Creativity. Creativity! Creativity?

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Abstract

Once we accept that there is something called creativity we are led to wonder how are the creative people and what are the creative acts. This wonderment compels us to understand the underlying cognitive process in a creative act and the hardware requirements for this process to go on. We then arrive at a position for seeking an implementable model of and the paradoxicalness involved therein. This leaves us asking more and more questions, and we try to answer them. Perhaps our creativity will come of help in answering these questions!

Keywords : Creative Acts, Memory, Cognitive Process

1. Introduction

We have been created to be creative. The existence of creativity in us can perhaps be attributed to our own existence in the sense of Darwinian *survival of the fittest*. In the micro-scale (or macro?), genes use organisms as survival machines to transport instructions for making other survival machines in the future. Any such survival machine is discarded once a new and better survival machine is produced. The scenario is conventionally described as a *dynamic fitness landscape*. The survival machines that climb the peaks are considered fit enough to pass the instructions into the future. In us, humans, the genes and other congenital mechanisms provide sufficient background for producing the survival machines that can learn in order to adopt suitably into the landscape. The genes place the survival machines close to some hills in the landscape by providing the necessary background material such as potential for creativity. This may be roughly compared with a global search in the whole landscape. Once developed, the brain of the survival machine does not rest; it tries to climb a hill in order to reach the peak. This activity may be compared to a local search in the fitness space.

The survival machine is a complex system that acts and is activated by external influences in an orderly fashion. Often external influences cause disturbances and perturbs the order that is inherited to the system. This causes an error in the expected action of the system. The system then reacts to the error in order to reestablish the order through self-organization. The self-organization may cause it to move into a better arrangement or worse. But only the better ones survive; in fact, the self-organization process of those that survive are called the better ones. The improved internal state is now integrated into the system and the error that was earlier so named, is no more an error; it is an accepted behaviour of the system. The error and the reaction of the system to it by self-organization is the basis for creativity in the micro-scale. Creative errors are those having an impact on the system which favours its survival on the long run. This is how creativity can be seen as a self-emergent property of a complex system capable of self-organization.

However, creativity as a potentiality to many manifestations of creative acts has an altogether different connotation. Artists, scientists, mathematicians, engineers, management gurus, and psychologists have their own definitions of creativity. We describe some of these facets of creativity in Section 2 through problem solving skills. In section 3, we argue that some of the commonly understood creative acts need not be creative. In Section 4, we surmise what happens during a creative process till a satisfactory product comes up. This would lead us to have some requirements on the storage devise or memory, which would render the creative process possible. We describe such a possibility in Section 5. In Section 6, we briefly mention two kinds of attempts for modeling a creative system. Finally, we ask some questions, answers to which will lead to a better understanding of creativity that is so native to us.

2. Creative Acts

Creativity is the potential of a person to produce creative works whether he (I will write ‘he’ instead of ‘he/she’.) has produced it yet or not. This sense of the word ‘creativity’ is described in the last section, though with a more global intonation. In a second broad sense the word is used to to be associated with various day-to-day activities. The creativity that is exposed in the works of the artists or scientists intersects with both the meanings, and sometimes, it includes more, and is constrained to various factors which change from time to time. For example, work of a scientist is often subjected to peer judg-

ments and the judgment is frequently influenced by irrelevant factors. Despite various anomalies, there seems to be some commonalities that help us finding trends in creative acts. I will try to formulate these trends through some examples involving perceptual perspectives.

Take a hexagon $ABCDEF$ and join the diagonals AD, BE and CF. As we have constructed, it looks like a star graph whose ends are also joined by edges. You can immediately discover the six triangles in it each sharing a side with two neighbouring triangles. Take four ellipses E_1, E_2, E_3, E_4 and place them in a cyclic order so that E_1 touches E_4 and intersects E_2 (getting three regions out of two ellipses), E_2 touches E_3 and intersects E_1, E_3 touches E_2 and intersects E_4, and E_4 touches E_1 intersecting E_3. Look at this figure for some time and then at the hexagon. You will see that there are parallelograms or trapeziums in the hexagon.

The point is that context brings out features which would not be noticed otherwise. This change in perspective takes place in every creative act whether consciously or unconsciously. No matter how much effort has been put or how well an act has been performed it is not considered creative unless there is some novel component in it which cannot be derived *easily* from the earlier work. It cannot be certified to be creative without this novel component even if the performer has already been marked as a creative individual. All the paintings of a known creative painter are not considered creative paintings. All the movies directed by a well known creative director are not creative. And all the papers of Einstein are not considered reporting creative works.

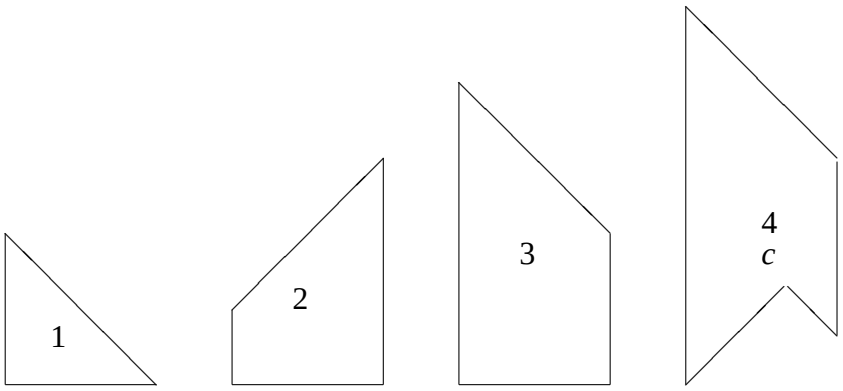

Figure 1 Pieces of the T-Puzzle

As another example of creativity in perceptual tasks, consider the well known T-puzzle. You have four wooden pieces as shown in Figure 1. The goal is to arrange the pieces together to form a 'T'.

The puzzle seems quite simple because the number of possible combinations is not very large. Yet, it takes considerable amount of time to get the correct solution. There has been a detailed study (see [17]) of how people attempt to solve the T-puzzle. It shows that they waste time in thinking that the corner marked (c) in the fourth piece must be fitting with another piece somewhere in the interior of the 'T'. However, the solution is entirely different. The corner (c) is, in fact, on the boundary. Once this perspective is taken, one solves the puzzle almost without any effort.

You can find many such examples in day-to-day life. Many conversation episodes base on this type of 'change in perspective' nature of creativity. It often goes under the umbrella of lateral thinking. The same change in perspective occurs in conceptual domains. One such example has been discussed by Schön [16]. A product development team was faced with the problem of figuring out why synthetic fiber paint brushes do not perform as well as the natural ones. They noticed that the natural fibers have frayed ends. They made synthetic fibers with frayed ends, but without success. Many such peculiarities were noticed and tried, but in vain. One of the team members suggested a remote idea that the paint brush might be working as a pump, just by juxtaposing a dissimilar concept. This idea was very shocking because a paint brush has nothing to do with a pump. However, this juxtaposition of dissimilar ideas did work and a new ontology for a paint brush was created.

This is the nature of the component of *novelty* in a creative act. However, there might be novelty in many acts which would not be recognized as creative acts. Any odd is not a style. It should be elegant; it must have some *value*. A composer may arrange notes in a new and unexpected manner, but the work would not be considered creative unless it is also judged to have musical value. Taking new axioms and creating a novel axiomatic system will not be mathematics unless it is judged mathematically appealing or having applications The appeal may be from within, as summarized in the dictum "Art is for art's sake".

A third trend of creative acts has something to do with serendipity. If a monkey given a

paint brush, paints *Gornica*, we would not say that it is an act of creativity. If an interesting and novel work of some great value is produced accidentally, then it is not judged a creative act. Chance does have something to do with creativity, but creativity is different from sheer chance. A creative act reflects the intelligence or skill of the performer. We will discuss this trend in Section 4 once again.

3. Non-creative Acts

You can give many examples of non-creative acts. In this section we review some acts which are commonly believed to be creative, but they are not. At least, all the individual acts which can go under such acts are not creative. I do not subscribe to the view that these acts are completely non-creative. They are, in fact, controversial; they are not-necessarily creative acts. A partial list of such acts include problem solving, logical deduction, induction, abduction, trial and error, imitation, heuristic search, and learning. A brief explanation follows.

Differentiating a function which is specified by a big complicated expression in the independent variable cannot be called a creative act. Problem solving involves applying a known rule to an individual problem at hand. There might be some variation in a particular problem requiring an association with other problems or even with other problem domains; however, conventional problem solving is a mechanical process, in general. Evidence: First rankers do not usually produce creative work in their later career. We also see that sparks of creativity is sometimes required in recognizing that a class of new problems can be solved by applying old rules.

A related domain is logical deduction. From the premises 'All men are mortal', 'Socrates is a man', inferring 'Socrates is mortal' involves no creativity. Since all mathematical proofs are logical deductions, doing proofs is, in general, not creative! However, all deductions are not *trivial*, and though a proof is *effective*, construction of a proof is not. Some proofs really need creativity. This suggests that creativity has something to do with solving difficult problems that defy old rules and old views.

Everyday inductive reasoning is very gradual and uncreative. Every Sunday we have dosai in our breakfast. Once on a Wednesday, for some reason, we find dosai on our breakfast table. My son (5 years at that time) says he does not have to go to school that day. This reasoning involves both deduction and induction. It does not matter whether

the conclusion is wrong or right; it is not a creative act. However, the *nontrivial* inductive reasoning such as the formulation of Kepler's laws from the available date of planetary positions is a creative act. It cannot be called a mere inductive reasoning; it is a creative act.

According to Peirce [12], the originator of it, abduction involves right generalization from considering simple cases even though probabilities of finding a general principle is far too low. He also believed that the reason we so often succeed in finding one such improbable generalization is that the solutions are somehow already built into our brains. Then creativity through abduction would be some sort of 'remembering', it would be innate, and in part, a kind of instinctive skill. However, the process of abduction is hypothetical and sometimes counter-factual and then it has ingredients of novelty pointing toward creativity.

Problem solving is sometimes accomplished not by application of old rules but by trial and error. One then demonstrates a smart way of solving a problem using the finished product of his crude process of trial and error. Such a solution when presented, is sometimes very appealing and it is immediately branded as a creative solution. No doubt that the solution might be unusually smarter, efficient and elegant; however, the process of 'trial and error' is not creative. By definition, it is a crude brute-force search procedure involving randomness. It differs from the notion of serendipity. The latter, though involves chance, needs some preparation in the sense of Pasteaur. we will discuss it again in Section 4.

In imitating one simply shows once again what was already there; so it is not creative. But what about the Greek theory that 'art imitates nature'? What about the creative innovators who might have started imitating other works? Invariably the new resembles the old, though in an unexpected way.

A related strategy called heuristics is also employed for solving problems. Heuristics is an unintegrated, incomplete, but a set of suggestive 'rules of thumb' that works in some cases, but not in all. This is as uncreative as an algorithm. However, creating heuristics for solving those problems for which there has been found no algorithmic solutions is a creative process.

As we understand today, learning is acquisition of knowledge and skills by instruc-

tions and practice. It does not give rise to new things or new perspectives on its own. Hence learning is not creative. However there are surprises; the creative students re-discover while learning and add new facets and new insights to the old. Thus learning promotes creativity, and is not entirely devoid of creativity. It is also well known that creative individuals learn the topics of their interest in a pace quite faster than the others.

In all the cases above we see that distinction has to be made between the trivial and the non-trivial. It is this certification of distinction that matters in recognizing an act as a creative act. And this test is, of course, open to debate.

4. Creative Process

The picture of creativity that we have today based on the objective measurement of differences between individuals is not very informative. It leaves open the possibility that except where it depends heavily on a special uncreative intellectual skill, there may be no measurable *trait* in creativity. On the other hand, we have somewhat better but subjective characteristics of creativity as a state or process. As this process occurs in some individuals over only a certain period of time and only on special topics of their interest, we might quickly scan through the idiosyncrasies of these individuals. The trends in their behaviors have been found statistically; thus, they are not conclusive, but they may be taken as evidences.

Several studies ([1, 6, 11]) indicate that highly creative individuals in a field do not have higher IQ than matched individuals in their field who are not judged to be creative. However, they have higher IQ than the average worker in the same field. This paradoxical views are accounted for in two ways. First, a person to be creative must have a greater IQ than a certain threshold value. And beyond the threshold, there is no connection between one's IQ and his creativity. Second, there may not be any connection between the IQ and the creativity, not even the threshold. However, we know only those creative people who could be known easily due to some irrelevant factors. For example, a creative person working in a university could perhaps be known easily compared to one who is working in a village engaged in cultivating land. This is the *certification* theory of Hayes [8] suggesting that the creative people may not need a high IQ to be creative but they may need it to be certified to get jobs where they can put their creativity to work.

As the psychological studies show [2, 7, 14, 18], one common characteristic of cre-

ative people is that *they work hard*. The creative people get absorbed in their work, over long years, and frequently, to the exclusion of everything else. A second characteristic of the creative individuals is their drive for *independence* of thought and action. Chambers [2] finds that the creative scientist "... is not the type of person who waits for someone else to tell him what to do, but rather thinks things through and then takes action on his own with little regard to convention or current fashion." Mac Kinnon [11] found that creative architects strongly preferred independent thought and action. Ypma [18] found that creative scientists answer 'Yes' to the question: "Did you ever build an apparatus or device of your own design on your own initiative and not as part of any required assignment during your later school years?" Third, creative people have a drive for *originality*, as the studies show. Moreover, they are very *flexible*, as reported in [9, 15].

With this short report of correlation of personality traits of creative individuals we try to analyze what undergoes in a creative process. There is, of course, some rationale behind the debate whether creative process is really analyzable, and whether creative process is at all a special process. Since we want to understand creativity, it is more of a necessity to analyze the process even if it is not analyzable in a holistic sense.

Contrary to the common sense meaning of the term creativity, the process starts with a *preparation* as has been phrased by Pasteaur: "In the experimental field . . . chance favours the prepared mind." His paradoxical suggestion says that the requirement for creative process to start is the most uncreative one; one has to learn what is already known. Only then one is likely to have enough requisite raw material for an original contribution, and only then one will be able to recognize what is a worthwhile contribution. Even the most talented composers, painters, scientists, mathematicians, and engineers required years of preparation before they began to produce the work for which they became famous. The exceptions to this observation are below one percent, not only comparing the creative individuals, but also with their respective works.

This stage of preparation is followed by *goal setting*. According to Einstein and Infeld [3], "Galileo formulated the problem of determining the velocity of light, but did not solve it. The formulation of a problem is often more essential than its solution, which may be merely a matter of mathematical or experimental skill. To raise new questions, new possibilities, to regard old problems from a new angle requires creative imagination and marks

real advance in science." What distinguishes the creative people from others is that they recognize an opportunity or a problem when others do not. There can, of course, be flexibility in goal setting. Pavlov was investigating the salivary reflex in dogs. Dogs salivate automatically when food is placed in their mouths. But he discovered that dogs began to salivate even before the food was placed in their mouths. This seriously complicated his study. However, seeing that it was an annoyance to be eliminated, he set new goals which led to his historic work on conditional reflex. Manet's painting *Luncheon on the grass* was historically significant because it set a new goal, emphasizing the importance of visual effects on the canvas in contrast to social or literary meanings which a painting might convey. Setting of such goals is guided by many factors including constraints, intuitive and aesthetic factors. Stranisky once said why he continued to compose tonal music after most composers had abandoned the tonal system by saying that"You cannot create against a yielding medium." He needs the tonal system as a constraint within which he could exercise his creativity. Within these two stages of preparation and goal setting the creator becomes obsessed with the problem, he collects relevant data and traditional approaches to it.

Then he goes for new formulations of the problem involving various *representations*. The problem is represented and solution tried. Since tasks that allow for creativity are more often ill-defined, various representations are tried. The represented problems are again tried for solutions. There had been a lot of emphasis on this stage where we come to hear of many ear-brushing phrases such as lateral thinking, brain storming, juxtaposing the unlikely, etc. It is believed that creative insights are often provoked by encountering an *anomaly* in the existing solutions. It helps leading toword *analogical thinking* in an unknown domain. Analogies may well involve a basic cognitive process related to how well knowledge is represented and manipulated. An elaboration of analogies can be found in the so called *metaphor theory*.

This stage, when carried out unconsciously, is termed *incubation*. There have been many experiments (See [4] for a report.) suggesting that creative process might involve incubation but no definite proof can be given. In this stage of incubation the creator does not actively attempt to solve the problem, but unconsciously works on it. We will see in Section 5, what memory requirements it may force upon us to allow incubation to occur.

The scenario is that for a time one consciously works on a problem, and when one fails, one's unconscious mind *somehow* continues to work and mysteriously accomplishes what the conscious could not. This position does not help understanding the cognitive process underlying a creative act. Because, cognitive science wants to explain the unconscious cognitive acts, and by merely telling that somehow the unconscious achieves it only gives a name to the unknown, but does not explain it. However, this wondering and pondering over the facts might help us to obtain or create an explanation someday.

The period of incubation might be accounted for by considering the method of blind variation and selective retention as outlined in Section 1. The variational process of generating many possible solutions is not completely random; here comes help from the preparation stage. Like a blind person can be guided to an object by auditory signals in an unfamiliar environment, variation can also be guided by means of a feedback loop. The standards of goal setting as an evaluative process also helps; it is a verification of a suggested solution in a rigorous manner. This loop of variation and verification is repeated many times toward a refined end-product, where it is retained. We recall that the method of blind variation and retention is only trying to explain the unconscious process of incubation. The verification involved here is not a conscious phenomenon. The process of conscious verification is described below as a later phase.

The next phase is termed as *illumination*, where a possible solution surfaces to consciousness in a vague form. It also involves the selective-retention stage discussed above, but now, not entirely unconsciously. Subjective accounts of creative people speak of this phase of the creative process in a vivid manner pointing toward some sort of unexpected and unknown association or underlying order amidst the chaos of ill-defined concepts presented in the problem. As Poincare [13] told: "Creative ideas ... reveal unsuspected kinships between other facts well known but wrongly believed to be strangers to one another." These might be the success stories, which must have been preceded by many unsuccessful 'illuminations'. When unsuccessful, we term them not as illuminations, but as errors, mistakes, etc. The successful ones, obtained unconsciously, are sometimes connected to serendipity. However, consciously, they are found by heuristic strategies, variable focus, abduction, natural analogs, etc. Unconsciously, they are found, perhaps, by blind variation, selective retention, adaptive fitness landscapes, etc, exploiting some

hypothesized innate structure of the mind.

The next important phase in the creative process is the so-called *verification* stage. This involves revision of the ideas, improvisation and performance, perhaps guided by the standards, or intuitive and aesthetic factors set by the creator himself. During this phase, the creator stops creation and evaluates what has he created to improve upon any shortcomings that might have lurked in. This revision process is very important for him due to his eye on standards. This stage is often repeated in conjunction with the whole process starting from representation to itself again, in a loop. Finally, the idea is worked out into a form that can be proved and communicated to others.

The final stages involve unconscious effort of the creative individual guided by the conscious verification. Cognitive science has the responsibility of explaining this unconscious effort and the process involved therein instead of merely giving it a name as incubation, illumination, etc. We attempt to speculate some of the requirements for possible explanations of the cognitive process underlying the creative act.

5. Memory requirements

Here is a speculation of our storage requirments. In order to gather together the pieces of cognitive mechanism underlying the creative process we must know how the episodes of experience as well as abstract items such as concepts and attitudes are stored in our memory. The term memory includes not only the physical memory locations, as in a computer, but also the possible data structure that is perpetually at work. To begin with, the number of permutations in the episodes of experience and the variations in abstract concepts is too large to be contained in a small brain as of ours. A property might be concrete such as ‘green’, or more abstract such as ‘respectable’ or it may be something very unlikely for which we have hardly any word to express. Only a fraction of these properties or tokens of memory items can be realized as occupying actual memory locations. Much of our memory is still lying blank for some more episodes of experience, and for some more associations to take place. The episodes are not even stored at each individual places as is done in a computer, for otherwise, while invoking a past experience we would get an identical experience flashing back to us. It cannot be explained by merely asserting that there might always be noise factor in data retrieval, for otherwise, evolution would have taken care of such a vivid thing. This memory ought to be *sparse and distributed*. Upon

retrieval, it searches for an important location and then other locations get associated or activated. Exactly which ones are activated might be guided by what type of retrieval is sought for giving certain *constraints* for the association or distribution of episodes across the memory locations.

Further, the retrieval would use an address formed by systematic relationship between the content of an experience, its qualitative feel, and the memory location where it is stored. The distributed nature of our memory prohibits the one-to-one addressing used in a computer. For an experience to be engraved in a certain memory location, a particular pattern of activation must occur at the storing stage. Then the address of a memory location can be taken as this pattern of activation that is to be retrieved. Thus, memory is *content addressable*.

In such a content addressable memory, if two items share a common feature, then they would share a memory location or a unit thereof. This hints toward the possibility that relationship between memories is a matter of correlation than of causation. This might also explain the psychological attributes such as defocused attention and sensitivity to subliminal impressions associated with creativity. Content addressability ensures that items with related meanings get stored in overlapping regions. This allows one to retrieve similar or relevant items when prompted for something else. A person may remind us of another person, a particular smell might remind us of a picture causally unrelated. It also allows one to retrieve a not-so-well-related item due to ever-expanding associations of patterns.

One thought leads to another and in succession, we go to one which is conceptually very different from the starting one, looked through the chain of causation. This behaviour may be termed as our capability for *conceptual fluidity*. But mere conceptual fluidity does not suffice for creativity. It accounts for looking at various possibilities allowing an unusual choice to be taken. But a choice is to be made. And this requires focusing and control. As has been pointed out by many researchers, creative people exhibit paradoxical behaviour patterns. They are sometimes very reliable, and sometimes not; they are more destructive and also more constructive, etc. They have the capability not only to focus, make their choice for a solution, but also to vary their focus in a constrained and controlled manner, and choosing as and when whatever required with tremendous amount of

flexibility. The sparse, constrained, distributed content addressable memory allows both conceptual fluidity and *variable focus*. This allows to choose a path for climbing a hill in the conceptual landscape by defining its own way.

6. Explaining Creativity

Explaining something amounts to making a model in terms of the known concepts or of entirely new primitives which might be well understood or simple enough to be accepted. The facet of creativity that is found in the creative people, if taken denotationally, will not yield a handy model and it would not render itself to manipulations we would like to make out of our understanding. However, we can focus upon creativity as a property of solutions rather than people. It is the *judgement of products* approach to creativity that we might try to explain. Since human memory is (or accepting that it is) organized into a bundle of related items derived from experiences, our basic blocks will be these bundles or patterns; we call these patterns as *frames*. Knowledge is derived or represented into an association of frames. Due to the sheer size of possible associations, only a small number of these frames get activated at any time interval. We may say that the temporary activation of an association happens in *short term memory*, the activated frames being *salient* at the instance. The particular association might come up due to other factors as we explained in Section 2, where a juxtaposed figure presents a new perspective on the an old figure. Patterns of these activations are usually unconscious; and creativity training intends to achieve it consciously using the ideas of *juxtaposing the dissimilar* and other methods. Abduction is also one of these methods.

As it happens, the process of making new and unexpected associations between previously unrelated frames often leads to formation of creative solutions. However, maintaining the ever-expanding associations in short term memory is not possible. It is made possible by creating *chunks* of associations, lifting to a higher abstract level. This capability of creating chunks of associations is perhaps a memory management technique that is innate to human mind. There is, of course, a possibility of bringing in various levels of consciousness through this technique, but that is altogether a different matter. The chunked associations become new frames in a different level and cognitive load is reduced increasing the sophistication of the problem frames. These frames can form a background for the neural network model of human mind that is capable of creativity [10]. This can

also serve as a background for the quantum mechanical approach [8] to model the creative process. These models are far better than the descriptive models in the sense that they are implementable. However, they have not been implemented as such; only some parts of these models have been implemented and that too for tackling creative reasoning in some special domains such as legal reasoning or scientific theory formation. The suceess is eye catching though not complete. In order that the models become really helpful, either they be modified or drastically new models are to be constructed.

7. Conclusion

Modeling creativity, however, leaves us in a paradoxical situation. Suppose that we have an implementable model of creativity. then clearly, we have an algorithm to have creative solutions. Now that we have a program to play chess do we accept chess playing as a creative activity, or has it lost that property? Are we prepared to accept that the algorithmic way for generating creative solutions is creative? Will we term such products as creative products? On the other hand, if we do not aspire for an implementable model, will we be satisfied with a descriptive model which is not implementable and therefore, impractical? We accept the existence of creativity, the potentiality in us to generate creative solutions, We also accept the possibility of modeling the process of obtaining creative solutions. At the same time, we also wonder at our marvelous potentiality which is largely taking place unconsciously, where chance plays a greater role. We then ask questions regarding its mysterious existence. Can we have a mathematical theory of creativity providing the basis for building creative programs, just as formal logic provides the basis for deductive programs? Will it be really possible to take care of all possible forms of reasonings associated with the creative process including deduction, induction, abduction, invention, reflection, analogy, metaphor, serendipity, abstraction, experimentation, observation, evaluation, reparation, justification, exploitation, imagination, innovation, interpretation, discovery, exploration, and synthesis? Is it that evolution gave us creativity for making us fit for survival? What happens in the mind when a creative idea takes place? Will practice make us more creative? Is creativity a cognitive trait that some people have more than others? Back to the beginning, what is it really?

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