while the two stances seem to converge on the general need for high-level information in our models, on the one hand (cPP) this information is used to «repeatedly infer when we are in situations where low-cost strategies are viable»; in this sense invoking all the apparatus of knowledge we enjoy, while on the other hand (rPP), once we have acquired such information (once we have learned), we do not repeatedly put to use the entire wealth of knowledge we have gained over time. Rather, this acquired knowledge allows us to operate in a default manner whenever possible. More precisely, we exert «default precision-assignments that install the transient organizational structure that best confronts that kind of puzzle in that kind of context».[88]

The take-home message goes as follows: since a reformist approach embraces disparate concepts and structures in their differences, to conjugate these, it must *be rigorous about the features and the use of the structures it postulates*.

Further reflection can be conducted as to the possibility of preserving all this richness only to shut it away in tangible experience. This point highlights that the amphibious position of action-oriented representations still meets with inconsistencies. It would seem that we stockpile a great deal of information without actually invoking it in experience.[89]

Recapitulating. Clark's "radical reformism" still holds the notion of representation, but it emphasizes its pragmatic nature. The paradigmatic case of a representation is action-oriented representations. Concurrently, Clark retains rich models, claiming both that they make quick-and-dirty operations available and, concurrently, that their objective is pragmatic. Further, these different structures interact with one another, as well as with model-free operations. All these processes lie along a *continuum*.

The open questions are thus condensed: in what measure are action-oriented representations still such? Why should we retain the notion of representations if there are non-representational processes (given the "unifying" rationale of PP)? Or, complementarily, why shouldn't we retain the notion of representations if there are representational processes? More generally: why resort to a hybrid notion if we do have a well-grounded notion of representation (that of cPP) that does not neglect the role of action, but rather emphasizes its prominence in our cognitive processes?

5 Conclusions

In this paper we have carved out a reformist agenda within the debate on the foundations of cognitive science, a reformist agenda that aims to incorporate some important ideas from the literature on 4E cognition in the computational-representational framework.

We are deeply sympathetic to this reformist program since we think that, despite some strong criticisms of the concept of computation and the related notion of representation, computational models are still at the core of the disciplines of the mind. Computational models and, more generally, mechanistic explanations are still the dominant methods in cognitive science. Indeed, on the one hand, the complexity of animal and specifically human behavior requires an appropriately complex model, like computational models provide; on the other hand, more traditional nomological explanations do not appear apt to hit the explanatory target: psychological explanation is closer to the biological than the physical kind.[90]

At the same time, we recognize the need for a liberalization of the computational and representational framework that offers a satisfactory response to the deep dissatisfaction with the antibiologism and radical internalism of classical cognitive science. In this perspective, the evaluation of the tenability of the reformist program is the main task of the philosophy of cognitive science. Our article focused on two paradigmatic cases of reformism. First, we conducted some reflections on Bechtel's attempt to combine mechanistic-computational explanations and dynamicist explanations. Then, we critically examined Clark's strategy for integrating representationalism and 4E cognition through radical predictive processing.

As we have seen, many open questions remain -- reforming is undoubtedly an arduous task. It is therefore not surprising that, as early as 1998, Bechtel, Graham and Abrahamsen contemplated the possibility that «the simultaneous pulls *downwards* into the brain and *outwards* into the world may prove to be too much pulling, and lead to the disintegration of cognitive science».[91] However, the authors hastened to point out that the volume they introduced (a companion to cognitive science) was an attempt to combine the two thrusts. Reformism *is* the belief that a coherent synthesis can be found between vertical and horizontal expansion.

Notes

[1] W. BECHTEL, G. GRAHAM, A. ABRAHAMSEN, *The life of cognitive science*, p. 77.
[2] W. SCHNEIDER, *Connectionism: Is it a paradigm shift for psychology?*
[3] Cf., e.g., A. NEWEN, L. DE BRUIN, S. GALLAGHER (eds.), *The Oxford handbook of 4E cognition*.
[4] Cf. E. HUTCHINS, *Cognition in the wild*.
[5] Cf. E. MACHERY, *Philosophy of psychology*, pp. 273-274.
[6] That is, the tacit knowledge of the patterns of covariation between our bodily movements and the sensory stimulus.
[7] Cf. L. SHAPIRO, S. SPAULDING, *Embodied cognition*, §2.4.
[8] U. NEISSER, *Cognition and reality*.
[9] P. JACOB, M. JEANNEROD, *Ways of seeing*. The authors build on Ungerleider and Mishkin's famous what vs. where distinction, which was then modified by Goodale and Milner and became the action vs. perception distinction. Another attempt to make a synthesis between environmentalism and computationalism is in J. NORMAN, *Two visual systems and two theories of perception*.
[10] A. CLARK, *Being there*, p. 108.
[11] C. ELIASMITH, *The third contender*.
[12] R. PORT, T.J. VAN GELDER (eds.), *Mind as motion*, p. 4.
[13] Neural networks are a class of dynamic systems: the evolution of a network can be described by a system of differential equations.
[14] Note that the existence of a direct systematic dependence between movements and stimulation and the related intrinsically dynamic nature of perception are the main reasons that radical enactivists identify complex dynamical systems as the most appropriate models for the sensorimotor system. Such dependence is in fact an exemplification of what dynamicists call "coupling relations".
[15] T.J. VAN GELDER, *What might cognition be, if not computation?*, p. 373.
[16] W. BECHTEL, GRAHAM, ABRAHAMSEN, *The life of cognitive science*, p. 96.
[17] Cf. W. BECHTEL, *Representations and cognitive explanations*; J. WALMSLEY, *Explanation in dynamical cognitive science*; A. CHEMERO, *Radical Embodied Cognitive Science*.
[18] Cf., e.g., A. CHEMERO, M. SILBERSTEIN, *After the philosophy of mind*. The authors offer the Haken-Kelso-Bunz model of bimanual coordination as evidence that some explanations in cognitive science and neuroscience are nonmechanistic and that for many complex behavioral and neural systems the primary explanatory tools are the mathematical methods of nonlinear dynamical systems theory.
[19] Cf., e.g., A. CHEMERO, *Radical embodied cognitive science*; G. SANCHES DE OLIVEIRA, V. RAJA, A. CHEMERO,

Radical embodied cognitive science and "real cognition".
[20] Cf., e.g., N. ALKSNIS, J. REYNOLDS, *Revaluing the behaviorist ghost in enactivism and embodied cognition*.
[21] T.J. VAN GELDER, *Dynamic approaches to cognition*, p. 244.
[22] A. CLARK, *Being there*, p. 126.
[23] M. ROWLANDS, J. LAU, M. DEUTSCH, *Externalism about the mind*.
[24] Cf. D. BALLARD, *Animate vision*.
[25] The reference here is to R. MILLIKAN, *Pushmi-pullyu representations*.
[26] Cf. J. HAUGELAND, *Having thought*, p. 172.
[27] A. CLARK, *Being there*, p. 147.
[28] A. CLARK, J. TORIBIO, *Doing without representing?*, p. 403. Shaun Gallagher has recently called this the "scaling-up problem," i.e., the problem of making current approaches to «lower-order or basic types of processes involving perception and action» also work for explaining «higher-order cognitive abilities, such as memory, imagination, reflective judgment, and so on» (S. GALLAGHER, *Enactivist interventions*, p. 187).
[29] W. BECHTEL, R. RICHARDSON, *Discovering complexity*, Ch. 7.
[30] This would be the case with Jerry Fodor's encapsulated modules.
[31] W. BECHTEL, *The compatibility of complex systems and reduction*. Cf. also A. CLARK, *Being there*, p. 114.
[32] This radically holistic conception is endorsed by G.C. VAN ORDEN, B.F. PENNINGTON, G.O. STONE, *What do double dissociations prove?*
[33] W. BECHTEL, *Mental mechanisms*, Ch. 3.
[34] W. BECHTEL, *The compatibility of complex systems and reduction*, p. 483.
[35] D.M. KAPLAN, W. BECHTEL, *Dynamical models*, p. 443.
[36] D.M. KAPLAN, C.F. CRAVER, *The explanatory force of dynamical and mathematical models in neuroscience*, p. 602. Milkowski and colleagues (*From wide cognition to mechanisms*, p. 2393) subscribe to Kaplan and Craver's thesis, situating it within a broader theoretical framework in which "broad" perspectives on cognition (i.e., those of the 4E approach) are reinterpreted as research heuristics to construct mechanistic explanations.
[37] W. BECHTEL, A. ABRAHAMSEN, *Dynamic mechanistic explanation*; W. BECHTEL, *Addressing the vitalist's challenge to mechanistic science*.
[38] W. BECHTEL, *Referring to localized cognitive operations in parts of dynamically active brains*, p. 263.
[39] P. CARRUTHERS, *The architecture of the mind*, p. 58.
[40] S. DEHAENE, *Consciousness and the brain*. For a recent review of GW-Inspired Architectures, cf. A. SIGNA, A. CHELLA, M. GENTILE, *Cognitive robots and the conscious mind*.
[41] Cf., e.g., E. BULLMORE, O. SPORNS, *Complex brain networks*; G. GONG, Y. HE, L. CONCHA, C. LEBEL, D.W. GROSS, A.C. EVANS, C. BEALIEU, *Mapping anatomical connectivity patterns of human cerebral cortex*; M. SHANAHAN, *Embodiment and the inner life*.
[42] Cf. P. CARRUTHERS, *The centered mind*.
[43] Cf. E.C. DEISE, *Frame problems, Fodor's challenge, and practical reason*; P. CARRUTHERS, *On central cognition*.
[44] J. HOHWY, *The predictive mind*; C. WHYTE, *Integrating the global neuronal workspace into the framework of predictive processing: towards a working hypothesis*.
[45] Cf. J. HOHWY, *The predictive mind*; P. GŁADZIEJEWSKI, *Predictive coding and representationalism*; W. WIESE, *What are the contents of representations in predictive processing?*; D. WILLIAMS, *Predictive processing and the representation wars*.
[46] We note that, despite their importance to the debate, we here set aside anti-representationalist takes on PP since they would countenance no reformism whatsoever – at least not in the terms we hope for here. Cf., e.g., J. BRUINEBERG, J. KIVERSTEIN, E. RIETVELD, *The anticipating brain is not a scientist*.
[47] Cf., e.g., P. GŁADZIEJEWSKI, *Just how conservative is conservative predictive processing?*; J. HOHWY, *Quick'n'lean or slow and rich?*
[48] Cf. M. ANDERSON, *After phrenology*.
[49] This is noted in K. DOŁĘGA, *Moderate predictive processing*.
[50] Cf. references in footnote 55.
[51] We call his approach "deflationary" as it seems to downplay the degree of (at least the canonical) "representationality" of representations as will appear below.
[52] Cf. A. CLARK, *Radical predictive processing*; M.K. MCBEATH, D.M. SHAFFER, M.K. KAISER, *How baseball outfielders determine where to run to catch fly balls*.
[53] F.J. VARELA, E. THOMPSON, E. ROSCH, *The embodied mind*.
[54] Cf. R.A. BROOKS, A.M. FLYNN, *Fast, cheap and out of control*.
[55] Cf., e.g., R. BEER, *Dynamical approaches to cognitive science*; R. BEER, *The dynamics of active categorical perception in an evolved model agent*.
[56] F.J. VARELA, E. THOMPSON, E. ROSCH, *The embodied mind*, p. 173.
[57] M. LUNGARELLA, O. SPORNS, *Information self-structuring: Key principles for learning and development*, p. 25 as in A. CLARK, *Radical predictive processing*, p. 12.
[58] However, conservative views, while leaning towards rich and thorough representations, do not correlate these necessarily with complexity: Hohwy diffusely refers to models as both "simple" and "low-cost, energy-efficient".
[59] A. CLARK, *Radical predictive processing*, p. 11.
[60] *Ibid.*, p. 15.
[61] M. WILSON, *Six views of embodied cognition*, as in D. WILLIAMS, *Predictive processing and the representation wars*, p.148.
[62] These points are well said by D. WILLIAMS, *Predictive processing and the representation wars*, pp. 148-149.
[63] Cf. J.A. FODOR, *The language of thought*.
[64] Cf. D. WILLIAMS, *Predictive processing and the representation wars*, p. 154; GŁADZIEJEWSKI, *Predictive coding and representationalism*.
[65] D. WILLIAMS, *Predictive processing and the representation wars.*
[66] Note that we do not mean to say that there are no issues in cPP or that there is nothing controversial with its concept of representation. Aspects of these criticalities have been reviewed, (e.g., DOŁĘGA, *Moderate Predictive Processing*), not to mention the issues uncovered by the non-representational camp (e.g., BRUINEBERG ET AL., *The anticipating brain is not a scientist*).
[67] See references to Clark's work in footnote 45.
[68] N.D. DAW, S.J. GERSHMAN, B. SEYMOUR, P. DAYAN, R.J. DOLAN, *Model-based influences on humans' choices and striatal prediction errors*.
[69] A. CLARK, *Radical predictive processing*, pp. 16-17.
[70] Clark does not refrain from using this expression: A. CLARK, *Whatever next?*, p. 200.
[71] The cogency of these ambiguities is highlighted by

several contributions from M. COLOMBO, E. IRVINE, M. STAPLETON (eds.), *Andy Clark and his critics*. There, informatively, Clark is in fact pressured by both ends of the battlefield (i.e., by Hohwy's cPP approach on the one hand and by Barrett's and Anderson and Chemero's Gibsonian and ecological approaches on the other). Cf. L. BARRETT, *Supercharged apes versus super-sized minds*; M. ANDERSON, A. CHEMERO, *The world well gained*. We see Clark's ecumenical answers, *especially to members of the "affordance/ecological" camp*, to indicate the existence of these open questions in his proposal.

[72] Cf. P. GŁADZIEJEWSKI, *Just how conservative is conservative predictive processing?*

[73] *Ibid.*, p. 105

[74] e.g., N. SHEA, *VI-exploitable isomorphism and structural representation*.

[75] We note again that this claim is not plainly uncontroversial.

[76] Note that the issue is not with the ambiguity or duplicity of the notion, but with the rigor with which it is able to explain cognitive features. Thus far, it seems that cPP is more able to convey such rigor.

[77] R.N. SHEPARD, *Ecological constraints on internal representation* as in L. BARRETT, *Supercharged apes versus super-sized minds*.

[78] J.J. GIBSON, *The senses considered as perceptual systems*.

[79] Cf., e.g., N.D. DAW, S.J. GERSHMAN, B. SEYMOUR, P. DAYAN, R.J. DOLAN, *Model-based influences on humans' choices and striatal prediction errors*.

[80] M. ANDERSON, T. CHEMERO, *The problem with brain GUTs*.

[81] M. ANDERSON T. CHEMERO, *The problem with brain GUTs*, p. 205. K. DOŁĘGA, (*Moderate predictive processing*, p. 11), emphasized that PP requires parity from the formal point of view with regard to prediction estimations: «from a formal perspective, each PE level [Prediction Estimation level] in the hierarchy is performing the same kind of basic function – carrying out probabilistic inferences aimed at producing hypotheses, which are best at accommodating the currently available data (incorporating the information fed from the level downstream into the next estimation about the activity on that level)». This supports the contention that double standards are hard to import into a framework like PP.

[82] This point is based, as D. Williams notes, on the fact that the predictive processing architecture can be seen as a "process theory" (D. WILLIAMS, *Predictive processing and the representation wars,* p. 159).

[83] Cf. N. ORLANDI, *Bayesian perception is ecological perception*. It must be further noted that this is a critique that has been moved towards the representational interpretation of as a whole. I couldn't decode this sentence.

[84] J. HOHWY, *Quick'n'lean or slow and rich?*, p. 195.

[85] Given that fastness and frugality are related (see above), one point to be better explained is how the pragmatic prerogative of high-level cognition can correlate with richness.

[86] A. CLARK, *Radical predictive processing*, p. 22.

[87] J. HOHWY, *Quick'n'lean or slow and rich?*, p. 195.

[88] A. CLARK, *Replies to critics*, pp. 289-90.

[89] J. HOHWY in *Quick'n'lean or slow and rich?* highlights how it is precisely this information that allows for sparse sampling to occur.

[90] Cf. M. MARRAFFA, A. PATERNOSTER, *Models and mechanisms in cognitive sciences*.

[91] W. BECHTEL, G. GRAHAM, A. ABRAHAMSEN, *The life of cognitive science*, p. 96.

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