DOI: http://doi.org/10.28939/iam.debats-en.2021-9
ISSN 2530-898X (print)
ISSN 2530-8262 (electronic)

What the #®¥§≠$@ is Creativity?

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Received: 28/04/2020
Accepted: 14/09/2020

ABSTRACT
Creativity is The Holy Grail of the Cognitive Sciences and it is very important for researchers in the Computer Sciences and AI fields. Although all attempts to explain and replicate intelligence have so far failed, the quest remains a key part of their research. This paper takes two innovative approaches. First, we see cognitive processes as involving rule-following and as flexible, even chaotic, heuristics. This first concept uses a multi-heuristic concept without any complexes as mixed-cognition. Second, we propose abduction which, though seldom employed in this specific debate, is nonetheless a good way to explore creativity. Using both strategies, along with analysis of specific human creativity cases, we suggest a new cognitive paradigm that is both more realistic and truthful than hitherto. The idea is to offer a new way to achieve more powerful, complex artificial reasoning systems.

Keywords: creativity, abduction, mixed-cognition, constraints, triggers, multi-heuristic.

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Suggested citation: Sans Pinillos, A. and Vallverdú, J. (2021). What the #®¥§≠$@ is Creativity? *Debats. Journal on Culture, Power and Society, 6*, 135-147. DOI: http://doi.org/10.28939/iam.debats-en.2021-9

To read this paper's title (whether in Catalan or in English), your mind has performed a creative act and has ingeniously grappled with the words it contains. Yet the truth is you have not improvised at all, even within the limited probabilities that your mind has analysed in choosing some words instead of others.

In this paper, we want to offer a raw picture of creativity. We will work with an amalgam of elements that are linked with one another in an erratic, disparate, anarchic fashion. In short, we will analyse an atypical concept of creativity to argue the case that the concept cannot be reduced to any given general pattern or model.

We consider that the information involved in the 'creative' process interacts in different ways, depending on the circumstances. We thus face a paradox, namely that there is no method that explains how to be creative. However, one can analyse what creative people do and explore the studies analysing them. Furthermore, one can talk about those moments when creativity emerges. This creative ability is not something that we merely indulge in for pleasure. That is because creativity often gives us our only chance of surviving in a hostile environment.

"HOUSTON, WE HAVE A PROBLEM!"

Let us recall this now immortal utterance by the Apollo 13 astronauts and ponder its meaning. The words teach us two things. The first is humans' amazing ability to creatively tackle and solve unforeseen problems (King, 1997). The second is that we are creative whether we want to be or not. While the words actually spoken were "OK, Houston, we've had a problem here", their meaning remains the same. External pressures force us to be creative in dealing with unforeseen events and in striving towards clear goals. Yet we can be creative in any circumstance. While not everyone is creative all the time (most people are creatures of habit and routine), it is something that is a hallmark of our species.

That is why there are no patterns for sparking creativity. Yet there are 'constraints' that facilitate the emergence of creative processes. Here it is worth noting that people combine many methods and heuristics in a wholly opportunistic and often unconscious fashion. We are not only rational agents but also natural problem-solvers who adapt to many conditions.

What makes the human mind even harder to fathom is the way it adapts to different settings and its ability to choose or combine many strategies or rituals (Currey, 2014) —an approach often termed 'heuristics'. Currey's recently-published book on the subject comes up with the innovative *blended cognition* concept to explain this ability (Vallverdú and Müller, 2019).

From an evolutionary perspective, humans have had to adapt and react to a wide variety of events. There are any number of problems we need to find answers to yet in many cases we lack sufficient information to be sure of making the right choice or are overwhelmed with information or have to make a decision on the spur of the moment. These intuitive ways of solving the various scenarios have been negatively labelled as 'biases¡. Yet from a technical standpoint, such intuitions are vital for our survival. Being able to take decisions and act without having all of the pieces of the puzzle has helped us survive. That is why there are many projects underway that aim to create chip-based and computing approaches to simulating this behaviour. Of course, one also needs to ascertain the scope and value of the approach used and the implications of its bias. Even common sense is a cultural product — something that is evidenced by code-switching among bilingual speakers (Kharkhurin and Wei, 2015). These metaphorical and ontological situations can contribute to the creation and design of new heuristics. For example, three-dimensional understanding of temporal events is very different at the metaphorical level between cultures: (a) horizontality perspectives, in which English understands future = forward / past = backward; Aymara future = behind / past = in front; (b) from verticality: Mandarin Chinese future = descending / past = ascending. This means that morphological cognitive mechanisms (Casacuberta *et al*,, 2010) are influential but not coercive, which means one should be wary of taking a naive realistic approach to cognition and creativity.

As well as the evolutionary perspective (which conditions our minds' morphology and actions), one needs to consider the cultural contexts — schools, families, social settings, and other learning centres all shape our strategies, producing as it were a 'grammar' and a way of reckoning that fits our skills at any given moment. For instance, with regard to Physics, what we study and know of the material world varies

greatly depending on whether we are in the 5th year of Junior School, the 2nd Sixth Form year, or the last year of a degree course.

This raises the issue of what constitutes a science and in the end justifies it. Even though we may not understand the science's foundations, we can still understand its rules. In other words, we learn these rules in parallel with their justification. Here one might note that it took Bertrand Russell and Alfred North Whitehead almost 379 pages to prove the mathematical foundations of addition in their three-volume monster-work *Principia Matematica*, yet children are schooled in 'adding' from a tender age (Wittgenstein, 1967: §§1-3). In other words, we learn to the extent that we understand the coherence that governs the things that are added (their temporality, mass, etc.), without having to logically justify the process involved.

The most fascinating insight yielded by the heuristic approach is the revelation that we combine dozens of trial-and-error techniques every day. We do not apply the same decision-making rules to what to have for breakfast, the best way to get home, choosing what to study, choosing a mate, or deciding whether to buy a house or rent. We have limited time to choose from among a host of options so our decisions end up being shaped by character, general context, and our acquired skills. Thus, we can see ourselves as contradictory beings: Slaver-Christians, scientists who are religious believers, or even Kantian Nazis (Vallverdú, 2019). We live in a multi-heuristic environment, where we show ourselves to be opportunists in action. In this context, the fundamental question lies in how we can choose.

THE MECHANISMS THAT ALLOW US TO CHOOSE OPTIONS: CONSTRAINTS/TRIGGERS

Given the host of mechanisms and options at hand for coming up with diverse strategies and actions, what — in creative terms — are the mechanisms that let us manage and draw upon this cognitive wealth? An optimal, widely-accepted approach is one that conceives of the process in terms of constraints and triggers. Both represent the operational bivalence of morphological and cultural aspects in drawing the bounds (and thus the constraints) of our reality while letting us use triggers to re-draw them and in so doing, changing our conception of the world.

The strength of this approach is that it allows us to address the logical and cognitive relationship of our reasoning to various degrees of materiality. This is so because on the one hand it lets us account for the interaction between the various agents. On the other hand, it sheds light on the interaction with the technological and other devices providing the information that shapes our concept of reality, which we round off through our web searches. The notion of constraint is rooted in psychological research on creativity (Csikszentmihalyi, 1996), whereas a trigger involves the incorporation — whether logical (Aliseda, 2006) or simply cognitive (Gabbay and Woods, 2005) — made by research on abductive reasoning.

Some aspects of who we are can be ascribed to 'nature'. These are well-nigh fixed because they form part of our individual morphology. Our character, such as the A1 mutation that creates fit and persistent people, or the constant restlessness aroused by the DRD4 gene ('The Wanderlust Gene') is the most basic system for assessing reality, and can also be affected by neurochemical variations (the rise and fall of neuro-transmitters such as dopamine, serotonin, and norepinephrine (Vallverdú, 2016). Other aspects of our character can be ascribed to 'nurture'. These include culturally acquired strategies, and even humour. This brings to mind a personal experience. Several years ago, our university research group solely focused on creativity. In many sessions we had to discuss certain aspects of Mihaly Csikszentmihalyi's work. Given that we knew no Magyar, we had no idea how to pronounce his name. In one session, researcher David Casacuberta made a great contribution by explaining a phonetic mnemonic rule so that we could get it roughly right: "Chick sent me high".

Aside from laughter, a socially cohesive fact, we learned an easy way to refer to the author. The idea and rule is

still etched on our memory to this day. Casacuberta's creative act proved highly effective and cognitively 'cheap'. The role of the unconscious work performed by the mind is also a factor in understanding certain highly creative processes, such as Kekulé's dream idea in relation to the chemical structure of benzene or the profound mathematical discoveries made in dreams by Indian mathematician Ramanujan. There are other environmental constraints, such as chance in an operationally 'controlled' context that makes us aware of an anomaly or unexpected fact — something that sparked many scientific discoveries (Roberts, 1989). Penicillin, X-rays, saccharin and many other discoveries were the result of such 'happy accidents'. The importance of the controlled context recalls Picasso's idea in relation to inspiration, which came to him while he was working. If many hours are spent on a given job, certain options open up to the researcher, which would explain why many experts often work independently on the same ideas. That said, it is a 'winner-takes-all' game in which the runners-up are consigned to oblivion.

Another group of cultural factors has to do with formal tools: natural language, specialised language, and the various systems for quantifying reality. Thanks to these tools we can think about reality and categorise it. Depending on the characteristics of the language used, one or more possibilities then open up, helping us think about and change our world (Schroeder and Vallverdú, 2015; Vallverdú 2017; Vallverdú and Schroeder, 2017). Western classical bivalent logics, which considered a proposition only true or false, did not fit the changing reality of the world. Although the temporal logics of the second half of the twentieth century remedied this shortcoming, ancient Buddhist thought had beaten them to a solution centuries before with the tetravalent logic of the *Catuṣkoṭi*.

Thought is impossible without words but using them draws the bounds of reality. As a result, words let us study certain things but not others. Creation is based on these tools and in some cases allows one to overcome them. We think that there is a need for metaphor in scientific thought. Yet poets transcend the reality of language, revealing previously hidden aspects simply by making freer use of syntax and semantics. At the same time, the language we use to understand our setting also conditions how we see the world and ourselves (Huang and Jaszczolt, 2018), and creates a cultural eco-cognitive environment that we can analyse in the creative traces of our history, such as archaeological objects (Criado-Boadoet *et al.*, 2019). The Cognitive anthropologists specialising in language have furnished a lot of evidence in this regard (think of the classical, well-studied Sapir-Whorf hypothesis). Some cultural psychologists have also made important contributions on these issues (Nisbet, 2004).

All these elements are hard to conceptualise through simple categorisation. One way to do so and use them precisely is by incorporating constraints into abduction research and show how they operate with triggers. This perspective lets us put the two elements on the same footing by seeing them in terms of the agent's cognitive strategies in his interactions with his setting. At the same time, such an approach helps blur the boundary between the two elements.

WHICH MECHANISM IS BEST FOR CHOOSING FROM AMONG MANY OPTIONS?

In the film *Star Wars: Episode II - Attack of the Clones* there is a scene in which Master Yoda is giving a lesson, where some *Padawans* are working on intuition. Using force, they try to stop the laser shots of the training drones with their light sabres even though their training helmets hinder them from spotting the drones. Suddenly, a bewildered master Obi-Wan comes in for advice. The problem that bothers him so much is that he cannot find a planet that a friend of his described to him because the files of the Jedi Order do not include the star system it belongs to ("I'm looking for a planet described to me by an old friend. I trust him. But the system doesn't show up on the archive maps"). Like Obi-Wan, Yoda is also surprised that the described planet cannot be located.

However, when Obi-Wan puts the file in the map reader, a change comes over Yoda, who no longer sees the problem in the same way. A set of systems and an anomaly can be seen in the projection, which Obi-Wan states thus:

> This is where it ought to be ... but it isn't. Gravity is pulling all the stars in this area inward to this spot. There should be a star here ... but there isn't.

Like Le Verrier with Neptune, Yoda already knows where the lost planet is, namely where there is nothing. Obviously, Obi-Wan's bewilderment does not lie in the concentration of matter and the possibility of a body attracting it, but in the fact that the planet that should emerge from the map does not. This is obvious in context because, unlike Le Verrier, he can check with all his senses whether or not there is a planet in that place (it is amusing to imagine Le Verrier piloting a Jedi starfighter to fly to Uranus and check the existence of Neptune). In addition, he is not surprised by Yoda's abduction of an existing planet as an explanation. That is why Yoda finds the situation so intriguing:

> Most interesting — gravity's silhouette remains, but the star and all its planets have disappeared. How can this be?

That's when one of the Padawan boys, in the purest style of Chevalier Auguste Dupin, states,

> Because someone erased it from the archive memory.

Yoda nods and remarks:

> Truly wonderful the mind of a child is. The Padawan is right, go to the centre of gravity's pull and find your planet you will".

In this scene we can ask the following questions: Why does Obi-Wan need to talk to Yoda?; How important is the latter in the scene?; How valuable is the Padawan's explanation? We are faced with a brilliant exercise in maieutics, where there is a dialectical relationship between the questions, producing a pedagogical outcome by yielding a possible if surprising explanation. As in the *Meno*, there is a management of information from ignorance (partial in Obi-Wan's case and utter in the Padawan's), through the questions of the only one of the three (Yoda) who knows what the other two do not but who cannot find the solution on his own.

It precisely when the Padawan gives his answer (that the data must have been erased), revealing Obi-Wan's partial ignorance. Even so, Obi-Wan objects:

> But Master Yoda, who could empty information from the archives? That is impossible.

Yoda, who has seen the light after the Padawan's childish but brilliant answer concludes thus:

> Is not. It dangerous and disturbing this puzzle is. Only a Jedi could have erased those files but who and why harder to answer. Meditate on this I will (sic).
>
> [As *Star Wars* fans know, Yoda speaks English like the green alien he is].

We thus see a situation in which the degree of knowledge being investigated by the group does not matter nor is the riddle solved by information other than that given. Here, the creative process is reduced to combining information in new ways to solve the conundrum. The Padawan's seemingly ingenuous comment opens the door to new research.

This *Star Wars* scene is relevant because it mixes different factors and actors. Basically, the personal paradigm of problem analysis is suppressed. This brings different kinds of knowledge into play to tackle the apparently unsolvable enigma. For example, as has already been said, Obi-Wan acts under the constraint of not having considered that a member of the Jedi Order may be a traitor. On the other hand, the constraints that lead the Padawan to suggest deletion of the records act as the 'trigger', broadening the range of possibilities and escaping the impasse by pointing to a new line of enquiry. In this paper, we advocate abduction as the operational basis of our reasoning, letting us constrain and trigger information, generating options from which choices can then be made.

Defining abductive reasoning is a tricky task. Attempts to account for this concept in a full-length description have been abandoned for some years. For now, the trend is to adopt a definition that fits well with the specific field to which it will be applied, while conserving the essential features of reasoning that were established at the beginning of this century. These features emerged from debate on the subject, giving rise to the interpretation represented by the non-explanatory GW scheme (Gabbay and Woods, 2005) and the explanatory AKM scheme (Alchourrón, *et al*., 1985, Aliseda, 2006, Magnani, 2009, etc.), in which there was broad consensus that abductive reasoning *is a process by which something that would be rejected under the classical approach might well be accepted by resorting to other kinds of reasoning* (Gabbay and Woods, 2005, Magnani, 2015, 2016, 2017).

Magnani's EC model commands fairly broad support when it comes to a definition of abduction. The model is based on drawing up a definition from the context (Aliseda, 2014[1]) to the point where some of the features formerly seen as basic are considered circumstantial — for example, whether abduction is an explanatory model (AKM) and should preserve ignorance (GW) (Magnani, 2017). This development has done much to defuse the debate while allowing issues that used to be considered unsolvable to be examined locally. An example of this is IB(A)E[2] (Harman, 1965, Schurz, 2008, *et al*.), which can now be understood contextually and applied computationally as abduction in which inference (or reverse deduction) yields the best explanation (Kakas, 2017).

This has made it possible to focus abduction research on how a problem unfolds in a given context without fretting over its essential characteristics. In other words, one can concentrate on what is given in any circumstance. Here, an abductive process is a reasoning that generates something new (fill-up) and that, among the options, allows one to choose one or more over the others (cutdown) and to identify any other kinds of knowledge yielded when a result is checked or compared in some way.

Unlike deduction, abduction broadens the result rather than yielding a necessary one. Unlike induction, this broadening is tentative. Here, one should distinguish the usual meaning of 'tentative' from the one it is given in this debate. Here, 'tentative' refers to the characteristic to be captured in the debate on abduction, and lies in added epistemic value shedding light on the reasoning. The insight gained is that the reasoning operates *as if it were* classical knowledge inasmuch as we use it as part of our epistemic baggage but without there being a one-to-one correspondence with it. In this case, one cannot make inferences from probabilities or generalisations. The latter role would continue to be played by induction, dealing with the traditional stage of verification and provisional validation found in the Natural Sciences. That is why abduction's epistemological value is one of the most controversial topics in the current debate. Indeed, Hintikka has highlighted abduction as the fundamental problem in contemporary epistemology (1998-9, 2007).

This problem arises from not bearing in mind the operations involved in abduction — a tendency that stems from 'The Inherited View of Science' in which there is a dichotomy between the context of justification and the context of discovery. It is widely held that justification is what can be explained (captured) through formalisation, while discovery is the set of psychological processes that combine in an anarchic (heuristic) way and as such, cannot be formalised. These heuristics are not considered to form

1 This is an excellent example of what I mean given that Aliseda continues to defend his AKM model but now focuses it on medical diagnosis. In an earlier publication ([A. C.] Rodríguez, *et al*., 2008), Aliseda considered that diagnosis represented abduction and that this could be formulated in terms of the AKM model.

2 Inference to the best explanation

part of knowledge in general (Popper, 2002[3]). This view stems directly from Frege's dichotomy between logic and psychology, in which he considered that a theory could only refer to those elements that could be described (Niiniluoto, 2014, 378). These boundaries are inherited from the distinction between analytical and synthetic (Putnam, 2002), which in the final analysis makes it impossible to describe the world other than in a way that is based on a hierarchy of specific parameters.

This inherited view draws directly from the kind of systems seeking to explain a given phenomenon. That is why they prove hopelessly unsuitable when they are applied to other kinds of descriptions of the world. An obvious example is the question of value, which is relegated to the realm of pseudo-psychology or, worse, to a type of 'intuitionism' — in short, such an approach cannot describe anything in the world (*ibid*.). However, even at the time there were dissonant voices defending a neglected view (Aliseda, 2006: 39). These voices argued that the explanatory models offered were unsatisfactory because they failed to: (a) explain the paradigm shift (Kuhn, 1996, Feyerabend, 2010); (b) consider the theoretical burden in explaining the observed phenomena (Hanson, 1971-2[4]); (c) the reality of research practice (Lakatos, 1976); (d) account for technological advances, as noted in Simon's critique of the then-emerging computing field (1977). This is interesting for two reasons. The first may not bear strongly on what concerns us here but it is this: Simon was an Economist and this discipline was and still is a controversial one within the Philosophy of Science. Reading Hanson, Simon states that if there is no logic to introducing new things, then there is no way to do so (*ibid*: 378). Yet Simon also felt that there might well be some underlying logic that lay beyond our ken, and that it could be captured through computing. Here, computing seemed a way of representing the heuristics that had been so blithely consigned to the realm of psychology and seen as irrelevant to the foundation of knowledge. He also thought that the use of computing might well change the status of some of the sciences, such as Economics.

All such discussions end up reaching the same conclusion, namely that neither classic Western logic nor a purely epistemological approach can give the whole answer. Abduction offers a way out of this impasse by re-introducing the psychological into logic but without underestimating it. Obviously, the most recent examples are those that make up the current spate of research, which seeks to capture the abductive element from sundry branches. Yet its goal is always the eminently practical one of finding out what kind of reasoning is involved in acquiring knowledge and how this can change.

The first aim is perhaps the classic one stemming from Peirce's pragmatism (CP: 5,348[5]) which sought to complete the transcendental aesthetic (Kant, 1961: 34[6]). This, in short enshrines the practical aspect of Pure Reason's architecture, postulating that experimentation is an action in which one interacts with the world.

The naturalised version of this interpretation lies in avoiding reductionism (Magnani, 2018) and instead seeking an ambit for those elements we currently see as psychological and that play a role in the most conscious (and least common) kinds of reasoning. Here, abduction helps in representing the most primary perceptual stages (Shanahan, 2005) where our minds are modified through interaction with

3 One should note Aliseda's warning (2006: 12) on the bad translation of the original German in the English version in which *Logik der Forschung* [Research Logic] was translated as The Logic of Scientific Discovery. [Translator's Note: The full German title was Logik der Forschung. Zur Erkenntnistheorie der modernen Naturwissenschaft, which could be translated as: *Research Logic. Towards an Epistemology of the Modern Natural Sciences*]

4 A good exposition and analysis of *Theory-ladenness* can be found in «Estany: 2011».

5 Reference taken from "Aliseda, 2006: 170", who cites directly from "Hookway, 1992: 18".

6 Reference taken from "Dilman, 1973: 2".

and manipulation of the environment (Magnani, 2018[a]), acquiring and generating knowledge in the process (Hintikka, 2007: 11). Yet this proposal can be read in the light of the EC model, thus preserving the application context. Those sciences that lost credibility when classical explanatory methods were applied gain epistemological status under the new approach, noteworthy cases being Archaeology (Shelley, 1996[7]), Medicine ([AC] Rodríguez, *et al*., 2008, *et al*.) and Psychoanalysis (Sans, 2019)[8], yielding new, unforeseen outcomes.

From this perspective, one can go further so that when the first perceptual stage and/or an unexpected fact calls for another kind of reasoning, abduction may ride to the rescue by embodying tentativeness to grapple with the creative process. Whether it is to conceive of a possible union of facts, or deal with an explanation emerging unexpectedly, abduction may spawn creativity by incorporating tentativeness. Given that abduction has often been linked to hypothetical reasoning (Harman, 1965, *et al*.), we can grasp Łukasiewicz' argument (1970) that states that creativity is present in all reasoning — for example, when capturing the facts of the world through generalisations, laws, and so on.

Nevertheless, this creativity operates more intensely in cases where other methods of reasoning cannot account for the fact, namely, when generating hypotheses (which we easily grasp as possibilities). Łukasiewicz understands the generation of hypotheses through reduction[9] (*ibid*: 7), whose creativity would differ from say deduction (which reconstructs) whereas reduction constructs. Thagard (1988) also sees abduction as a bridge between justification (hypothetical-deductive) and discovery (psychological). For him, abduction is the way to generate hypotheses (*ibid*: 51-52) from a concatenation of active rules that lead from the *explanans* to the *explanandum*. As with Harman's lemmas (1965: 91), Thagard's active rules are the gnoseological content that allows relationships to be made that cannot be glimpsed solely by making associations or generalisations. The result of the abduction is a projected-truth, which is determined by the plausibility of the same hypothesis. This plausibility arises from different constraints. Some of these are as obvious to us as the enumeration of observable cases. Yet other constraints are not so apparent and thus much less account is taken of them within a given cosmology. Le Verrier — the astronomer who posited the existence of Neptune — furnishes a good example of the latter. The planet was merely a hypothesis until Arret and Galle observed it (Grosser, 1979: 117). It is interesting because the reasons why it was considered a projected truth (Sans, 2017: 85-88) were: (1) the high plausibility of the hypothesis born from existential abduction (Thagard, 1988: 54), and (2) it was based on a harmonic conception of the Cosmos[10] plus a set of mathematical calculations.

However, this relationship between abduction and creativity is the same as other abduction theories insofar as it cannot give a clear answer to generation (fill-up) and choice of hypotheses (cutdown). That is why we seek to understand the creative path taken by the individual in the community, in which generating and choosing options is a shared activity. In this sense, one needs to discard the notion of a creative individual who is cut off from others or who is 'divinely' inspired (Feyerabend, 1987). That is because we share in one another's actions in managing the flow of information we receive throughout our lives. It is this sharing that spurs creativity. Because of this, the conceptual elements with which we build our systems can be broken down and combined as we see fit *(ibid*: 704), enabling us to use them in whatever way yields the best results.

7 Feyerabend (2018) began archaeological studies to justify his criticisms of the concept of process that the inherited vision has given rise to. His views on the subject have been vindicated.

8 This makes us think of Rivadulla and his argument for improving the inherited view by appropriating pragmatism (Rivadulla, 2015: 23-46).

9 Reduction is the term traditionally used to translate the passage in Aristotle (1995: 25, 20-35) in which he speaks of *ἀπαγωγή(apagōgē)*, which is to say, of abduction.

10 This was how 'planet' was thought of at the time.

WHAT IF CREATIVITY IS IRRATIONAL?

We can extract several ideas from the ground covered so far: (a) creativity is an evolutionary mechanism; (b) there is no single model for explaining creativity; (c) cultural constraints both allow and limit creative capacity. So, can we consider the possibility of formalising creativity? The answer must be no, but this should not make us believe that creativity is ineffable. While there are machines that have overtaken humans in mental challenges such as chess (IBM's *Deep Blue*) or Go (Google-*DeepMind*, *AlphaGo* and *Alpha Zero*) by following certain strategies, none of them have shown themselves capable of efficiently applying their 'mental schemes' to all the problems affecting humans. Nor can the machines reprogramme themselves and decide between computational systems, from a naturalistic perspective of algorithmic cognition (Zenilet *et al*., 2018). At the same time, causality disappears, lost in an indecipherable welter of opaque data (Pearl and Mackenzie, 218).

There are interesting strategies employing deep learning, genetic algorithms, and multivariate logics that can be formalised in artificial systems yet it is not possible to programme a synthetic creativity (Vallverdú, 2013). Just as epistemologists (who take cognition into account) consider that humans make approaches that are 'sufficiently reasonable' (Elgin, 2019), artificial approaches to creativity must consider computing design, and variable constraints that allow systems to glimpse a certain creative horizon. Here, machines have to pay the same price that we do by venturing into the realm of fallibility and uncertainty, making irrational bets driven by intuitions. In any case, the computational paradigm goes first through a characterisation of human cognition as it relates to creativity.

A viable approach lies in the characterisation of abduction parameters from the cognitive EC proposal (Magnani, 2009), which tries to characterise how the environment affects us when it comes to generating knowledge. In other words, it looks at the role that context plays in determining how hypotheses are spawned as we interact with those around us. Every step determines the path taken, with each twist and turn leading to new opportunities. Within all the parameters, the key thing to bear in mind is that abduction generates a state of uncertainty *vis-à-vis* a fact we cannot account for by other means either because we lack previous experience or because it is presented to us in a way that it different enough for us not to recognise it for what it is (Aliseda, 2006: 46). This sparks emotions and sensations that impel us to apply different strategies to grapple with the uncertainty. Although these strategies are hard to conceptualise, abduction theories have worked on the element of surprise — a line of enquiry whose beginnings go back to Peirce (CP 5.188-189, 7.202, *et al*.). One way of grasping this concept in the modern world lies in capturing surprise as an event that violates pre-existing belief (Gabbay and Woods, 2005: 82). Another classic trigger is ignorance, which can be traced back to the Socratic method of dialectically nudging the agent towards knowledge by showing ignorance. In contemporary terms, the difficulty lies in assigning epistemological value to this state of 'unknowing'. The characterisation of abduction yields the aforementioned 'tentativeness', which conserves a measure of ignorance. Here, one should note that ignorance is never total. On the one hand, this lessens the element of surprise because we are less taken aback when what is shrouded from our sight is revealed. Put another way, there is a heuristic relationship between the elements making up the context and the surprised agent. We refer to everything cultural and circumstantial that: (a) makes the surprise possible; (b) helps to solve the problem. We must also bear in mind knowledge of our ignorance — something that impels us to fill the gap in our knowledge.

All these facts interact with the context in the quest for an answer yet they are also constrained insofar as the same culture and material factors that help form hypotheses also place limitations on testing them.

CONCLUSIONS

So far, when we have talked about creativity we have only done so from a human cognitive perspective yet it is a skill that can be found in other biological species

ranging from mycetozoa (slime moulds) to insects and all kinds of animals, notably chimpanzees (Sawyer, 2011). As an open topic, approaches to creativity still start from resolutions to specific problems where other proposals crop up along the way and that better guide the debate. We propose a solution that does not fall into the trap of identifying one element with another. This is because we see each process as having an identity all its own, with each aspect affecting the outcome in a given way. We have presented this from an eco-cognitive point of view in which it is taken for granted that the person plays at least an essential natural part and almost always a social part (a Mowgli or Tarzan would only play the first part). This is why one needs to interpret the signs that let a human being act in a conscious fashion and to learn things from our fellow men. Robinson Crusoe and Chuck Noland [the film character of *Cast Away*] owed their language and culture to a Desert Island. These elements let one draw and delimit a given reality (constraints) that also contain the key (triggers) to widening those bounds. This is done by combining the host of codes differently (multi-heuristically, in a blended fashion). We have identified abductive reasoning as the basic element of our cognitive apparatus when it comes to generating and choosing different responses, many of which can be considered to be creative. At the same time, for this reasoning to operate, constraints and triggers are needed. These are extracted from the many ways of combining diverse (heuristic) pieces of information.

It is interesting to see the extent to which rational agents perform tasks by combining multiple theoretical and action management patterns. This rationality involves situated, contextual adaptation by each individual in tackling the problem he wants to solve. A degree of fallibility and lack of completeness only spurs alternative ways of seeing reality. Creativity does not mean recombining a finite number of concepts in a game played with unchanging rules. On the contrary, it involves an ability to create new meanings even if one has to resort to novel ways of processing information.

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