Creativity and self-organization: contributions from cognitive science and semiotics

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ABSTRACT

What sort of contribution has Cognitive Science to offer to the understanding of creativity? Is it appropriate to investigate creative processes from a mechanistic perspective or do they involve subjective elements which cannot - in principle - be investigated from such a perspective? These two basic questions will guide this paper which investigates creativity focusing on the nature of abductive reasoning. As an initial hypothesis we characterize creativity as a self-organizing process in which abductive reasoning occurs allowing the expansion of well structured set of beliefs. This process is considered a part of the establishment of order parameters in the flow of information available to self-organizing systems. In this sense, we argue that a deeper understanding of how self-organizing processes involving abductive reasoning may take place in dynamic systems could assist Cognitive Science in its study of creativity.

1 INTRODUCTION

It is our objective in this paper to investigate the contrast, as commonly perceived, between mechanistic and anti-mechanistic approaches to creativity. In order to do so we will first of all address this opposition in the context of cognitive science. Then, we will present a classification of creativity proposed by Boden (1990; 1996) according to which two senses - historical and psychological - of creativity are distinguished. In both senses, as we will indicate, creativity is related to abductive reasoning, as introduced by Peirce (1931-1958). Finally, abductive reasoning is described in terms of the activity of dynamic self-organizing systems. We claim that such a description allows us to indicate a way out of the opposition 'mechanicism versus anti-mechanicism' in relation to creativity. We will conclude that the experience of surprise is essential to creativity.

2 CREATIVITY, MECHANICISM AND ANTI-MECHANICISM

The contrast between creative and mechanistic processes of information has always been a common characteristic of objections addressed to the mechanistic approach to the mind proposed by cognitive science (according to which intelligence can be modelled by a Turing machine). Thus, for example, in the early stages of artificial intelligence we find such a contrast in an objection discussed by Turing (1950) in his well known article 'Computing Machinery and Intelligence', addressing Lady Lovelace's remarks on the impossibility of creative computers. In the nineteenth century, she argued that computers can do only what their programs allow them to do, and in this sense they do not constitute good instruments to understand creative thinking. Even though her remarks seem to be intuitively true they leave unexplained the nature of creativity. Apparently, the reason why a computer could not be creative, in her terms, is the absence of novelty in its flow of information processing

In response to the remark of Lady Lovelace, Turing insists that computers often surprise him in his expectation about their performances either because he is distracted or because he forgets the calculations involved in specific tasks. However, by rejecting Lovelace's objection to mechanistic approaches to creativity, Turing seems to ignore the importance of *experiencing* surprise in creative thinking. Although he conceives the possibility of machines surprising us, he does not consider the possibility that machines themselves could be surprised (not even in his list of the 'Arguments from various disabilities').

One hypothesis we would like to consider here is that creativity is directly related to the ability of being surprised. This ability, in turn, is related to problem solving activity in which explorations of problem spaces lead to the expansion of belief domains. A successful expansion of beliefs is initiated by (and then eliminates) the feeling of surprise.

General heuristics have been described to guide search processes in problem solving activities; they include strategies for examining, comparing, altering and combining concepts, strings of symbols, and the heuristics themselves. However, critics insist that, despite their general appearance, heuristics are shaped for specific purposes and computers incorporating them will only do what their programs tell them to do: no real creativity is involved in their activities, so the history goes.

But what kind of creativity is under discussion in this context? The natural answer is that it is the one which we humans experience in our everyday life: the experience of new and original ideas that we value, either of our own or of others. This personal evaluation or appreciation of creativity makes it difficult to be analysed from an objective perspective.

In this context, Peirce (1931-1958) proposed the concept of *abduction* as a candidate to explain, from an objective perspective, a form of inference upon which creative reasoning is based. As we will attempt to show in section III, the feeling of surprise seems to be the triggering element of abductive reasoning. Before going on to this topic, we will investigate briefly the notion of creativity on the basis of the work of Boden (1990; 1996).

3 CONCEPTUAL SPACE AND TWO SENSES OF CREATIVITY

According to Boden (1990: 30) surprise and value, though important, are not enough to consider an idea as creative: “To be creative, is not enough for an idea to be unusual – not even if it is valuable, too. Nor is it enough for it to be a mere novelty, something which has never happened before”. She proposes to analyse creativity in terms of exploration and transformation of conceptual spaces. These are, as she stresses, multidimensional structures organized in accordance with principles that unify a domain of thinking. Such principles constitute the *generative system* that underlies a certain domain and defines its range of possibilities. Explorations in domains of thinking often lead to the expansion and, sometimes, to useful transformations in their structure which provides the basis for novelties.

It is the process of expansion and transformation of what is possible in a conceptual space that can be called truly creative. From this perspective, Lady Lovelace’s objection indicates that mechanic processes can merely search through the conceptual spaces that human beings provide for them and are incapable of changing spaces by or for themselves.

An important contribution to the study of creativity in the domain of Cognitive Science is given by Boden's analysis of how exploration in conceptual spaces may lead to relevant novelties in the domain of music, visual arts, literature and science. In science, for instance, she investigates Mendeleyev's creative process with the proposal of the periodic table in the 1860s: initially he classified chemical elements in rows and columns according to their similar observable properties and behavior. In his processes of classification he left some gaps, predicting that in the future new appropriate elements could be discovered to fill them. Several years latter such elements were discovered whose properties satisfied his predictions and, moreover his table led to a more powerful classification of elements in terms of atomic number. This, in turn, explained the gaps originally left by Mendeleyev in his original classification.

Examples like the above illustrate situations in which mapping and explorations in conceptual spaces may lead to the expansion and generation of new ideas. Sometimes changes in conceptual spaces may lead to radical transformations, and not just expansions, in the constraints that define them. In this context, Boden (1996) describes the structural changes found in the development of post-Renaissance Western music based on the generative system known as tonal harmony:

"From its origins to the end of the nineteenth century, the harmonic dimensions of this space were continually tweaked to open up the possibilities ... implicit in it from the start. Finally, a major transformation generated the deeply unfamiliar (yet closely related) space of atonality."

After investigating the steps of the process of undermining the notion of 'home key', which led to atonal music, Boden stresses that the final, culminating, transformation realized by Schoenberg was the adoption of different constraints (such as the usage of every note in the chromatic scale) to structure his atonal music. Schoenberg's creativity consisted not just in the rejection of a constraint, but also in the generation of new ones which allowed new forms of musical compositions.

In summary, the essential contribution given by Boden to the understanding of the origins of new ideas lies in making clear that conceptual exploration leading to the expansion or sometimes to the transformation of their generative structure can be seen as a form of creativity.

Moreover, she suggests two senses in which creativity should be described. The first focuses on the psychological aspects which characterise a creative (individual) mind in its uniqueness: "A valuable idea is P-creative if the person in whose mind it arises could not have had it before; it does not matter how many times other people have already had the same idea " (Boden 1996)

In contrast, the second sense of creativity stresses its *historical* characteristics: "A valuable idea is H-creative if it is P-creative and no one else, in all human history, has ever had it before" (Boden 1996).

Acknowledging the role played by cultural values in the classification of ideas as creative or not (given that worthless new ideas are not considered creative), Boden is mainly concerned with the question of "what does it mean to say that an idea could not have arisen before?". She distinguishes ideas that are merely novel ones - that can be produced by the same set of generative rules which produced other familiar ideas (as in Mendeleyev's classificatory procedures) - from radical and genuinely original ideas that cannot be produced in this familiar way (like Schoenberg's atonal music). The appearance of such new ideas presupposes going beyond the limitations of the pre-existing conceptual area in which they would not have found their natural space. As Boden (1996) stresses:

"... the ascription of creativity always involves tacit or explicit reference to some specific generative system ... It follows that constraints - far from being opposed to creativity - make creativity possible. To throw away all constraints would be to destroy the capacity for creative thinking. Random processes alone, if they happen to produce anything interesting at all, can result only in first-time curiosities, not radical surprises."

In this sense, creative thinking seems to presuppose: (a) some form of recognition of the principles and regularities that structure and, consequently, constrain a well established conceptual space, and (b) a subsequent impulse to overcome them. As we are going to see in the next section, these two steps involved in creative thinking constitute the basis of abductive reasoning as proposed by Peirce.

4 CREATIVITY AND ABDUCTIVE REASONING

According to Peirce (1931-1958), the production of habits constitutes the main activity of the mind. A network of strong habits, in turn, gives place to beliefs on the basis of which novelties, followed by the experience of surprises, may exist:

"For belief, while it lasts, is a strong habit, and as such, forces the man to believe until some surprise breaks up the habit" (CP 5.524).

On the basis of well established beliefs, embodied minds operate in everyday, habitual, life with expectations (from oneself and from others) that allow the anticipation of events. Fortunately, these expectations are fulfilled most of the time, but given the dynamical character of life sometimes there is a conflict between well established beliefs and the environment in which organisms exist. This conflict produces in the mind a *surprising effect,* which according to Peirce, may be active or passive. The first occurs "... when what one perceives positively conflicts with expectations". The second kind of surprise occurs "...when having no positive expectations but only the absence of any suspicion of anything out of the common something quite unexpected occurs, - such as a total eclipse of the sun which one had not anticipated" (CP 8.315).

Under the effect of a surprise, which confronts expectations produced by well established beliefs, several doubts appear in the mind stimulating it to inquiry until the experience of surprise disappears. Given the nature of beliefs (understood as strong habits), doubts will not disappear easily. They will persist until a new set of beliefs arises, transforming the surprising situation into 'a matter of course'. It is in this process of expansion or abandoning of well established beliefs that creative thinking may happen.

One of the greatest contributions of Peirce for the study of creativity resides in his analysis of the process of generation of new beliefs presents in creative reasoning. In a well known passage, he suggests the following logic description of creative reasoning, known as *abductive reasoning*:

A surprising fact, C, is observed.

But if H were true, C would be a matter of course.

Hence, there is reason to suspect that H is true (CP 5.189).

Peirce stresses that abductive inference, underlying creative thinking, does not provide absolute guarantees about its correctness: abduction is a fallible, but extremely useful form of reasoning guiding the mind in its attempt to free itself from doubts. He expresses his wonder about the organism's tendency to 'err' in the right direction when acting on the basis of this "natural instinctive faculty" :

"This Faculty is at the same time of general nature of instinct, resembling the instincts of animals in its so far surpassing the general powers of our reason and for its directing us as if we were in the possession of facts that are entirely beyond the reach of our sense. It resembles instinct too in its small liability to error: for though it goes wrong oftener than right, yet the relative frequency with which is right is on the whole the most wonderful thing in our constitution" (CP 5.173)

As is well known, Peirce does not restrict abductive reasoning to the human mind. He also insists that thought is not an exclusive capacity of the human brain:

"Thought is not necessarily connected with a brain. It appears in the work of bees, of crystals, and throughout the purely physical world; and one can no more deny that it is really there, than that the colours, the shapes, etc. of objects are really there" (CP 4.551)

At the same time, his use of terms like 'instinct' in relation to abductive reasoning could be taken as an indication that he would have considered abductive reasoning as a property of naturally evolving organisms, and not of artificially created, mechanical, systems. Moreover, Peirce related abduction to the experience of surprise, something that could be seen as outside of the capacity of artificial mechanical systems.

The experience of surprise, as produced by the perception of events that do not conform to expectations generated by well established beliefs, constitutes the first step of abductive reasoning underlying creative thinking.

The common element to different creative systems seems to be the process of generating new habits. In living beings, the ability to create and change habits allows organisms to act in order to further their own survival and to adjust their behaviour in accordance with environmental requests, changing the environment and being affected by it in a circular feedback way. But, how are we going to understand this whole process of adaptation in the case of artificial creatures? What would be the reason for them to change their habits when confronted with new events? And more, what would be for them the equivalent of our experience of surprise, which initiates abductive reasoning?

To conclude this paper we will investigate these questions in the context of the self-organization paradigm. But before doing that, let us summarise our main topic here: according to Peirce the role played by abductive reasoning in creative thinking is directly related to the experience of surprise, which initiates the process of generation, change and expansion of beliefs understood as a form of strong habit. This, we claim, is similar to the process of expansion of conceptual spaces suggested by Boden, as presented in the previous section. The main similarity between the ideas of Peirce and Boden resides in the supposition that the mind, in its tendencies to operate with well stabilised forms of beliefs, sometimes experiences the perception of anomalies or unsolvable problems in the domain of existing beliefs. Surprise and doubts initiate the abductive process of search of those possible hypotheses that, if proved true, could resolve the problem in question. However, Boden, in contrast with Peirce (but not with Turing), does not seem to attribute any importance to the experience of surprise in the creative process. Would this difference make any difference (to use Bateson's notion of information) for the investigation of creativity?

5 SURPRISE AND THE EXPERIENCE OF OVERCOMING CONSTRAINTS: ANY CONTRIBUTION FROM THE THEORY OF SELF-ORGANIZATION?

If creativity involves, in general, a set of well structured beliefs, which operate as constraints in relation to which surprising facts can be experienced, how are these constraints produced in the first place? We propose to examine this question on the basis of the Theory of Self-organization (TSO). As pointed out in Gonzalez and Haselager (2002), the label ‘self-organization’ refers to a process through which new forms of organization emerge mainly from the *dynamic interactions* between elements of a system without any *a priori* plan or central controller. According to Debrun (1996) and Gonzalez (2000) it is important to distinguish two basic phases in a self-organization process; the primary and secondary phase of self-organization.

In the *primary phase*, organic or inorganic elements initially separated (or with independent behaviors) get together, ideally by chance, initiating an interaction amongst themselves in such a way that they become coordinated and interdependent. In this primary phase, such an spontaneous interaction may give place to new structures or distinct forms of organizations. It is “...self-organizing in the sense that it changes from *separated parts* to *parts joined*” (Ashby 1962) without the presence of any kind of pre-established program.

In cognitive science, examples of primary self-organization are found in processes of pattern formation in neural networks. These patterns emerge from the interaction of a large number of neurone like units that send excitatory and inhibitory signals to one another. Even though the activity of individual units may be governed by local rules, the emergent overall pattern, produced by a collective effect, is not rule governed. In other words, even though each singular unit plays a role in the organizational dynamics of the net, the property that really matters to its final emergent organization is a *collective*, self-organizing, one.

A further aspect of TSO is that the dynamic interaction amongst the system constituents may allow the emergence of an order parameter. As characterised by Haken (1999), order parameters result from the interaction between low-level components. They constitute high-level patterns which, once created, constrain and control the behaviour of the low-level components. These, in turn, may change, in a circular feed-back way, the high-level order parameters. The dynamic of order parameter formation characterises the *second phase of self-organization*.

As indicated by Gonzalez (2000), the dynamics of order parameters formation distinguishes artificial neural nets from traditional machines. Initially, the net's units have little or no relevant interdependent relations amongst themselves. With training, primary self-organization may take place; each unit is affected by other units, forming patterns of connectivity. Their organizations emerge mainly from the dynamics of *competition, co-operation and adjustment* established between the net's units and informational patterns in the environment. Temporarily, different forms of organization may emerge from the primary process of self-organization, but only one of them will evolve. In order to do that neural nets have to acquire the ability to allow the emergence of order parameters. If such a condition is fulfilled, and considering order parameters as a form of *habit*, then we may look at neural networks as possible candidates to help us to understand creative thinking.

So far we have argued that creative thinking can be understood as a self-organizing process in which abductive reasoning occurs allowing the expansion of well structured beliefs. The emergence of order parameters is essential to understand this process, because it shapes the flow of habits generated by self-organizing systems, operating as constraints. Furthermore, the theory of self-organization provides many examples of cases where a system with a well established order parameter (i.e. a stable behavioral pattern that constitutes a habit) can suddenly jump to a different state after encountering a disturbance. This sensitivity to perturbations is a central characteristic of dynamical systems that are on the verge of changing the order parameter.

We submit that creativity as involving abductive reasoning can be partially understood from this dynamic perspective. Through secondary self-organization a system behaves within the confines of a stable set of order parameters (habits). Under certain circumstances the appearance of disturbances provides sufficient conditions for the system to change its behavioral mode into an entirely new and different stable pattern. Thus, abduction can be partially understood as a self-*re*organization of the system into a new order parameter in response to perturbations by the environment. We say 'partially' because, as mentioned, abduction involves, in general, the experiencing of surprise, which requires a background of an intricate web of interconnected habits. In the case of humans, beliefs are socially, biologically and historically created and sustained. But, in the case of artificially created creatures, what would be the equivalent of this scenario?

To conclude this paper we are going to investigate the possibility of creativity in robot-environment systems like Roboser (Verschure 1996), which incorporates circular feedback and self-organizing mechanisms. This system contains a light-sensitive robot which moves around, propelled by external sources of light, on a flat surface. As it is designed, Roboser has a mechanism of aversion to any sort of physical contact, so that while it is attracted to light, it will run away whenever its body touches any object.

Now, would it be correct to suppose that Roboser is a creative system? At first glance, the answer is no; according to our common sense notion of creativity presented in the introduction of this paper, it does not make sense to talk about creativity in robots because they are pre-wired systems with no freedom to choose any particular item available in the world. However, if we include in them, as is the case with Roboser, circular feedback and self-organization mechanisms, then it becomes difficult to give an uncontroversial answer to this question.

The difficulty occurs, in part, because Roboser operates mainly on the basis of independent habits; it does not have beliefs. As a consequence, it does not have criteria of relevance for distinguishing between appropriate and inappropriate habits. Moreover, Roboser is unable to generate (or examine) its own conceptual space. In this context, it becomes difficult to see how Roboser *could* be 'surprised' with a new event while it is moving around. Could Roboser (or a more sophisticated robot) develop, in a self-organized way, its own set of beliefs and notice its conceptual space because of a surprising event? We do not have a response yet to such questions, but it does seem clear that a deeper understanding of biological, historical and social aspects of cognition is essential to provide an appropriate answer to them.

6 CONCLUSION

In section I we raised the question whether machines themselves could be surprised (in contrast with machines surprising us). As we indicated in section III, surprise contains an *experiential* component. It is the realization that something is blocking the usual path or that something unusual is happening – in the background of beliefs – that abduction initiates. Combining this with Boden's suggestion (quoted in section II) that constraints make creativity possible, we would like to suggest that *the surprise comes from the sudden realization that the constraints exist*. The surprising event *reveals* the existence of the constraints that normally and often invisibly guide our habitual actions and experiences. In this circumstance, creative systems adjust their behaviour by transcending the constraints (i.e. anomalies) or through abiding by them in unexpected ways, thereby drawing attention to the regularity itself. Once one becomes aware of the generative principles constituting the conceptual space, it is possible to transform them deliberately (and not just through random processes).

We have presented some ideas on the nature of creativity and the theory of self-organization. From this perspective it seems that the contrast between creative and mechanistic processes looses its strength. Creative minds seem to deal with great amount of mechanical processes, particularly in the production of habits and order parameters. However, creative systems not only have the capacity to create habits but, in addition, have the capacity to experience surprise and then are able to self-organize to dissolve, temporarily, this feeling of surprise. Ultimately, then, it is the capacity to experience surprise, to feel habits being thwarted, that differentiates creative organisms from purely mechanical systems.

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