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Understanding the Process of Creation: a New Approach

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Abstract: Our contemporary civilization increasingly relies on creative approaches and solutions. This growing dependence makes issues of control, regulation and management of the process of creation ever more important.This article finds two major current theoretical perspectives on creativity and the process of creation to be vulnerable in one important respect: their explanation of the production of disequilibrium, which plays a singularly important role in the process of creation, does not pass the test of rational justification. This article suggests that the production of disequilibrium is intimately related to equilibration — the essential operation of rational thought processes. The emphasis on the role equilibration makes a rational justification of the production of disequilibrium possible. The new theoretical perspective opens the path toward a comprehensive and objective understanding of the process of creation, which is the main condition for regulating, controlling, and managing this process.

Key words: Creativity, the process of creation, equilibration, the production of disequilibrium, Margaret Boden, computation.

JEL classification: B59,O31

1. Introduction

Every age has its defining characterization. If one had to choose a characterization for our age, the most likely candidate would be “the era of creativity” (Kirstetter et al., 2013). Creativity is at the center of public attention. It is the subject of discussions by politicians, scientists, business people, media and public figures, and by ordinary people. We expect creativity to bring enormous benefits to our economy, expand our horizons, solve our problems, and provide aesthetic enjoyment and gratification. There is hardly any sphere of life in our civilization today where creativity would not be regarded as an extremely important asset.

The volume of literature that deals with creativity and the process of creation is enormous and constantly growing (Machlup, 1980; Nonaka, 1994; Nonaka and Takeuchi, 1995; Wierzbicki and Nakamori, n. d.; Davenport, Jarvenpaa, and Beers, 1995; Davenport, De Long, and Beers, 1998; Nonaka, Krogh, and Voelpel, 2006; Brocke and Rosemann, 2010). Given the importance and the amount of attention that is focused on the subject, this fact hardly comes as a surprise. We seek to gain a better understanding of creativity in order to control and enhance our capacity to create. There is certainly no shortage of theoretical perspectives that try to explain creativity and the process of creation. Yet the sad fact remains that our understanding of the process of creation remains very rudimentary, to say nothing about controlling it. Margaret Boden, one of the pre-eminent researchers in artificial intelligence, draws the following conclusion in her very influential book on creativity:

> Our ignorance of our own creativity is very great. We are not aware of all the structural constraints involved in particular domains, still less of the ways in which they can be creatively transformed. We use creative heuristics, but know very little about what they are or how

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> they work. If we do have any sense of these matters, it is very likely tacit rather than explicit: many people can be surprised by a novel harmony, but relatively few can explicitly predict even a plagal cadence (Boden, 2004, pp. 145-46).

And as to the thought processes involved in creative acts, Boden thinks that it "will be many years, if ever, before we can identify them in scientific terms" (Boden, 2004, pp. 145-46).

Not withstanding such pessimistic predictions, the interest in the process of creation hardly subsides. It continues to intrigue and attract new researchers who probe the mysteries of creativity in their studies. All signs suggest that the fascination with the subject will not diminish and is likely to grow.

2. Critique of the Current Approaches Toward the Study of Creativity

So, what is creativity and what is this mysterious process that makes it possible? There is no shortage of definitions that try to capture the essence of creativity, but perhaps the simplest one will do best: creativity is the capacity to perform creative acts; and creative act is an instantiation of the general process of creation. The problem involved in explaining creativity appears to be deceptively simple. Creation represents a radical break with the past and the emergence of something that has had no prior existence. Creation disturbs balance and violates status quo. It is decidedly about disequilibrium. So, naturally, in order to explain creativity and the process of creation, we have to explain what produces disequilibrium. And that is where the problem arises.

There are two principal theoretical approaches in creativity studies that explain the production of disequilibrium. One of them has its roots in biology and particularly in the neo-Darwinian theory of natural selection. It sees randomness—random transformations or mutations—as the principal mechanism for producing changes that are then selected for fitness (Deutsch, 2011a; Deutsch, 2011b; Sweller, 2009). For John Sweller, there does not seem to be any alternative to randomness in explaining the production of creative disequilibrium. Randomness, he concludes, "is not only required by evolution by natural selection to explain biological creativity, it may similarly be required for human creativity;" and more affirmatively, "randomness as genesis principle provides the basis for human creativity" (Sweller, 2009, pp. 15-16).

The other approach downplays the significance of randomness in producing disequilibrium and places more emphasis on controlled and disciplined procedures performed by humans. Margaret Boden, whose influential book *Creative Mind* is widely regarded as one of the most authoritative studies on creativity, sees play and exploration as having an important role in producing creative changes. She regards both as the type of disinterested activities that are performed for their own sake. It is in the course of play or exploration that individuals "tweak" the generative rules or styles that operate in a given conceptual space and produce new ones that radically change this space and create radical novelties. Boden writes:

> The deepest cases of creativity involve someone's thinking something which, with respect to the conceptual spaces in their minds, they couldn't have thought before. The supposedly impossible idea can come about only if the creator changes the preexisting style in some way. It must be tweaked, or even radically transformed, so that thoughts are now possible which previously (within the untransformed space) were literally inconceivable (Boden, 2004, p. 6).

In play and exploration, creative individuals "think in a disciplined manner," Boden observes,

> . . . they may be playful, but they aren't merely playing around. When something of potential interest turns up as a result of their playfulness, they focus on it—accepting, amending and developing it in disciplined ways. Only when it fails, or when the limits of its potential are glimpsed, do they turn to other things—perhaps, by transforming the old space into a radically different one (Boden, 2004, p. 319).

In order to be considered valid, any theory must pass the muster of rational justification. In other words, it should provide a logical proof that what it asserts has no logical reasons for denial. Logical justification is an assurance that we can trust the thinking that has resulted in creating a theory under consideration. In-

sufficient justification, justification that is logically flawed or is simply absent sends an important signal that there is no conscious control over the entire theoretical construct offered to us for consideration, which makes such construct vulnerable. Let us see then whether the two perspectives on the production of disequilibrium in the process of creation can pass this test of such validation.

The idea that randomness plays an important role in the process of creation owes its inspiration to quantum mechanics that views physical reality as ultimately uncertain and indeterminate. Francis Bailly and Giuseppe Longo (2007), for example, relate randomness to quantum non-separability and non-locality; they regard randomness as an intrinsic property of the phenomena that occur on the level of elementary particles—the level that they, among many others, consider the most fundamental to nature. Geoffrey Hellman in his piece "Einstein and Bell: Strengthening the Case for Metaphysical Randomness" (1982) makes a similar argument in support of the ultimately random behavior of quantum mechanical systems. Others, like Jean Bricmont and Hans Primas, see ontic determinism lurking behind the appearance of quantum randomness (Bricmont, n.d.; Primas, 2002).

Despite the fact that the two positions are diametrically opposed to each other, they do share some unsettling questions: If you have some random or deterministic phenomena, how do you know that they are truly random or truly deterministic? Can one demonstrate that the randomness or determinism of these phenomena is truly ontic?

In his article Ulvi Yurtsever makes a strong argument that quantum mechanical probabilities are genuine, that is, that they are algorithmically random, or incompressible. However, he also emphasizes that "no algorithmically incompressible binary string can ever be *constructed* via a finitely-prescribed procedure (since, otherwise, such a procedure would present an obvious algorithm to compress the string thus obtained)" (Yurtsever, 2000, p.1). This observation recognizes that although truly algorithmically random strings may indeed exist, their existence cannot be demonstrated.

In the opposite camp, Jean Bricmont's analysis yields a result that simply dismisses the entire issue of the intrinsic nature of determinism as ultimately irrelevant. Bricmont examines two current definitions of determinism. He finds that one definition in which determinism is conflated with predictability renders determinism trivially false. With regard to another definition that avoids conflation, Bricmont raises a question whether there is a function—in a Platonic sense (that is, independent of our ignorance)—that determines a finite sequence of sets of numbers that never repeats itself in a unique way. His answer is that the existence of such function is simply impossible to disprove because one can always find a function or even many functions that map "each set into the next one"(Bricmont, n.d., p.4). Bricmont's conclusion dismisses the whole issue of determinism as utterly irrelevant to science. In his view, "there is no notion of determinism that would make the question [of determinism] scientifically relevant . . . ontically it [determinism] is true but uninteresting [that is, impossible to disprove]" (Bricmont, n.d., p.4). "I don't know," he adds, "how to formulate the issue of determinism so that the question becomes interesting" (Bricmont, n.d., p.1).
For Hans Primas, determinism refers strictly to ontic descriptions. Like Bricmont, he makes a very convincing argument against conflating, as is often done, determinism with predictability. Even quantum interactions, he stresses, which are notoriously unpredictable, are "governed by *strict* statistical laws" (Primas, 2002, p.1 [emphasis in the original]). Primas follows the principle of scientific determinism as formulated by the French mathematician Jacque Hadamard. According to this principle, "in a well posed forward-deterministic dynamical system every initial state determines all future states uniquely" (Primas, 2002, p.10). However, in contrast to others who subscribe to similar definitions of determinism (for example, Laplace, 1995), Primas follows Hadamard in regarding the principle of determination as regulative, and not in some absolute sense; in other words, if in some cases this principle is not satisfied, "it can be enforced by choosing a larger state space" (Primas, 2002, p.10). According to Primas, such enforcement is perfectly compatible with mathematical probability theory because:

> Every mathematically formulated dynamics of statistically reproducible events can be extended to a description in terms of a one-parameter group of automorphisms on an enlarged mathematical structure which describes a *fictitious hidden determinism*. Consequently, randomness in the sense of mathematical probability theory is only a weak generalization of determinism (Primas, 2002, p.1).

It is not difficult to see similarities in the way that Bricmont and Primas resolve the problem of determinism. Both see that there is always a possibility to find a deterministic function for a sample or set by enlarging the state space. This solution resonates with the famous proof of consistency and completeness by the Austrian logician and mathematician Kurt Gödel. As Gödel has shown, any deductive system can have true sentences whose truth is indemonstrable. In order to demonstrate their truth, one should resort to meta-mathematical procedures and construct a new and broader axiomatic structure that would be powerful enough to make such proof possible. However, even the new and enlarged structure will not be able to escape the same paradox as it will also allow other true but unprovable sentences (Nagel and Newman, 1953).

As one can see from the above, the three authors have essentially reformulated the whole problem of randomness vs. determinism. In the new formulation, the problem is no longer whether randomness or determinism objectively exist, but rather whether one can offer a proof of their existence. Thus they transform the problem from ontological into epistemological, or from how reality is to how we know. The connection, whether explicit (Bricmont) or implicit (Yurtsever and Primas), with Gödel is also very indicative and significant insofar as Gödel's proof deals with how we know, not with what is. If the solution of the problem of randomness vs. determinism lies in epistemology, as the above interpretations suggest, it is logical to assume that its origin may also lie in how we know rather than in what is out there.

One can also glean the connection of this problem to epistemology from another angle. There is a great deal of empirical evidence suggesting that nature does not give preference to either randomness or determinism. In fact, many natural phenomena point to a close relationship and complex interaction between random and deterministic processes. Many processes in nature can be often classified as random and deterministic at the same time (Berkowitz, et al., 2006, p. 661). The Nobel laureate Ilya Prigogine noted a close relationship between random and deterministic processes in his book with a characteristic title *Order out of Chaos* (Prigogine and Stengers, 1984, pp. 292-95). In his book *A New Kind of Science* Steven Wolfram (2002) also shows that randomness can evolve into order and vice versa. Adducing to the fractal geometrical patterns in nature, Paul Carr observes that many natural phenomena reveal "the complex interplay between randomness (symbolized by dice) and global determinism (which loads the dice)" (Carr, 2003, p. 934). The neo-Darwinist approach to evolution, Carr points out, also emphasizes the interplay between random genetic mutations and the globally deterministic natural selection (Carr, 2003, p. 934). Summarizing the evidence related to such diverse phenomena as turbulent flows and neural interactions, Tamas Viscek in his article that appeared in *Nature* stresses that:

> . . . in both these systems [turbulent flows and neural interactions] (and in many others), randomness and determinism are both relevant to the system's overall behavior. Such systems exist on the edge of chaos; they may exhibit almost regular behavior, but also can change dramatically and stochastically in time and/or space as a result of small changes in conditions (Vicsek, 2002, p. 131).

In another piece, also published in *Nature*, Kees Wapenaar and Roel Snieder make a similar point, drawing on evidence from physics:

> Our view of the universe may have shifted from the deterministic to the random, but since the turn of the last century physics itself has provided a less simplistic view. Fields generated by random sources can be used for imaging and for monitoring of systems such as Earth's subsurface, or mechanical structures such as bridges. Randomness is no longer at odds with determinism; it has instead become a new window on the deterministic response of the physical world (Wapenaar and Snieder, 2007, p. 643).

As the physicist Joseph Ford succinctly put it, "God plays dice with the universe. But they are loaded dice" (as quoted in Glieck, 1987, p. 314).

There have also been challenges to the exclusive emphasis on randomness central to standard quantum mechanics. In the most recent one, the physicists Sheldon Goldstein, Detlef Dürr, and Nino Zhangi offer an interpretation of quantum mechanics that is, in Goldstein's words, "precise, objective—and deterministic" (quoted in Buchanan, 2008). In their view, the observed randomness is merely apparent. In another challenge, the data obtained in the study of neutron resonances have led a group of physicists at Oak Ridge Electron Linear Accelerator, headed by Dr. Paul Koehler, to question the applicability of the random matrix theory

to movements of neutrons and protons in the nucleus. The data indicate that the particles in the nucleus are moving in a coordinated fashion, rather than randomly as suggested by the random matrix theory (Reich, 2010, p. 1034). At the same time physicists also report observing quantum phenomena in macro events. A group of Russian physicists, led by S. M. Korotaev, have observed the phenomenon of non-locality, usually associated with the quantum domain, in dissipative geomagnetic macro processes (Korotaev et al., 2005).

Empirical evidence also shows that nature does not favor either equilibrium (associated with randomness) or disequilibrium (associated with determinism). For example, in his interpretation of the current state of the universe, the astrophysicist Manasse Mbonye argues that "the universe is always in search of a dynamical equilibrium," which suggests an interplay between the states of equilibrium and disequilibrium (Mbonye, 2003, pp.1-2). Although the currently dominant cosmological theory asserts that our universe originated in the state of primal disequilibrium, or the Big Bang, numerous critics of this theory point to its speculative nature and argue that since it is an extrapolation from the current conditions into the past, this theory is not justified and still lacks unambiguous empirical support. Sean Carroll, for example, observes that ". . . scenarios of this type are extremely speculative and may very well be wrong" (Carroll, 2005, p.5). Paul Steinhardt and Neil Turok—two prominent critics of Big Bang—also point to the speculative nature of this theory and counter it with their own cyclical theory of the universe (Steinhardt and Turok, 2002).

The above discussion shows that randomness, or chance, may indeed exist, but its existence is, to put it simply, indemonstrable. There is no rational justification that can demonstrate that a particular phenomenon is due to chance, rather than to some underlying order. Therefore, one would be ill advised to use it as the fundamental principle on which to construct one's theoretical explanation. Thus the theoretical perspective that relies on randomness in its explanation of the production of disequilibrium in the process of creation is vulnerable because randomness is indemonstrable. In other words, this perspective essentially directs us to accept its fundamental proposition regarding randomness on faith.

The second perspective—so eloquently presented, among others, by Margaret Boden—downplays the significance of randomness in the production of creative disequilibrium and emphasizes the role of play and exploration.

This perspective is clearly trying to bridge the gap between the Scylla of randomness and the Charybdis of orderly thought processes. In Boden's view, play and exploration of possibilities involve mental processes that are different from those involved in rational thinking, as they are "open-ended, with no particular goal or aim." However, these mental processes are not random either, as they are "disciplined and intelligible." New and creative ideas are "neither random nor perverse (as it might have been had it arisen in the mind of an uneducated crossing-sweeper or a semi-educated crank), but arose while exploring the relevant conceptual space in an intelligible way" (Boden, 2004, pp. 4, 58-59, 96). In addition, when creative ideas arise in the course of play or exploration, they are subject to the evaluative procedures employed by their creators. In a creative act, Boden maintains, "[p]urposeful behaviour should be more common than random processes, and any randomness must be constrained by the general nature of the creative domain concerned" (Boden, 2004, p. 163). As Boden argues, creative individuals

> . . . think in a disciplined manner: they may be playful, but they aren't merely playing around. When something of potential interest turns up as a result of their playfulness, they focus on it—accepting, amending and developing it in disciplined ways (Boden, 2004, p. 319).

Since the second perspective on the production of creative disequilibrium downplays the role of chance and relies more on disciplined, orderly, and intelligible way of thinking, it is less susceptible to criticism that affect the perspective that relies on randomness. Yet it also has problems with justification, even if the set of problems in this case is very different.

Boden constructs her perspective on creativity and the process of creation on the claim that play and explorations are "open-ended, with no particular goal or aim." In other words, the processes involved in game or exploration are different from operations involved in our rational thinking that are about establishing correspondences and, hence, equilibration. She rests her theory on the claim that play and exploration can produce something unexpected, new, discontinuous, and yet not random.

However, are play and explorations so "open-ended" and have no particular goal or aim? Indeed, the mental processes involved in play and exploration may be different from those involved in rational thinking, but they are not necessarily without aim or goal, except that these goals can be different in nature from those we set when thinking rationally.

Both play and exploration may not be about rational goals but our engagement in these pursuits is not devoid of purpose. They entertain us and give pleasure. Therefore, our reasons for engaging in play and exploration have to do with pleasure and gratification, and are, consequently, aesthetic, rather than cognitive, in nature. Boden says as much when she emphasizes the role of style and aesthetic sensibilities in tweaking generating rules that operate in conceptual spaces. The fact that the aim of play and exploration has to do with gratification leads to the conclusion that they are not purposeless but serve our deeply felt need of emotional gratification.

If, however, the actions we perform when participating in play or exploration satisfy our deeply felt needs and are, consequently, guided by our sense of style and aesthetic sensibilities, we must conclude that they are also guided by our inner knowledge and inclinations, albeit emotional rather than rational; and if this is the case, then they are also about establishing correspondences and, hence equilibration. The fact that our actions in play and exploration are about equilibration raises a question: How can equilibration lead to the production of disequilibrium? Boden does not raise this question explicitly, but her observation that we may never be creative enough to create a machine that can perform creative acts comparable to our own suggests that she may implicitly be sensitive to inconsistencies in her theory.

There is also another and even more troubling paradox looming at the heart of Boden's theoretical perspective. Boden argues that creative acts involve rational and evaluative procedures employed by their creators. These rational and conscious actions in many ways determine which creative idea will ultimately be chosen as the most fruitful (selected for fitness?). The only basis for making such selection is the knowledge possessed by the creator. But if in making these choices the creator relies on knowledge that he or she already has, then no creation is involved.

Boden certainly shows her awareness of this paradox when she makes the reference to the fact that religion, or more specifically the Judeo-Christian tradition, has already grappled with a similar paradox when addressing the issue of creation. Central to the Judeo-Christian tradition is the acceptance of God the Creator—the subject—as its primary ontological reality. The argument that creates the paradox goes something like this: In order to be able to create, the Creator must be omnipotent. He must be capable of anything. However, in order to be omnipotent, the Creator must be perfect and contain all possibilities. He must represent full plenitude of all possibilities. But this conclusion leads to a paradox. If the Creator is perfect and contains everything, then the Creator cannot create anything since everything already exists and is contained in the Creator. If, however, the Creator creates something—something radically new, something that has had no existence prior to the act of creation—then the Creator is not perfect and hence is not omnipotent.

The Judeo-Christian tradition does not resolve this paradox and does not explain the production of disequilibrium. But then it does not have to. Its important advantage over secular rational discourse is that it can resort to faith when dealing with divine paradoxes. Christianity directs the believers to accept divine paradoxes, including the paradox of creation, on faith as ones that objectively exist and are ultimately inaccessible to human understanding. Not so in rational discourse that we value in our secular world. We demand that our theoretical constructs should be able to withstand the test of rational justification and both theoretical perspectives on the process of creation fail to provide such justification. Why do they fail and what can we glean from this failure?

3. Equilibration and the Production of Disequilibrium in the Process of Creation

Justification is essentially a logical operation. As any other logical operation, it establishes correspondences between our mental constructs. Therefore, justification is essentially an equilibrating procedure. There is only one way that equilibration can work in justifying the production of disequilibrium: the two must be related. However, as the preceding discussion has shown, the current perspective on the process of creation does not see equilibration and the production of disequilibrium as in any way related to each other. There-

fore, they cannot possibly produce a rational justification for the production of disequilibrium. Their efforts to provide such justification have to end up in a failure. As has been shown above, one of these perspectives simply does not provide any justification for its reliance on randomness; and the other perspective—one that emphasizes "orderly and disciplined" thought processes—results in paradoxes. If equilibration and the production of disequilibrium are not related, our mind that is capable to perform equilibration should not be able to create. Yet the fact that our mind is capable of creation stares right into our face. We can create and, consequently, our mind is capable of producing disequilibrium. If our mind can do both—perform equilibration and produce disequilibrium—the two must be related. As sophisticated as Boden's thinking on creativity is, she does not recognize the relationship between equilibration and the production of disequilibrium—in fact, she even doubts if equilibration is even important (Boden, 1982). Perhaps this failure to recognize the relationship between equilibration and the production of disequilibrium is the main reason why her theory of creativity ends up in paradoxes.

As many have argued and agreed, paradoxes are not intrinsic to reality; they originate in our thinking (Shkliarevsky, 2010). Paradoxes are about our views of reality, rather than the way reality is. In their uncertain light reality appears to be uncertain, ambivalent, and ambiguous—true and false at the same time. Kurt Gödel in his famous proof of consistency and completeness dealt with the nature of paradoxes. He has proven that any axiomatic system is bound to contain statements that are true—in the sense that they exist—but at the same time their truth is indemonstrable within this system. If indemonstrable, the truth of such statements cannot be verified; and if a statement cannot be verified, it can as well be false. Gödel has also argued that the truth of these propositions can be demonstrated but such demonstration requires changing the assumptions of the axiomatic system. However, Gödel also proves that such change does not resolve the problem of the existence of paradoxes since a new and modified axiomatic system will also contain possible statements that are true but ultimately indemonstrable. We may continue changing our axiomatic systems ad infinitum; but no matter how many times we modify them, we can never escape the paradox (Nagel and Newman, 1953).

Gödel's proof demonstrates the connection between equilibration—which is involved in the construction of axiomatic systems—and the production of disequilibrium, i.e., creation of new axiomatic systems. This demonstration suggests that equilibration and the production of disequilibrium are not diametrically opposed to each other; on the contrary, they are closely related and complement each other in the process of creation. We know that our mind can execute logical operations and is, therefore, capable of performing equilibration. We also know that our mind can create. Therefore, our mind is also capable of producing disequilibrium. Since our mind can perform equilibration and also produce disequilibrium, the two must be related. As a result of her failure to recognize this relationship, Boden has to deny that play and exploration involve equilibration since she sees them as the principal source of the production of disequilibrium.

But how does equilibration lead to the production of disequilibrium? In order to answer this question, a closer look at the way the process of creation functions is in order. One example of this process in action is the emergence of intelligence in children discussed by Jean Piaget in his remarkable book *The Origins of Intelligence in Children* (Piaget, 1998). For Piaget, the starting point in this development is reflex triggered by nerve signals. Neural functions regulate and act recursively upon physiological functions (for example, muscle contraction). Signals from neurons trigger physiological functions and thus help to conserve them. The more often this triggering occurs, the more often physiological functions are exercised; and the more often they are exercised, the more stable they are.

Thus the need to conserve physiological functions creates the regulatory mechanism of the neural networks that acts recursively on these functions. The result is the development of sensory-motor operations that, in turn, also need to be conserved. They conserve themselves in two ways. First, they become increasingly oriented toward external reality in search of stimulation. This process evolves from random groping to a more directed search for stimuli, which leads to a gradual construction of the object on the level of sensory-motor operations (but not yet on the representational level). As more objects are incorporated into sensory-motor schemes (the operation that Piaget calls assimilation), the infant becomes increasingly orientated toward the exogenous sphere.

Sensory-motor operations—for example, tactile, audio, visual, gustatory, and other functions—also conserve themselves through mutual assimilation. One example of such mutual assimilation is activations of audio functions by visual ones, and vice versa (e.g. infants begin to turn their head to catch the sight of the mother when they hear her voice). Mutual assimilations give rise to the construction of permanent mental

representations. This process is completed at the beginning of the second year when infants begin to look for objects that are hidden from their direct view. The search for a hidden object signifies that an infant has already constructed a permanent mental image of the object.

Mental representations regulate sensory-motor operations and act recursively on them. The stabilization and conservation of mental representations also requires a regulatory mechanism that is provided by symbolic operations. The construction of symbolic operations is also a two-pronged process that involves internal mental processes and social interactions. There is a strong dependence of the conservation of mental representations on social relations. The conservation of mental structures requires interaction among individuals on a much broader scale than was possible or necessary prior to their emergence. As many thinkers (including Piaget and Vygotsky) have argued, the development of mental structures is intimately related to the development of social relations (Piaget, 1965; Vygotskii, 1978; 1929). The creation of symbolic operations opens infinite possibilities in constructing symbolic systems (linguistic, political, economic, legal, moral and value systems etc.).

Piaget's study shows that equilibration of differences leads to the emergence of new and more powerful levels of organization, i.e., to disequilibrium. The new and more powerful levels of organization offer more new possible ways of approaching reality and observe properties that have not been observed before. Piaget's study demonstrates that equilibration and the production of disequilibrium are closely interrelated aspects of the same process—the process that brings about radical novelties, which is how we understand creation. The perspectives that dissociate equilibration from the production of disequilibrium make the process of creation look incomprehensible. They simply cannot see the causal relationship between equilibration and the production of disequilibrium. As a result, in their description the production of disequilibrium—i.e., creation—appears uncaused as if a miracle that emerges out of nothing. Since the two current perspectives on creativity discussed in this article do not recognize the connection between equilibration and the production of disequilibrium, they cannot understand how the process of creation works and, as a result, they fail to provide a justification for their approach.

Much work undoubtedly needs to be done to gain a comprehensive understanding of the process of creation. Rational justification is essential for completing this work since it guarantees strict rational control. The fact that the theoretical perspective based on the recognition of the close and complementary relationship between equilibration and the production of disequilibrium has such rational justification is an assurance of the success of this approach. It opens the path toward a comprehensive and objective understanding of the process of creation, which is essential for regulating this process and thus controlling our creative capacity.

Objectivity requires taking into account all points of view. One can gain an objective view only from the position that does not privilege any point of view and particularly one's own. But is it possible to take a position that does not privilege one's own point of view with regard to the process of creation? After all, subjectivity is deeply embedded in this process. Any claim of objectivity requires that the creator should take a position that would allow objective reflection on the creator's own act of creation. But how can one who is deeply embedded in the process of creation be able to take an objective and reflective stance vis-à-vis this process? Where can one locate a position that would allow such reflection? Is it at all possible to do without getting into what Luhmann calls an "infinite reflective regression"? After all, in taking such position the creator has to rely on subjective choices and making such choices will necessarily reassert subjectivity.

The above discussion of Piaget's study of the emergence of intelligence in children shows that this process is sustained by two internally generated operations—conservation and regulation—that are dynamically interrelated. All systems, including mental and symbolic systems, conserve themselves through reproduction. Conservation requires stabilization; and stabilization, in turn, requires a mechanism of regulation that, as the above description shows, is generated internally. The better the regulatory mechanism performs its function, the better it handles perturbations, including potential perturbations, the more stable the system is and the better it is conserved. In order to perform its function, the regulatory mechanism also requires stabilization. The stabilization of regulatory operations, in turn, requires a regulatory mechanism that also needs to be stabilized. Thus the system enters a new cycle of equilibration, disequilibrium and re-equilibration.Thus the need to conserve the system results in constructing new levels of regulation. Since there is no reason to suppose that at some level of stabilization the need for conservation will disappear, one must conclude that the construction of regulations will never cease. It is essential to the process of creation.

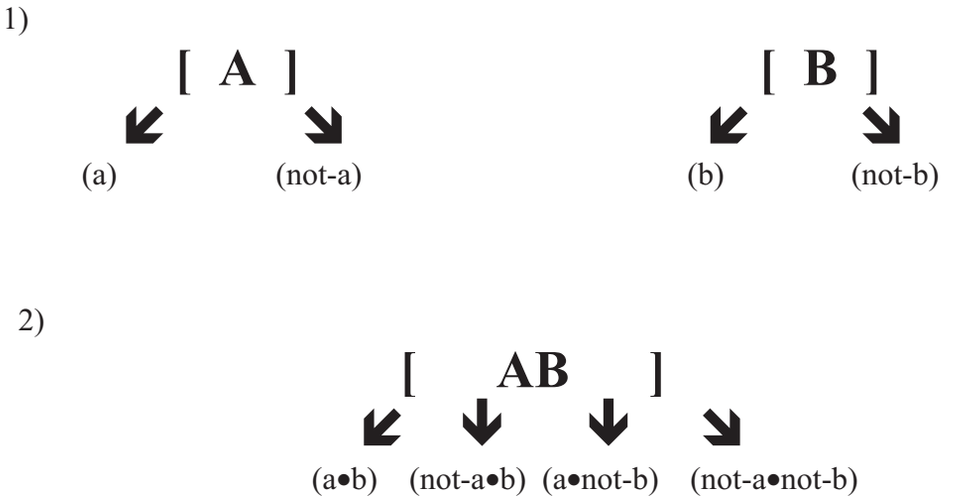

Figure 1: Schematic representation of the process of creation

The above diagram is a schematic representation of the process of creation. Diagram 1 represents each function and its operational capacity. Diagram 2 represents the combination of these functions after their mutual assimilation. It is quite clear that the new level of organization that emerged after the two functions are combined offers more combinatorial possibilities and, consequently, is more powerful.

Regulation is a reflective operation. The mechanism of regulation is more powerful than each of the subsystems it regulates or their sum total. Its power offers a possibility of reflection on the entire system.

This perspective on the process of creation may appear to suggest, as it does to Luhmann, that there is really no way to reflect on the process itself since for every reflective position there will always be a possibility of constructing another one. Every point of reflection can and will be succeeded by new ones, no less embedded in the process of creation than its predecessors. Should one conclude, then, that the problem of the embedded creator cannot be resolved and all that is left is to rely on palliatives, such as Luhmann's conditioning (Luhmann, 1995, p. 479)?

It is logically correct to view the process of creation as a system. Just like any other system, it requires stabilization and, therefore, regulation that offers a possibility of reflection. If the process of creation requires regulation, then there must exist a position from which one should be able to reflect on the entire process of creation.

As has been indicated earlier, conservation and regulation are at the heart of the process of creation. Conservation of functional operations requires regulation. In the initial stages of their development the regulatory mechanism is unstable. In order to acquire stability, it needs a regulatory mechanism of its own. As the new mechanism stabilizes itself, the creative process enters a new cycle. Thus the process of creation involves constant oscillation between equilibrium and disequilibrium—equilibration produces disequilibrium. Both equilibrium and disequilibrium are dynamically related in the evolution of the process of creation. The repetition of the cycle eventually leads to the improvement of the function of regulation and the process of creation becomes increasingly more stable, despite constant changes. One can probably best describe this dynamic stability as homeorhesis—the term that was introduced by the biologist Conrad Waddington and used by Piaget—rather than homeostasis (Waddington, 1957; Piaget, 1971; Piaget, 1974). Homeorhesis is not a static condition but a stable equilibrium between equilibrium and disequilibrium. This dynamic balance has a function of regulation and, as a regulatory operation, offers a possibility of objective reflection on the functioning of the process as a whole.

Conslusion

Our civilization increasingly relies on creativity to sustain itself. The demand for creative decisions, approaches, and ideas in all spheres of our life—economic, political, and social—is constantly on the rise. As this demand grows, so does the need to control and manage creativity. This need is particularly acute in the economic sphere where creativity is rapidly becoming one of the principal commodities (Manzoni and Volker, 2017). The commodification of creativity has attracted attention of many researchers as is evidenced by an extensive body of literature that brings into focus the issue of control and management of creative processes (Machlup, 1980; Nonaka, 1994; Nonaka and Takeuchi, 1995; Wierzbicki and Nakamori, n.d.; Davenport, Jarvenpaa, and Beers, 1995; Davenport, De Long and Beers, 1998; Nonaka, Krogh and Voelpel, 2006; Brocke and Rosemann, 2010). Yet, as many have noted (Piffer, 2012), despite this interest and the growing urgency of the issue of management and control, our capacity to foster, assess, and measure creativity, which is essential if creativity is to become our major commodity, remains very limited.

One important reason for the slow progress in this area is the fact that the process of creation still remains, to paraphrase Winston Churchill, "a riddle wrapped in a mystery inside an enigma." Margaret Boden recognizes this fact when she observes: "It is difficult enough for a literary critic, or a poet, to give an intuitive indication of the sorts of thought processes involved. It will be many years, if ever, before we can identify them in scientific terms" (Boden, 2004, pp. 145-46); and elsewhere: "A psychological explanation of creativity, it seems, is in principle unachievable. It is not even clear that there can possibly be anything for it to explain. And yet, undeniably, there is" (Boden, 2004, p. 12). This strong proponent of artificial intelligence ends her long, well-informed and argued analysis of the creative process and creativity on a rather pessimistic note:

> No matter how far we learn to swim in the future, we can't expect ever to know exactly how and why an individual person wrote a particular story, or chose a particular poetic or visual image. We may have some partial explanations, based on close personal knowledge or scholarship, like Livingston-Lowes' detailed detective work on Coleridge's poetry. However, explaining (and predicting) such matters in full detail is out of the question . . . Human minds are far too complex: too rich, too subtle, and above all too idiosyncratic. In a word, too marvelous (Boden, 2004, p. 322).

The lack of a clear understanding of the process of creation impedes the efforts to develop practical applications that would allow greater control over creativity. In his article "Can creativity be measured?" Davide Piffer, for example, points out that a lack of clear definitions "hamper the progress of creativity research" and affects our capacity to measure creativity. Piffer expresses serious doubts that a comprehensive methodology for direct assessment of creativity will ever be possible. As a palliative, Piffer recommends resorting to indirect methods such as unstructured or semi-structured interviews, self-report questionnaires and official external recognition (Piffer, 2012, p. 263).

Manzoni and Volker—two other practitioners in creativity research—also bring attention to the problem of assessing creativity. They focus on the difficulties creative companies experience when they compete with each other for customers. Manzoni and Volker find the entire competition procedure beset by paradoxes and complexities that can only be managed and negotiated, not resolved (Manzoni and Volker, 2017). These are just some of the examples of the difficulties that practitioners of creativity research experience in developing applications for creativity research. The palliative approaches they recommend are certainly useful but they are not solutions to what is an obvious problem. Only a clear understanding of the process of creation can lead to the development of applications that will provide guidance to those involved in economic practice.

The reason why the process of creation remains an enigma is the fact that we still have no clear description of the mechanism for the production of disequilibrium. Neither of the two perspectives that currently dominate the study of creativity offers such a description. One of them invokes random mutations as the mechanism that produces disequilibrium. This approach precludes any search for an orderly mechanism accessible to rational understanding. In addition, as this article has argued, this explanation cannot pass the test of rational justification—a critical requirement for any theory—since it does not establish the fact of randomness.

The other perspective—one that Margaret Boden represents—offers a description of the mechanism of creation in which rational thinking plays a greater role. The key intuition of this perspective points to the connection between equilibrating processes and the production of disequilibrium. Yet it fails to provide a clear explanation of how equilibration and the production of disequilibrium are related. As a result, the description it offers creates confusion and raises more questions than it provides answers.

This article proposes a new approach in studying the process of creation and creativity. In contrast to the two currently dominant approaches that view equilibration and the production of disequilibrium as ontologically separate and diametrically

opposed to each other, this approach does not oppose equilibration that constitutes the basis of our rational thinking and the production of disequilibrium. According to this perspective, equilibration combines differences and establishes correspondences. This process gives rise to new and more powerful levels and forms of organization that are the source of disequilibrium. In this view, equilibration and the production of disequilibrium are two integral aspects of the process of creation that complement, rather than oppose, each other. Since this perspective closely associates rational thinking with creation, it removes the principal obstacle to rational analysis and description of the process of creation and avoids the need of making assumptions that cannot pass the test of rational justification.

All these advantages open the process of creation to rational analysis and, consequently practical applications of our knowledge about this process. We certainly need to learn more about the process of creation but even what we already know may provide clues for resolving some critical problems associated with creative practice. For example, the perspective outlined in this article indicates that the process of creation works on inclusion of differences. If integration of differences is the source of creativity, then we can measure creativity by the degree of integration of differences: the more differences are integrated into a common frame as its particular cases (that is, cases that are true under specific conditions or assumptions), the greater is the degree of creativity. Also, as this article has explained, maintaining the balance between equilibrium and disequilibrium is another important feature of the process of creation. The need to maintain such balance in creative practice suggests that creative organizations should also work out a model that would allow them to maintain a balance between non-hierarchical and hierarchical interactions, associated with equilibration and disequilibrium, or hierarchy, respectively. As has been explained elsewhere, the need to maintain such balance will profoundly affect the role of management and leadership in creative organizations (Shkliarevsky, 2017).

There is no doubt that much more theoretical and empirical work will have to be done to gain a comprehensive understanding of the process of creation and creativity. Such understanding is essential for gaining the capacity to assess and measure creative work, manage the process of creation, and make creativity a major commodity in our economic system.

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