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Acquisition of Autonomy in Biotechnology and Artificial Intelligence

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Abstract

This presentation discusses a notion encountered across disciplines, and in different facets of human activity: autonomous activity. We engage it in an interdisciplinary way. We start by considering the reactions and behaviors of biological entities to biotechnological intervention. An attempt is made to characterize the degree of freedom of embryos & clones, which show openness to different outcomes when the epigenetic developmental landscape is factored in. We then consider the claim made in programming and artificial intelligence that automata could show self-directed behavior as to the determination of their step-wise decisions on courses of action. This question remains largely open and calls for some important qualifications. We try to make sense of the presence of claims of freedom in agency, first in common sense, then by ascribing developmental plasticity in biology and biotechnology, and in the mapping of programmed systems in the presence of environmental cues and self-referenced circuits as well as environmental coupling. This is the occasion to recall attempts at working out a logical and methodological approach to the openness of concepts that are still to be found, and assess whether they can operate the structuring intelligibility of a yet undeveloped or under-developed field of study, where a "bisociation" and a unification of knowledge might be possible.

Keywords: Autonomy, Biotechnology, Artificial intelligence, abductive inference, behavior, development, individuation.

1. Introduction

One can encounter the concept of autonomy as one that functions in different areas of human thought and activity: in psychology and more largely the social sciences, when dealing for instance with education; in technology as some apparatuses are rendered capable of remaining independent from their users for more and more tasks; and finally in the natural sciences where living beings display different forms of autonomous processes. We will consider different uses of autonomy in Biology (section 2), Cognitive Science and Artificial Intelligence (section 3), and suggest that there is not a unique coherent definition of autonomy at play in these different contexts. This matter of fact raises multiples epistemological and methodological issues that will be discussed in a third part (section 4). It is important to stress that we will not in this discussion make attempts at addressing directly the idea of moral autonomy, but that we will restrict ourselves to a discussion of the acquisition of autonomy as a mode of independence of an entity (living being, artificial system, robot) when performing a set of non-directed tasks.

2. Autonomy in the Life Sciences and Biotechnology

The phenomenon of organic stabilization of conditions between the organism and its environment has been noted by researchers for a long time, and was tentatively defined, through the concept of 'homeostatis,' as a broad maintenance of a stable internal environment–which Claude Bernard termed "the internal milieu"–in coupling with an external environment that fluctuates [2]. The French physiologist and statistician Pierre Vendryès extended the work of Claude Bernard on this 'internal milieu,' and as such distinguished three levels in the acquisition of autonomy: the metabolic, the motor, and the mental. Those also represent three stages in evolution, with the motor autonomy using the metabolic, and the mental autonomy using the motor. The closure theorized by Vendryès speaking, already in 1942, of the living being as its own reference system [9:52; see synthesis in 28:37-70] was unwittingly followed by the approach of Maturana and Varela who proposed to define biological autonomy by its self-referenced organization, also called autopoiesis [17, 20]. Biological organisms possess a capacity as individuals, whether at the cellular or pluricellular levels, to act and become in space and time relative to *their own organization*, through unfolding of capacities to produce this structure, that are sometimes triggered according to their encounters with many environmental factors. From this point of view, any alteration to living organisms, including biotechnological intervention, could be limited by their relative impact on the systems' capacity to maintain its operating self-organization.

Yet, the biotechnological advances, especially as they pertain to cloning, present a challenge to this acquisition of biological autonomy, and to any idea of 'self'-adjusted internal factors creating adaptive conditions to be coupled to an external environment. They seem to call for a relational process, and also for epigenetic adaptiveness. C. H. Waddington broke a trend when he suggested an 'epigenetic landscape' as a visualization of the interaction between genes and the environment, and then attempted to model the developmental pathways a cell can take during differentiation, to finally feel the need to include in his model concepts such as regulation, competence, and induction [31].

Within experimentation in biotechnological modification of organisms, one has to assess whether there isn't a form of limitation on the side of the experimenter that would be the flipside of a variation on autonomy in such living entities. This might be the reason why attempts at cloning stem cells, or somatic adult cells, do not always deliver the expected outcome and why cloned animals display so many abnormalities during development [5]. Cloning by embryonic or somatic cell nuclear transfer has produced new animals which display a constitutive frailty stemming from both their creation mode and their developmental process. This questions the contribution of reproduction technologies in the becoming of such entities and, more generally, calls for a constructive influence of the environment–in a broad sense including technical interference–on natural developmental processes. This could also explain why human in vitro fertilized newborns display abnormalities at birth [4]. One is led to consider whether natural entities would have their own 'norm of development,' and whether this developmental autonomy would be set against constraints that come from the environment and that could be simulated in experimental protocols.

Epigenetics, which studies environments' impacts on developmental pathways, brings a new explanatory framework that can be added to the genetic one in order to fill the gaps within the biological significance of autonomy. Consequently, a corollary to this notion of autonomy as self-organization comes from the fact that biological entities have variable and metastable epigenetic profiles of possible becomings, and as such their biological autonomy is expressed as a form of plasticity [19]. Biological individuals are not only autonomous but plastic as their biological individuality is not yet determined but will be constructed *in response* and sometimes *against* internal or external constraints. Thanks to environmental influence and behavioral autonomy, epigenetic individuals possess a freedom of becoming [8] and therefore a biological autonomy dependent on the fulfilling of certain relations.

3. Autonomy in Artificial Intelligence and Cognitive Science

The notion of autonomy is also mobilized under various forms in AI and the cognitive sciences. In the field of Artificial Life and related fields of cognitive science where the concept of autonomy has been used in empirical research, a unique definition is far from being consensual, though common grounds between definitions exist [3]. This shows that such a fundamental notion is useful to characterize certain essential aspects or developments of artificial systems and that its use has pushed for a more thorough examination of heuristic concepts to widen their applicability. One way this has been achieved is by creating the distinction between levels or dimensions of the initial central concept of autonomy from which a living or artificial system is being characterized [11, 30]. Though artificial agents lack constitutive autonomy, because they don't self-determine their organization and structure, by achieving learning processes in a more self-developed manner they can achieve higher degrees of behavioral autonomy.

Recently, some researchers in programming, automation and artificial intelligence have asked the question whether it would be possible for automata to self-direct, and whether or not they could acquire a form of autonomy [12, 13], with an inspiration partly found in constructivism [see 18: 875]. This would partly withdraw those experimental entities from the realm of obedience to programming, as submitted to some atemporal logical or algorithmic framework, and launch them into the realm of becoming. If they truly have something akin to autonomy in their constitution, they could modify their own structure through a change in the program that specifies it, or 'codes' for it in the language of the geneticist. These modifications are low-level features that might evolve in time under local environmental influences by using a recollection of machine-environment interactions.

4. Analysis of the interdisciplinary landscape about autonomy

In light of the different definitions of autonomy exposed in the previous sections, it appears that there is no unique clarified meaning for this term that is mobilized in the different studied contexts. Rather, divergences and mismatches seem to occur.

Questions arise about the extent to which biological concepts can be meaningfully transferred to artificial intelligence, and even more so, become fruitful. Are researchers merely adopting a conventionalist strategy [24], or do they speak about autonomy in a strongly semantic sense, as it would relate to more entrenched uses such in biology?

Connections between the different uses of the notion of autonomy may be of different types. In AI research, the concept of autonomy is used to define a research project which intends to develop systems that bear the faculty to self-construct and self-determine a goal to be ultimately followed, with the associated fecundity it can bring for the related fields. Yet researchers know autonomy is not only a project but has different facets in common sense and metaphors.

There is indeed the recognition in the disciplinary context of something usually linked to autonomy in common sense. As such, we have here a case where we find in biotechnologies and in artificial intelligence research, the *convergence* of a theme and a vocabulary that overlaps around the idea of autonomy, whether it be in terms of the attempts to understand what programmed features map the acquisition of autonomy or the possibility of self-programming. These concepts were used in the context of cybernetics, and posterior developments on self-organized biological systems, to map the behavior of feedback-control systems–machine and animal–thinking them alongside each other in an analogical way.

The conceptual bridges force on us the use of metaphors. Developmental maps, and notions like the epigenetic landscape, have been dubbed ‘problematic metaphors’ [32: 13-16], but can we think that this problematic character is the flipside of a still unexploited heuristic fruitfulness beyond the multifariousness with which we are presently groping? Another metaphor which has shown a clear heuristic value across fields, between computer science and neuroscience, is the analogy between the nervous system’s operation and a computer’s, that of *processing information* through circuits. Though recognizing the clear distinction between these two systems, especially regarding their physical structure and organization, neuroscience research has built its fundamental knowledge of the system’s operation on this conceptual bridge.

Researchers acknowledge that artificial agents’ autonomy is probably not reachable as we find in the autonomy of living beings, but the fact is that observers can see the face of autonomy anyway, as if they were discovering facets of the idea as informally and indexically recognized in common sense. These facets of autonomy, as particulars, could be recognized as belonging to the comprehension of defined concepts in each fields and domains and allow the researcher to make ‘determinative’ judgments in a sense we will develop further down. This analogy is operating for example in the comparison between recursivity and iterativity. Barandiaran and Moreno compare the recursivity characteristic of autopoiesis in living models and the iterative aspects in artificial models, and they look there for a common logic that takes into account historical and structural/organizational features [1].

But the judgment can also be made the other way around and use particulars to enlighten the overall understanding independently of the given fields. This analogy is operating for example when looking for the general principle widening the scope of the relational aspect of autonomy. Ruiz-Mirazo and Moreno call for the existence of a general principle explaining the open-ended redefinition of autonomous systems thanks to the relative dynamic decoupling among distinct parts, modules or modes of operation in these systems, as we recognize the need for differentiated parts to maintain the system’s organization and allow homeostasis [25]. Thanks to an analogical and interdisciplinary use of concepts, the authors suggest that by decoupling their operational modes and structures or by widening the space of possible actions while still coupling them with the environment, systems–whether alive or artificial– might acquire autonomy.

Yet, do we observe a flexibility of in the use of such acquired autonomy in AI? The answer is a list of criteria to say that an agent is *more* or *less* autonomous. This list of criteria for the acquisition of autonomy starts from behavioral autonomy and continues with developmental learning and individuation. Constitutive autonomy would be an ultimate goal to reach [7, 10].

As neglected interactive aspects stemming from autonomy should be equally addressed, we prefer to talk about ‘developmental autonomy.’ Piaget thought that development is the process of establishing and enlarging the space of possible actions that the system can engage in while still maintaining the consistency of the coupling with the environment [29]. But a distinction must be made between the researchers’ objective and the targets of the artificial system. Recent studies therefore suggest to generate ‘non *target*-directed behaviors’ for an artificial system ‘in an unknown environment’ [13, 21]. Doing so, authors expect to observe a developmental individuation–when the entity explores an unknown environment–that could be considered more relational and thus more autonomous than a usual machine-learning individuation. Nevertheless, this developmental individuation is not close to living being’s individuation in that it cannot reach *agency*, because of the lack of a capacity of regulating its coupling with the environment (*interactional asymmetry*) and, most of all, in virtue of its lacking a capacity of creating its own rules, or necessities, of interaction (*normativity*) [7].

There could be an acquisition of autonomy when we have an agent exploring possibilities of interaction. But what learner or ‘acquirer’ of information should we compare it with? Only a mode of mapping allowing to analogize with less autonomous processes could, it seems, put us on the trace of the ‘Gestalt’ of autonomy.

- Living being individuation / crystal individuation

· Developmental individuation / usual machine learning individuation

These particulars can be associated in an ascending reflective judgment as all putatively belonging to the comprehension of 'autonomous' as grasped in common sense (together with other particulars recognized as belonging to this common sense comprehension).

Finally in AI research, the concept of autonomy is used to define a research project which intends to develop systems that bear the faculty to self-construct and self-determine a goal to follow ultimately, with the associated fecundity it can bring for the related fields.

All these uses, metaphors, analogies, subcategories of the same word 'autonomy' carry methodological interest for interdisciplinary research. Methodological questions addressing such interdisciplinary translation of concepts will explore whether concepts can be transferred and still operate in a new field, or how it is possible for a concept to be the same when associated with different definitions in different fields.

As we hinted, one hypothesis could be that the transfer operates through a switch between the 'determinative' and the 'reflective' modes of judgment. We mean that a 'determinative judgement' in one field could be an occasion for a 'reflective judgement' in another, and therefore give birth to novelty in this second field. Kant termed 'determinative' the judgment which placed the particular or singular under a universal, while he termed 'reflective' the judgment where the particular is given, and one has to find the universal, or the general rule, under which to place it [15: intro §IV, 15-16]. This insight favorably prepares Peirce's abductive views since, in the case of the living, Kant saw that its singular response, facing mechanical modeling forced on it from outside, might require from the experimenter to try to see if there would not be a greater fruitfulness in adopting the hypothesis of a causation by a final state [27: 271-288].

5. Conclusion: Open Remarks on Creativity

Thanks to an analogical transposition and translation of concepts, finding a logic of emergence of ideas is possible. In such a case, interdisciplinarity acts as the breeding ground of the abduction process where intuition captures the interlocking of two fields with no need of knowing the fields' structure and content. Peirce had observed that logic does not furnish us with new knowledge, because it does not speak of the relationship to the world but rather of relationships between terms and propositions, and he theorized that, for this very reason, there must be a capacity possessed by the mind which enables it not only to guess right, but to invite *reality itself* to take part in the process of inventing a scheme which will then be used to think this same reality adequately, and he went as far as holding that something in nature already 'syllogizes' before the human mind can start the questioning of the pathway it has followed [22: 175, 23]. It would be a step which, taking part in the logical progression of thought, would nevertheless contain a synthetic element, reconciling the intelligible and the empirical.

This could also be performed through the passage at a level where the concept is larger than what is targeted in a given discipline, with an open texture as happens very often in what we call common sense. If we were justified in so doing, we could see the metaphor, in line with its definition by Max Black, as a case of 'construing as.' In other words, thanks to the 'family resemblances' brought about by interdisciplinarity we would see an intuition able to detect a possible fruitfulness in another field, with the use of a concept that has been foundational in one field to see whether it could create new avenues for thought in another field.

But one question still remains: how can we be sure that this exploration of analogies and this creation of meaning still cope with reality? The process of discovery remains an enigmatic one. Arthur Koestler claimed that with the occurrence of invention there was a 'bisociation of matrices,' [16] and the interesting question is whether we can think its conditions of possibility. We know that abductive inference can rest upon a more common use of a concept in one field to search for its application and fruitfulness in another, by inventing a connection between the two that remains to be substantiated in its degree of certainty and provability: a "matter-of-factness" from an hypothesized law of principle [6: 8-9].

In order to answer Peirce's question about how human understanding may choose among possibilities the very one that copes with reality, we propose that the condition of possibility of an intuition able to detect a possible fruitfulness in another field is the testimony of the process of individuation of life and intelligence which is a process on the same kind as the one explored by Gilbert Simondon [26]. Because natural life and human thinking follow the same individuation process, analogies between biology and artificial intelligence can be legitimized. We suggest this common individuation process in reality is the foundation of the relation between analogical and logical thinking and that it can overtake the human determination of frontiers of species and disciplines.

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