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THE GIST OF CREATIVITY

Creativity is a notoriously evasive concept, and it is used to cover a lot of different phenomena. Different methods and a wide variety of angles have been used in the striving for a clear-cut conception. The focus has been on alternatively the personality of creative people, their childhood, the conditions that a society must fulfil to support a creative atmosphere, works of art contra the discoveries of science, changes in pedagogy to give rise to or improve creativity, computer models, intuition, and so on. Consequently, the resulting picture of creativity varies substantially depending on the goal of the inquiry as well as on the constraints that are set from the start, not only by the scope of the investigation, but also by the discipline that the investigator belongs to and the method that is used.

I will make use of a broad conception of creative activities. I do not think there is any difference in kind between everyday and scientific creativity or between the creativity of grown-ups and children. My examples of creativity come from cooking, architecture, science, and gardening. However, in order not to lose contact with that elusive characteristic we have in mind when we call something or somebody creative, we must pay attention to the common sense conceptions that surround creativity, and let these conceptions guide the account. The idea is to track that which lies behind all the things that get the epiteph 'creative'. According to how the word 'creative' is used in everyday language, the phenomena to which it applies should instantiate some, if not all, of the following properties: novelty[1], unexpectedness, fertility, surprise, adequacy or correctness, and finally in some sense be deliberate (as opposed to random).[2] It should also involve an active search, emanating from the efforts of the individual. An activity that can be described by these properties I will call *creative*, and I intend this use of the word to follow common usage. In a derived sense we can talk about the creative products of such activity. You will notice that I often talk about problem-solving instead of producing creative results, being creative, or similarly. The reason is that

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[1] M. Boden distinguishes between person-related and historical novelty, the former being new to the person who came up with it but possibly old to other people, the latter being of historical importance. I am mainly interested in the former kind of novelty. Cf. *The Creative Mind* (1991) New York: Basic Books.

[2] Most of these properties are relational: an action or thought is unexpected, fertile, surprising, adequate, et cetera, in relation to a person or certain people in a certain field at a certain time.

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I in fact consider creativity to be some sort of problem-solving, but of a specific kind. You will see what kind in a while.[3]

I want to start by making a distinction between three different angles on creativity: the contributions of the individual, the environment, and the knowledge domain, respectively. First, the *individual.* An inquiry that concentrates on the individual will bring up the origin or genetic causes that made that person creative. It will examine the childhood, the personality, and the personal qualities of the individual and try to determine what is required of an individual and its immediate surroundings for it to become creative. Secondly, the *environment.* The importance of the environment to creativity is manifold and can be assessed by a study of the social and cultural factors at a given point in time. For instance, a society that promotes and encourages creativity and strives for novelty and unexpected solutions to problems will probably foster more people that behave in a way that we would call creative than a society that is indifferent or negative. But what would an atmosphere that enhances creativity look like? Such a question is typical of this approach. Thirdly, we have the *knowledge domain* of the individual, characterised by a description of what the individual has knowledge of and by the kind of knowledge he or she has. Note that the general cognitive state that characterises the field in which the individual works or acts falls under the second point.

At this stage, two basic questions about the knowledge domain present themselves. One has to do with its *prevailing state*, the other with its *dynamics*. The first question is answered by facts about how well-developed and organised the domain is and about what kind of knowledge it involves. It seems that for an individual to be creative in an area, he or she must have a good grip of that area, or whatever result he or she attains, it will be random, and thus cannot be called creative. By 'having a good grip' I intend that the individual has rather detailed knowledge, whether tacit or explicit, and also has experience of working in the domain from earlier occasions. She should probably as well have some kind of background knowledge that gives a broader basis for solving the problem that she has encountered.

The second question, about the dynamics of the knowledge domain, is answered by an explanation of what has to happen in the domain if the knowledge that is represented in it shall result in creative solutions or actions. Let us say that two individuals are in the same state of knowledge with their knowledge domains organised in exactly the same way. They try to solve the same problem. Only one succeeds in giving an interesting, fruitful answer

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[3] It should be made clear that the concept of problem solving that I use is very general and broad. Anything from childrens' play to furnishing over painting and doing laboratory work count. In all these cases, the individual stands before a problem (how to furnish the flat, how to depict the landscape, et cetera) and tries to solve it by reasoning, although the reasoning not always needs to be explicit, that is, in words.

that leads to unexpected consequences. How come? This is the question that I am interested in here. To answer that question means to reveal some of the mysteries that go by the names of intuition, association, and imagination.

First, the difference between normal problem-solving and that specific kind that we call creativity must be made clear. Both kinds involve the same components: *knowledge representations*; *rules* for manipulating those representations; a *direction* to the activity; *standards for evaluating* the results that are produced; and finally something that *puts an end* to the inquiry. It is typical for situations that require creative efforts as opposed to step-by-step reasoning that they have an open-ended character. The goal of the inquiry is not well-defined. The direction in which the answer should lie is rather evident, but the nature of the answer is unknown, and there might even not be an answer. Because of this open-ended character, the evaluation standards must be less exigent than in the normal case. They must allow for solutions that are outside the scope of the inquiry, that exceed the expected. Before a solution can be chosen, it may be necessary to match different answers with one another and see onto what they lead. Likewise, the halting rule or stop mechanism has to be more flexible in creative problem-solving than in the normal case. One should not be satisfied with any result that gives what looks like a correct answer, but wait for a result that leads the inquiry in a new direction or at least gives a new and unexpected answer.

A consequence of a creative advance is a reevaluation of old evaluation standards and halting rules. The advance not only opens up a new field, it also sets new expectations for further inquiries. This fact helps distinguish between normal, as opposed to extraordinary, problem-solving, where the problem as well as the expectations that control the inquiry are well-defined, and the steps by which the solution can be reached are well-known. Extraordinary problem-solving occurs in situations where one cannot get to the solution by using the available tools. The problem stands in need of a creative solution. It lurks on the threshold between old and sterile knowledge and new but still uncovered ground, and the search for a creative solution is accompanied by a relaxation of the given standards.

The use of special evaluation and halting rules will nevertheless be futile unless the material that they are applied on is right. And now we get to the core. I maintain that creativity results from a certain kind of operations on the knowledge representations in the domain. Unless these operations occur, whatever the psychological, social, or cultural conditions are that hold of the individual, creativity will not arise. Normally, the rules for problem-solving proceed step-by-step in the following manner. Say that an agent is in a state of knowledge S_1 and performs an action A that consists in one single operation, for instance a negation of S. Then the next state S_2 will be a function of S_1 and A. The succeeding state S_3 will in turn be a function of S_2 and a second action A_2. And so on. Of course, this is a simplified model, but I hope the main idea is clear.

Another property of rules for normal problem-solving is that they are truth-preserving. A step that does not preserve the truth of the reasoning will not be taken into account. N-E. Sahlin has suggested (personal communication) that regarding creativity other characteristics may replace truth as being more salient or valuable. Such characteristics could be pragmatic values like fertility, aestethic values like elegance, or simply dissimilarity or divergence of the content generated by the rule, or why not the property of being energizing. I will not dwell on these properties, but concentrate on the fundamental nature of the rules at work in creativity.

It seems that there are two kinds of rule that operate in creativity: *intra-representational and inter-representational.* They both result in a change in how a piece of knowledge is represented. The first kind consist in changes within a representation, while the second one involves more than one representation. As regards this latter kind, it is suitable to talk about transfers between source and target representations. What is transferred to the target is either structural traits or contents of the source, and the change pertains to the target. It so to speak 'copies' properties from the source. The transfer between source and target both rests upon and generates judgments of similarity between the domains involved.[4]

Intra-representational rules do not depend on similarity judgments. They constitute a way to reorganise or reconceive a given content. If we look closer at the intra-representational changes, there are at least three sorts. A first one consists in *changes of the form* of representations. That is, the same information can be represented in different ways, and when changes are made, the information is put in a new light that may permit of new inductions or at least a new understanding. The changes I have in mind are between symbolic (or conceptual), indexical, and iconic forms of representations.[5] It is important to notice that these changes not only concern variations in linguistic notation, but apply to all kinds of representations. It is exactly this alteration between forms that make the rules so powerful as regards creativity.

I will give a few examples. We want to signal that smoking is forbidden. We can do so by writing a sign in a natural language, or we can use a picture of a cigarette that is crossed over, or we can use some kind of very strong fan that starts every time a cigarette is lit and puts it out. The first strategy is symbolic, the second predominantly iconic, and the third one predominantly

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[4] I distinguish between the structure and the content of representations. The structure organizes the content, while a certain content will make some structures more probable than others. Content is best described by a a list of features or characteristics. The organisation of those features is provided by a description of the structure that explains how the features are related.

[5] Indices represent by being close in time and space to the represented object and are often causally related to that object. Icons represent by having a pictorial similarity with the represented object. Symbols or concepts do not depend on either the presence or existence of what they represent. Linguistic symbols are usually considered to be conventional and arbitrary.

indexical. By changing between forms of representation in this manner one can escape from patterns of thinking that connect certain content with certain forms. Depending on how the content is represented, that is, what form and what medium are used, the same content may give rise to different thoughts and different behaviour on the part of the one who receives or entertains the information.

Say that we want to furnish a room. We can do it by simply putting the furniture in the room and moving it around till everything looks OK, or we can draw maps and make diagrams of the relation between the room and the furniture and between different pieces of furniture, or we can make drawings that depict the room with different arrangements of the furniture. We can also write lists of which pieces of furniture should be next to each other of practical or other reasons and then compare the results of the different lists. The changes can of course also pertain to different kinds of symbolic representations, as for instance Arab or Roman numerals, or linguistic or formal-logic representations of agruments and proofs.

A second sort of intra-representational rule concerns *changes of modality*, and has to do with which sensory modality carries the heaviest load in the reception of information. Say you are cooking a fish-soup. You make it with the help of a recipe. The result of the recipe is unsatisfactory, and you must improve on it. To facilitate the task, you concentrate on one aspect of the information that you have of the soup at the time. In turn, you taste it, smell it, check its consistency, and finally consider how it looks. Depending on at what your attention is directed your measures will vary.

A third sort of intra-representational rule consists in *shifts in the figure-ground organisation*. To shift your focus between the fish, the carrots, the tomatoes, the clams, and so on, of the soup will help you find new ways to improve it. Aspect-seeing can also be assigned to this group. It consists in variations of how a representation is understood depending on what aspect of it is highlighted. A famous example which most of us are familiar with was used by Wittgenstein: the duckrabbit.

As regards the inter-representational rules, I mentioned above that they involve a transfer between source and target representations. A first sort *transfers structure*. You have the basic material for solving the problem, but you do not know what to do with it. You need a way to organise the different elements of your representation. I will give three examples of this. First, Kekulé and the structure of the benzene molecule. According to the chemistry of that time, all organic molecules should be possible to describe in terms of a string of carbon atoms. But the proportion of the elements of the benzene molecule seemed to make such a description impossible. Kekulé was dozing by the fire when he woke up with a sudden insight. The form of the snake biting its tail that he saw in his mind's eye was also the form of the benzene molecule. The molecule had a ring- and not a string-structure. To proceed to explain the structure of the benzene molecule it was not sufficient

to reconceive its form from being linear to circular. Additional changes in the model had to be made, some of which could not be verified at the time. All the changes were, however, governed by the model based on the snake-vision.

A similar example concerns the model of the atom which at the beginning of this century came to be conceived of as a miniature solar system: the atom as a microscopic sun and the electrons circling around it as the planets. This model was contradicted by many established theories of the time, for instance in electromagnetics, but Bohr stuck to it. Gradually he succeeded in working out a new and successful theory of the atom based on the model. These two examples show that at times when no solution is at hand, the search may fruitfully be guided by a model or structure from an area apparently unrelated to the main subject.

A final example is drawn from architecture. On innumerable occasions architecture has been governed by models taken from other areas, and whose primary features have not had much to do with the comfort of living or building of houses. As one case Le Corbusier can be used. He wanted his housing areas to be biological or ecological systems, in which nature and housing supposedly had made a pact. New buildings were seen as plants that were introduced in the existing scenery. To Le Corbusier, constructions should be part of the life cycle, not stand outside it as static, dead objects.[6] Visions like these governed the planning of new areas and the calculations of new constructions. A second case is Brazilia, the capital of Brazil, that was created from scratch in the end of the 1950s by Costa and Niemeyer. It was guided by a vision of the future of the country, and it is built to resemble a jet plane from the air (that supposedly flies into the future). Unfortunately, the futuristic design appears to have been ahead of its inhabitants in time, who were not mentally (nor socioeconomically) ready to give up the more homey conglomeration of the modern city for a visionary, clean-cut and ultrafunctional world capital.

Let us proceed to inter-representational rules that *transfer content* between source and target domains. Examples can easily be found of situations in which you know how to do, but not what to use to do it. A first one I draw from grafting. Usually when a branch is grafted onto a tree, say an apple-tree, bast is used to keep the branch in place. A friend of mine was grafting but discovered in the last minute that he was out of bast. What should he do? Usually, when you want something to stick to another thing you use either glue or adhesive tape. Glue was not practicable in this case, but tape was. My friend used masking tape, which not only held the branch in place, but turned out to have better qualities than bast. It is stretchable and it does not burst because of bad weather conditions and thus does not have to be exchanged. Besides, the grafting was hundred per cent successful, a strikingly

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[6] See for instance his *La Maison des Hommes* (1936) Paris: Librairie Plon.

good result, and according to my friend a consequence of his using masking tape instead of bast. This is a case in which the function of the source and target domains coincide, while the qualities differ. Bast and masking tape have similar functions, at least in the case of grafting, and that led my friend to change the bast for the tape. They have, however, different properties.

A second example comes from the development of the theory of evolution. The problem concerns how to explain the creation in terms of evolution.[7] How should evolution be understood in order to give such an explanation? A proper description of what evolution involves was lacking. Both the traditions from early Greek philosophy and from Christianity conceive of the world as set. No qualitative evolution occurs, everything is already in place, created at one single point in time. In European 17th and 18th century thought, however, a new conception of change had developed. Science had made many improvements since the Middle Ages, and the belief in natural laws that govern the continuous progress of man grew strong. In the middle of the 18th century in France, the idea of progress was for the first time applied not only to man and to cosmos, but also to nature. This idea took its time to strike root, since it lead in the direction of a denial of God as the Creator. During the 19th century it slowly became accepted, but the thought about the constancy of the species still dominated. The impetus of Darwin to advocate the evolution of the species came from a work in geology. By the time Darwin was working on *On the Origin of Species* others came up with similar, but less detailed, ideas. One of the most important general ideas that were put forward in Darwin's book dealt with the design with which evolution took place. Darwin did not attribute that property to God, but introduced the principle of natural selection.

What conclusion concerning creativity can we draw from all this? No doubt, Darwin counts among the people that almost everybody would call creative. The interesting fact behind this story is that Darwin did not create anything from scratch. The idea about the evolution of the species grew slowly over the centuries, and over time borrowed its fundamental features from other areas, from comparisons of nature with man, with cosmos, and so on. This kind of slow development accounts for why often several people come up with the same idea independently of each other. It is not primarily the stimulating environment that provides the impulse for a new sort of solution to a problem, but prior comparisons between different knowledge domains, and the resulting transfer of features from source to target.

A third example of inter-representational transfer of content is the comparisons between man and machine. These go in both directions, depending

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[7] If the problem was how to explain the presence of organisms on earth we would have a case of transfer of structure, since we would know what we wanted to do, but not which explanation should be used or from what area it should be taken. To solve the problem we could for instance choose between creationism or Darwinism.

on the subject of interest. When we do research on intelligence and reasoning, we take the way the computer works as a model. When we search for new solutions within robotics, the way perception and motor activity function in man constitutes the model. In the first case, we need something new to fill in the model of what it is to think, in the second case we need an account of sensory and motor control of robots that does not take its starting-point in our knowledge of machines. A related example concerns the study of animals either from the view-point of animals as machines in the tradition of Descartes or as beings with a soul—the latter view verging on anthropomorphism.

The last examples all depict how characteristics pertaining to one domain are transferred to another. I have not discussed cases in which several domains are involved, since that would unnecessarily complicate the survey. I am sure, however, that such cases can be found. Above I used as wide a variety of examples as the space allows. Hopefully, the discussion has provided an answer to the basic question of this paper. That question, as you may well remember, concerns two individuals facing the same problem and being in identical states of knowledge. Only one of them succeeds in giving a creative answer. The question is what he can but the other cannot do. The answer should be clear by now. The person who finds a creative solution can change the form of the content he attends to and shift his attention between different features of the representation, and he can also use comparisons pertaining to structure or content to guide his reasoning and actions. It seems that he can play around with his representations in a more casual way than the other person and can set his thoughts free from the general or common conceptions that normally guide them.

So far I have supported my thesis by giving examples of creativity which, as I see it, univocally point in the direction of the rules I have set up. Another kind of support comes from linguistics and cognitive psychology. Experiences and detection of similarities obviously play an important role in decision-making and agency, especially in cases when the subject does not have explicit knowledge of the domain in question. When there is a lack of conceptual knowledge, perceptual experience substitutes for it. When we cannot deduce or infer, we reason by similarity or analogy. Higher-level symbolic thought co-operates with lower-level perceptual experience.

Much reasoning is guided by categorisation, by seeing one thing as another. Studies of reasoning and decision-making have often concentrated on logical, inferential thinking and calculation. In many cases, however, the results of these studies appear to have normative, rather than descriptive, import. Reasoning by similarity instead of calculation seems to have both evolutionary and parsimonious advantages and lies at the bottom of more complex reasoning.[8] The ability to categorise is of fundamental value for the

[8] Cf. the paper (in Swedish) by N.-E. Sahlin and P. Gärdenfors in *Huvudinnehåll* (eds. Å.E.

simplest train of thought. If a subject cannot identify and reidentify the object he reasons about, then he cannot entertain any continuous, coherent thoughts. He becomes a momentary individual.

Categorisation develops in children at an early age from a general ability to notice different features of objects over context-bound reidentification to abstract categorisation. Abstract categorisation is in principle independent of detection of perceptual similarities and rests upon theoretical knowledge. It appears that conceptual or symbolic thought in this manner evolves from imagery.[9]

Experimental work on categorisation and similarity judgments is relevant for studies of creativity since many of the insights that open up for creative solutions to problems consist in more or less temporary recategorisations. We have already seen examples of this: masking tape happened to be counted as a device used in grafting instead of bast, buildings were conceived of as a natural part of the ecological system and not primarily as cultural artefacts, and so on. Other examples can be found in biology, in the categorisation of whales as mammals instead of fish, or dinosaurs as birds instead of as reptiles, or in physics, where the categorisation of sound oscillates between wave and particle.

Recategorisations are often introduced to make a break with fixed conceptions. The part of categorisation that is of interest to people doing research on creativity pertains, I have argued, to two kinds of situations. First, situations in which the subject has satisfactory information, but does not know how to develop or organise it. The domain stands in need of a transfer of form from another domain with a similar content. Secondly, situations in which the subject has incomplete information and must improvise to fill it in. The transfer is of content from another domain with a similar form. In both these cases, the interesting similarity judgments are not those that are either naturally (psychologically or physiologically) or socially and culturally induced. On the contrary, an ability to escape from conformity and habits is valuable. This does of course not mean that the detection of similarities is completely independent of constraints, neither natural, contextual or task-dependent ones. The link between creativity in a certain domain and extensive knowledge of at least portions of that domain appears to be quite strong.

Categorisation and creative thinking have in common the comparisons, based upon similarity, between domains or instances of domains that lie at the bottom of reasoning. A difference is that in categorisation both source

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Andersson/N.-E. Sahlin) (1993) Falun: Nya Doxa. The issue has also been touched upon by S. Halldén in *The Strategy of Ignorance* (1986) Uppsala: Thales.

[9] For instance has L. Barsalou recently presented a both interesting and plausible theory of how linguistic symbols arise from perceptual ones in "Flexibility, Structure, and Linguistic Vagary in Concepts: Manifestations of a Compositional System of Perceptual Symbols" in *Theories of Memory* (eds. Collins/Gathercole/Conway/Morris) (1993) London: Erlbaum.

and target domains are known but not so in creative problem-solving. In categorisation, the subject perceives the relevant similarities between the instance and the category, and knows enough about the category (if he can apply it correctly) to be able to explain and justify the categorisation, if not from a general view-point, at least from his own subjective one. But when he tries to retrieve an adequate source for the target of a problem that demands creativity, he relies on incomplete knowledge of that target.[10] A problem requires a creative solution in exactly those situations in which the subject does not have sufficient knowledge to be able to reason inferentially. Instead, he has recourse to similarity judgments in the inductions and conclusions.[11]

A consequence of this is that he cannot, as in normal problem-solving, complete his forward search from target to source with a backward search from source to target and reconstruct the steps in between. Often, when we try to solve a problem, we know not only the question but also the answer we want to get, but we do not know how to produce it. In such cases, a good strategy consists in working both from question to answer and from answer to question. But when the answer lies in the dark, this strategy can of course not be used.

Another consequence of this lack of knowledge accounts for the fact that a fresh similarity can work as an impetus without being true. It can guide the search for a solution and point in the right direction, but still not produce any new inductive knowledge. The guiding similarity has an indirect influence on the solution but is not part of it. This distinction between the direct and indirect influence of similarity judgments links up with a distinction between surface and deep similarity. Surface similarity is perspicious enough to make us examine the relation between two domains that we have no *reason* to believe similar. If we are lucky, we discover a deep similarity between the domains as well. Surface similarity functions as the impetus to a solution, while deep similarity is the result of the investigation that follows upon the creative breakthrough.

Let me compare with grafting again. Initially, a similarity in function is found between bast and masking tape: they can both be used to keep things together and in place. Since no bast is available, tape is used. In this case, the result is beyond all expectation. It turns out that the tape has not only

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[10] This fact has been underlined by P. Johnson-Laird in "Analogy and the Exercise of Creativity" and S. Vosniadou in "Analogical Reasoning as a Mechanism in Knowledge Acquisition: A Developmental Perspective", both articles in *Similarity and Analogical Reasoning* (eds. S. Vosniadou/A. Ortony) (1989) New York: Cambridge University Press.

[11] E. Smith, E. Shafir, and D. Osherson have shown that inductive inferences made with unfamiliar predicates is based on similarity between the premise and the conclusion categories. When the predicates instead are familiar, judgments of plausibility become pertinent. Plausibility judgments rest upon analyses or decompositions of the familiar predicates. See "Similarity, Plausibility, and Judgments of Probability" in *Cognition*, 49 (1993) 67–96.

similar but better qualities than the bast. The surface similarity in function allowed masking tape to be used instead of bast, but it only indirectly influenced the role the tape came to play. A deeper similarity caused the tape to work so well. If the common adhesive tape had been used instead, or why not yarn, the result would no doubt have been less successful, even though the latter two devices also share a surface similarity with bast. Obviously, there are differences between the bast and the masking tape which are responsible for the superiority of the tape to the bast. But the tape could not have worked so well had it not had some necessary properties in common with the bast, for instance, that it lets the tree 'breathe' and that it is not too tight.

L. Barsalou has pointed to the use of ad hoc categories that are introduced when a subject pursues a novel goal.[12] These categories are temporary and introduced for a special purpose, as when throwing a big party you construct categories like 'dishes that are not expensive and still elegant and tasty' or 'music that is vigorous, but does not disturb the neighbours' to help organise the party. The similarities they rest upon are highly goal-dependent and personal. Ad hoc categories, as well as the metaphorical models that sometimes are introduced in the search for creative solutions, can misrepresent reality but still be of value. Their role consist in providing a guide-line of how to pursue the goal, in being an indirect influence on the solution. They can serve even if they are 'false' by giving an insight into what to do next.[13]

One rather central question has so far been left out of the account. It concerns how the relevant similarities are chosen in situations that require creativity. The choice is not straightforward, because, as just mentioned, the subject has incomplete knowledge of the target domain. Several factors influence it. First, some similarities apparently are perceptually hard-wired—we cannot but help to discover them. Secondly, the process of comparison itself helps select features in the sense that the similarities that are pertinent when I compare A and B do not present themselves when I compare A with C. Thirdly, the task description sets constraints on what features should be relevant in a certain context and thus subject to comparison.[14] Still, it does not seem that these three constraints alone can guarantee a creative solution. It has been suggested that an element of randomness enters into the process.[15] Personally, I am not sure if an appeal to randomness increases our

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[12] See e.g. "Ad hoc categories" in *Memory & Cognition*, 11 (1983) 211–227.

[13] J. Davidson underlines the role of selective comparison for getting insights in her study of gifted children in "Insight and Giftedness" in *Conceptions of Giftedness* (eds. R. J. Sternberg/J. E. Davidson) (1986) Cambridge: Cambridge University Press.

[14] These three factors are also mentioned in R. Goldstone "The Role of Similarity in Categorisation: Providing a Groundwork", *Cognition*, 52 (1994) 125–157.

[15] P. Johnson-Laird distinguishes between what he calls three main classes of algorithms that can yield a creative product (solution to a problem). The neo-Darwinian one starts with a random

understanding of the selection process. As far as I can see, one of the biggest and most important secrets of creativity lies buried here.

I would like to end this paper by relating to a very traditional view of creativity. That view first and foremost counts artists in different fields as 'truly' creative. There seems to be a grain of truth in it, namely, its reliance on a special metaphorical way of thinking, usually referred to as intuition. Intuition has long been regarded as noncognitive and figurative, as the opposition of deduction and also of hypothesis-framing and experimentation. The rules for manipulating representations that I have brought up here come close to this kind of intuitive thinking. Apparently, the figurative and the literal are not as much opposites as complementary. As some of the examples have shown, even science sometimes relies on the figurative. Recent work on metaphors show how they, conceived of in a very general manner as transfers of features across domains, help structure the information we receive from the world around us.[16] Metaphors lie at the bottom of many of our experiences, for instance of life as going up and down (like a path across a hilly landscape can go up and down) or of time as money or argument as war. I take this as another sign that creativity, or the ability to conceive of the given in a new light, is a fundamental trait of thought, whether conscious or not.

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generation, and then uses constraints to filter the products. The neo-Lamarckian one generates the products under constraints, and then selects randomly. The third, multistage algorithm uses constraints both in generating and testing, while the very final selection it makes is random. Johnson-Laird prefers the neo-Lamarckian algorithm, but points out that it is hard to imagine what constraints could be used in the initial generation of products, since these constraints should be common to all problems that require creative solutions. See "Analogy and the Exercise of Creativity" in *Similarity and Analogical Reasoning*.

[16] Important work in this field has been done by G. Lakoff and M. Johnson, among others. Metaphorical thinking can also be described as a superimposition of representations. It is wrong to believe that metaphors only involve a comparison between two entities or concepts. A metaphor usually stretches over several conceptual fields. It does not consist in a one-step metaphorical computation, but in several steps, and thus often rests upon a series of unexpressed, underlying metaphors.