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Scientific knowledge, algorithms and language creativity

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Abstract The paper deals with the controversial problem of the definition of creativity in Artificial Intelligence research, in the recent framework of machine learning. The starting point is to consider in which sense creativity is considered in the recent researches in Artificial Intelligence, highlighting that there is not just one kind of definition researchers refer to. Then we will consider creativity in scientific theories and language.

Keywords: science, scientific knowledge, algorithm, language, creativity

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> Where scientific observation addresses all phenomena existing in the real world, scientific experimentation addresses all possible real worlds, and scientific theory addresses conceivable real worlds, the humanities encompass all three of these levels and one more, the infinity of all fantasy worlds.
>
> Edward O. Wilson

1. The quest for creativity[1]

The comparison between the features of Artificial Intelligence and human intelligence traces, for some aspects, the traditional comparison between animals and humans. Since the resemblance relationships were used as a basis for transferring inferences from one domain of objects to another domain of objects we applied anthropomorphism as a form of knowledge by similarity to our knowledge of animals using all homologous traits that would allow us to understand their behaviour. Nowadays, the philosophy of Artificial Intelligence seems to follow the path above mentioned in order to conduct our comparison with machines.

Machine learning is one of the main research field in Artificial Intelligence. The development of this research field claims for some possible answers to big questions which deal with the comparison we are focusing on. Do machines think? What is the

[1] The authors have equally contributed to the ideas and content of this article. Claudia Stancati is responsible for sections 1, 3, 6. Giusy Gallo is responsible for section 2, 4, 5.

relationship between algorithms and recursive traits of human language? In which sense some interaction between machines and humans are cooperative? Do machines learn? Are some products of Artificial Intelligences creative?

In this paper we will focus on the creativity. According to us, creativity such a theme implies a wide range of perspectives: scientific, philosophical, ethical and political. We will ask whether the computational paradigm and its concepts could help us in understanding these perspectives, whether computers could make something creative or could make performances only apparently creative and whether computers will be able to recognize or produce creative aspects of poetical, literary or artistic works, but also of scientific developments.

First of all, we should address the issue of the definition of human creativity. The term creativity implies what is unexpected and largely unconscious, it deals with *ex nihilo* but also with an original combination of existing ideas and in this last case the creative aspect is the improbability of combinations.

We will investigate creativity whether the computational paradigm and its concepts support us to understand these aspects, whether computers do or will be able to do something creative or can realize performances only apparently creative and whether they are able to recognize or make the creative aspects of poetic, literary and artistic works but also advancements and scientific progress. It has to be clarified that the nature of these issues is very different: the first issue has a scientific nature; the second issue show a philosophical nature which now claims for ethical and political choices.

Margaret Boden, one of the authors who has worked on creativity and its relationship with Artificial Intelligence, maintains that: "creativity is a puzzle, a paradox, some say a mystery. Inventors, scientists and artists rarely know how their original ideas arise. They mention intuition but they cannot say how this works" (Boden 1994: 76) discarding the chance of an historical or psychological or scientific of the phenomenon. The paradoxical feature which make creativity impenetrable is that it is an unconscious process (such as language), also if creativity itself has to be considered at the top of human intelligence. According to Boden, even though creative processes are such a problem to solve for neuroscientists, Artificial Intelligence research could shed light on the principles that steer creativity. There are three kinds of creativity: combinational, exploratory, and transformational. Together the kinds of creativity set in motion psychological mechanisms and different way to "surprise".

The first kind of creativity is determined by the new combination of pre-existing ideas; the second kind generates new ideas and structure of thoughts starting from the exploration of conceptual areas or stylistic rules. The transformational creativity functions with a deep transformation of rules and constraints which can be added, removed, replaced or denied.

According to Boden the ways in which the novelty of creativity can be recognized concerns the P-creativity, that is psychological or personal creativity as the outcome is new and innovative for the agent who produces it, and H-creativity, that is historical creativity which produces developments known as innovation from the whole society.

Boden argues that AI accomplishes the three kinds of creativity also if the good outcomes in sciences and humanities are far from equal human creativity in general. There are some research programmes which reach creative results in various artistic areas: music (Cope 2001, 2006 and Hodgson 2005), architecture (Konig, Eizenberg 1981), designs and 3d images, color (Cohen 1981, McCorduck 1991, Todd e Latham 1992, Cohen 2002). The examples from computer-generated art and interactive art is particularly effective because, if it's true that the role of the artist or the audience is relevant, it is also true that the product is such that it could not have been imagined or realized without the computer.

2. Creativity, algorithms and human beings

Until a few years ago, we thought about computers in terms of input and output. Now machine learning is irreversibly in our life and has changed everything about AI: the starting point are data, which gathered together are processed by an algorithm which give a result as output. But the real power of machine learning deals with the chance that a learner can create other algorithms. Following Domingos, we can put the question this way: "Surely writing algorithms requires intelligence, creativity, problem-solving chops – things that computers just dont'have?" [3, 6].

A few years ago, two airplanes Boeing MAX 737 have crashed causing the death of all the passengers on board. Even though, soon after the accident, there were not evidences about the last disaster occurred in March 2019, after the first one disaster, Boeing invites all the owners of that plane model to update the managing software due to an algorithm error occurring while the aircraft is trying to get the cruising altitude. It seems that this error is connected to the first crash, but here the general and wide question at stake is how an algorithm can manage an unexpected situation. Is a software able to take an appropriate decision in an uncertain situation?

The previous questions are both linked the theme of creativity, whether it is defined as something unexpected or widely unconscious:

> What, then, is creativity? It is the innate quest for originality. The driving force is humanity's instinctive love of novelty—the discovery of new entities and processes, the solving of old challenges and disclosure of new ones, the aesthetic surprise of unanticipated facts and theories, the pleasure of new faces, the thrill of new worlds. We judge creativity by the magnitude of the emotional response it evokes. We follow it inward, toward the greatest depths of our shared minds, and outward, to imagine reality across the universe. Goals achieved lead to further goals, and the quest never ends (Wilson 2017, kindle edition).

Should we still use the label creativity while arguing about algorithms and machine learning? According to Boden, the attribution of creativity to androids depends from the attribution of intentionality and the place we would like to allow to androids in our lives (Boden 1995, 2009). This means that the issue is connected to the anthropocentric view on daily situations: manufacturing a tool, creating an artwork, performing an entire symphony, speaking, writing a journal article. Each of those realizations are the result of human work, even if this feature is not sufficient to mark them. We could attribute these outcomes to a single individual but we would suggest to place them in the dimension of a distributed mind or a collective mind in a complex process of knowledge transmission. Learning by doing is one of the ways of knowledge transmission and is based on (following) rules, planning actions and design combined with the freedom of action of the single human individual. The freedom to perform an action following rules at a certain degree oppose the idea of creativity as performing action without measure.

If we consider the multiple concrete manifestations of an algorithm we can consider it as a computational process which is able to monitor of user behavior, to aggregate information in the form of big data, and at the same time it is an engine bringing together different forms of statistical calculation to analyse data or it is a body of actions, recommendations and interfaces addressed to human beings that generally reflect only a small part of the cultural elaboration underway behind the scenes. Whatever you define an algorithm the most intriguing result is the creation of works of art or cultural product which show more than other realizations the strong relationship between human being and algorithms: this means that there is line which connects computations, imaginary, bodies and minds. Algorithms adapt to our behavior giving at

the same time the opportunity to act or doing or making something deepening the relationship between machine and human being. A subject of this type leaves room for the possibility of considering the relationship of cooperation between human beings and algorithm to the extent that only together, today, may be some achievements. In this way, a kind of democracy should guide some creative and imaginative processes. Of course, this could implicitly mean that one of the two terms of the question is being given more space than it deserves. In reality, playing with equal arms does not put us in a position to deny that an algorithm is the result of a human creation but, on the contrary, opens the way to a possible fruitful possibility of increasing cooperation between human beings.

So, probably, it might be useful to speculate that, in our incarnate dimension, our limitation could find possibilities of use and expansion - especially in fields such as physics and medicine - in a computational horizon that exploits human skills and strategies such as creativity and imagination. This challenge is not so far away: as already happens in some research of robotics, also in its bioinspired dimension that draws inspiration from the world of nature to create new types of robots able to adapt to the environment being, at the same time, eco-sustainable, man extends some faculties applying them to specific contexts drawing support, without eluding me the ethical and juridical implications of the "uses" of the results of Artificial Intelligence.

In this perspective of deep collaboration between disciplines of different nature, a kind of digital humanism is born, a way of looking at some human characteristics that does not reduce the possibility of new discoveries in the field of Artificial Intelligence, indeed opens the way to the integration of different knowledge as a strategy for the solution of problems (think, for example, the catastrophic event considered above and how some "errors" have long-term effects and of a different nature).

Ultimately, a long-term reflection on AI, algorithms and creative strategies should not have a conflictual nature, and we suggest that it may lead to an overcoming of that still unhealthy conflict that bears the name of the debate "the two cultures".

3. Algorithms and scientific knowledge

Machine learning is one of the most relevant research field in AI. For this reason, we would like to verify the kind of creativity to be attributed to AI.

Since the nineties, *Automatic Mathematician* and *EURISKO* by Douglas Lenat are examples of creativity. *Automatic Mathematician* generates and explores mathematical ideas. *Copycat* by Hofstader is an example of the creative use of a computational tool since it works on analogy which is considered as a new way to perceive things.

During the last decades there has been an exponential proliferation of AI music composition programs with a substantial increase of the quality and the sophistication of produced music. Although *Jukedeck* and *Flowmachines* are largely dependent upon the software designers and then considered such as a kind of extended mind, only *Generative Adversarial Networks (GANs)* is considered a software provided with sufficient autonomy to be thought creative.

Computers are electronic-members of the human community and if we were to admit them we should have to establish their precise legal status but even provide for the protection of their artistic creations. According to Boden the attribution of creativity to androids depends on two questions: first, the issue on intentionality; second, the issue of the space that we are willing to grant them in our society. Granting more space to androids is bond to the theme of self-consciousness in computational terms instead of in terms of phenomenal consciousness.

The most relevant test bench is scientific knowledge. Programmes such as BACON (Black, Glauber, Stahl and Dalton) by Herbert Simon's research group are able to shed light on the inductive aspects of scientific work but they can only rediscover already known relationships and are not able to reformulate in new terms a scientific law already known. Those programmes follow schemas of thought and existing paradigms, memory and computing powers are infinitely superior to the human mind but these capacities are not enough.

Conceptual frameworks which generate ideas can be also modified as Arnold Schoenberg or non-Euclidean geometry have showed. The benzene ring is another relevant example. These aspects of creativity show that combinatorial creativity, that could be attributed to an android, but does not offer a deep sense of creativity. The challenge is not only to elaborate things that have never been elaborated before, but thinking about what could not have been processed earlier.

Science robotics actual ambition is to elaborate some platforms which allow genuine scientific discoveries. At this stage we are experiencing the development of new and more sophisticated technologies and their application in wider and unexpected areas, from caring to medicine.

In this technological dimension, failures are only temporary difficulties. If we face the problem of creativity from the point of view of scientific knowledge, we should recognize that, from a philosophical and scientific standpoint, "knowledge and error" and "conjectures and confutations" are a valuable opportunity to deeply understand problems and developments of knowledge. The position which concerns the use of big data and AI, in order to make useless theory building, the invention of theories and the construction of models of theories, does not consider that there is no way to derive different causal relations from those which result from already known theories, from any data interpolation or extrapolation whatever are the applied method and the power of calculation. This would be possible only if the inductivist vision of the development of scientific knowledge were true. We can conclude that from an inductivist point of view, actually feasible in a perspective of knowledge grounded on AI, one will know the already explored areas up to a certain level of detail until now foreclosed. Yet no new territories will be known, which is the very feature of scientific progress as authentically creative and imbued of imagination.

4. Creativity and scientific research beyond divisions

> The two great branches of learning, science and the humanities, are complementary in our pursuit of creativity. They share the same roots of innovative endeavour. The realm of science is everything possible in the universe; the realm of the humanities is everything conceivable to the human mind (Wilson 2017, kindle edition).

Creative experiences have shaped the great changes of the human species and each of the two disciplinary branches, humanistic and scientific, has looked at them from its perspective, only rarely attempting an innovative not elitist approach. The perspective endorsed by Wilson in his *The origins of creativity* has and anthropological and philosophical precedent in the so-called two cultures debate, fueled by C.P. Snow at the end of the Fifties. When Snow offers his *Rede Lecture* at the Senate House of the University of Cambridge, he has already abandoned his career as a chemist to devote himself to writing short stories and novels. The focus of his speech was that the academic specialization of the 20th century developed to the point of incommunicability

and misunderstanding between scientists and humanists. Snow proposes an anthropological reading of the relations between the «two cultures». He puts forward the hypothesis that the increase of the technological development without equal, with consequent and unavoidable social implications, must be approached starting from a formation of scientific and humanistic nature. Therefore, Snow's *Rede Lecture* has the merit of igniting the debate on the consistency of humanistic culture and scientific culture and their role in social reality. Contrary to what can be considered given the luck of the expression «two cultures», the *Rede Lecture* by Snow did not immediately give rise to a debate, which, instead, originated from the lecture "The two cultures? The significance of C. P. Snow" held by F.R. Leavis . The latter launched a direct attack on Snow, deeming him unfit to deal with such a delicate subject and, in an attempt to demolish the argument, ends up strengthening it, pursuing the defense of humanistic disciplines .

The philosopher of science, previously leading researcher in physical-chemistry, Michael Polanyi[2] takes part to the debate from his peculiar position, a researcher in transition. Polanyi (1959) has agreed with Snow on the hiatus between scientific culture and humanistic culture but does not marry the anthropological reading nor the flattened cause on the hyperspecialization, so much so that it recalls that specialization succeeds in accounting for the progress of scientific knowledge and in its harmonious transmission. Hence the conception that manages to make scientific knowledge interact with authority and tradition, elements that Polanyi calls directly into question also with regard to the acquisition and use of language. His epistemology of science is marked by the relevance of scientific discovery and the powerful knowledge of the scientist: scientific discovery, in fact, is a process determined by different stages, from the identification of a problem, to the formulation of hypotheses, up to the solution and its proposal to the scientific community. So much depends on the scientist's ability and the way he accepted previous scientific theories, so authority, and the way he facilitates the transmission of scientific knowledge.

> Scientific research – in short – is an art; it is the art of making certain kinds of discoveries. The scientific profession as a whole has the function of cultivating that art by transmitting and developing the tradition of its practice (Polanyi 1951a: 64).

According to Polanyi, the work of the scientist is similar to the artist. Being a scientist means to make assumptions, being an artist is creating an artwork. The scientist and the

[2] Michael Polanyi (1891-1976) was a medical doctor, a researcher in physical chemistry, an economist and a philosopher. After obtaining his PhD from the University of Budapest, he worked in Karlsruhe and from 1920 in Berlin at the Institute of Fibre Chemistry. In 1923, he moved to the Institute of Physical Chemistry. In 1933, he accepted a position at the Victoria University in Manchester, UK. Two years later, his research interests started to turn to politics and economics. Polanyi proposes the theory of the polycentric system that converges in the theory of spontaneous order, a notion that is developed by F. Hayek. Some years later, Polanyi joined the Society for Freedom in Science, the Mont Pelerin Society and the Congress for Cultural Freedom. Opposed to totalitarianism and the planning of science, he supports a form of liberalism. His political and sociological thought turned to epistemological research with the publication of *Science, Faith and Society* (1946), in which Polanyi presents his ideas about pure science, the autonomy of the scientist and academic freedom: the *fil rouge* of this thought is knowledge and its transmission. In 1948 his university established a chair in Social Sciences to allow him to continue his studies. In the 1940s, Polanyi was involved in academic relationships with his colleagues Turing and Emmet whom he met in Manchester. From the 1950s, Polanyi's research began to fuel the epistemological debate: he was invited to speak at conferences, he lectured at important American universities and he had scientific relationships with respected scholars in different fields like Rogers, Maslow, Erikson, Chomsky, Bar-Hillel and Merton.

artist need an overall view to make effective each stage of their practical activity to achieve their goal, to solve their "good" scientific problem.

> I would answer that to have such a problem, a good problem, is to surmise the presence of something hidden, and yet possibly accessible, lying in a certain direction. Problems are evoked in the imagination by circumstances suspected to be clues to something hidden; and when the problem is solved, these clues are seen to form part of that which is discovered, or at least to be proper antecedents of it. Thus, the clues to a problem anticipates aspects of a future discovery and guide the questing mind to make the discovery (Polanyi 1997: 237-238).

Scientific research deals with the practice of science and discoveries. The scientist gathers data, develops ideas, makes assumptions, carries out the research, but discoveries are not the result of the activities mentioned above: discoveries arise from certain conditions provided that the scientist is able to detect it:

> The state of knowledge and the existing standards of science define the range within which he must find his task. […] There is in him a hidden key, capable of opening a hidden lock. There is only one force which can reveal both key and lock and bring the two together: the creative urge which is inherent in the faculties of man and which guides them instinctively to the opportunities for their manifestation (Polanyi 1951a: 63-64).

Creative imagination is the starter of scientific research and is useful to detect assumptions, while intuition has the task to approve the solution of the problem and to consider the result of the research as valid and consistent with reality. The creativity of the scientist depends on «a lonely belief in a line of experiments or of speculations, which at the time no one else considered to be profitable» (Polanyi 1951b: 12).
The evidence of this ability has to do with a philosophical way of considering creativity, not necessarily as a faculty not subject to rules, but as connected to discovery and the game of imagination and intuition.
Although this picture seems to insist on the figure of the individual, it is a starting point. As already mentioned, personal drive finds confirmation (or denial) in the scientific community and in the formation of scientific beliefs that are not personal concern but claim to have a universal validity.

5. Clues from linguistic creativity

Tullio De Mauro, linguist and philosopher of language, probably little known in the English-speaking philosophical world and in the research field of Artificial Intelligence, has long dealt with the value and the meaning of words, suspended between the creativity of the linguistic use of the individual speaker and the understanding between speakers.
Taking into account the history of ideas and his research on Saussure's general linguistics, De Mauro developed his reflection on semiological codes according to the way in which the plan of content is organized, leading to a classification according to principles. In this framework, De Mauro defined five senses of creativity, in order to fix his own notion of linguistic creativity. In his book *Minisemantica*, first published in 1982 and after revised in 2007, De Mauro detected:

1. the creativity which recalls Benedetto Croce or the saussurean *parole*: the utterance is one-time creation, which changes at each performance;

2. the chomskyan creativity, is a rule-governed creativity which shows a syntactic nature and recursive working mechanism:

> Although it was well understood that linguistic processes are in some sense "creative", the technical devices for expressing a system of recursive process were simply not available until much more recently. In fact, a real understanding of how language can (in Humboldt's words) "make infinite use of finite means" has developed only within the last thirty years, in the course of studies in the foundation of mathematics. Now that these insights are readily available it is possible to return to the problems that were raised, but not solved, in traditional linguistic theory, and to attempt an explicit formulation of the "creative" process of language. There is, in short, no longer a technical barrier to the full-scale study of generative grammar (Chomsky 1965: 8).

3. the creativity which recalls the thought of Humboldt, that is the kind of creativity showed by the strictly connection between one language and one nation and it's the capacity to build and manage languages;

4. the creativity of the educational psychologists, which is the ability to solve a problem arranging the pilot applying rules previously applied to similar problems but showing the ability to change them, if necessary, in order to achieve the goal (imitation, combination, breaking the rules);

5. the creativity of logicians is a kind of creativity based on making finite use of finite means. It is also called non-creativity since it is always computable.

Does one of these kinds of creativity match to algorithms ruled applications? On one hand, the first attempts of AI involve a kind of recursive non-creativity (data and rules are set and never change); on the other hand, nowadays, machine learning developments shows a complex notion of creativity, which necessarily is a rule-governed one but it is able to adapt to seen and unseen situations, combining the second and the forth kind of creativity given by De Mauro.
In his research on language, De Mauro gives his definition of creativity as the willingness to innovation, manipulation and deformation of the coded forms, and their rule-changing transformation[3]. Changing is the main feature of a (linguistic) system in De Mauro, and it is recognized by all the utterers.
Generally speaking, creativity (also linguistic creativity) deals with innovation and adaptation: the chance is in our biological heritage and it is one the natural strategies which warrants our survival as human beings. A new musical composition, a new word and a new tool are not simply the result of creativity, even though they are achievements of distributed minds, since there always will persist the relation with things and word already existing. The creative transmission of knowledge and practices share a common ground with cooperation:

> Processes of cultural learning are especially powerful forms of social learning because they constitute both (a) especially faithful forms of cultural transmission

[3] Cfr. the original text: «disponibilità all'innovazione, alla manipolazione e deformazione delle forme codificate, alla loro trasformazione *rule-changing*» e «investe […] ogni aspetto dei codici in cui è riconoscibile. Essa ha evidenti riflessi sugli aspetti più propriamente sintattici, semantici e pragmatici» (De Mauro, 1982/2007, pp. 53-54).

> (creating an especially powerful cultural ratchet) and (b) especially powerful forms of social-collaborative creativeness and inventiveness, that is, processes of sociogenesis in which multiple individuals create something together that no one individual could have created on its own (Tomasello 1999: 6).

In his long and accurate research in comparative psychology, Michael Tomasello highlights the role of cooperation such as a necessary condition to the survival of human species. From individual to community, human action employed the way of cooperative action as a creative human strategy. Among human strategies, the linguistic creativity is one of the most recent strategies.
Do AI challenge exactly this human creativity? Will androids be provided with a kind of creativity as a kind of survival strategy? If yes, will the machine learning be the master of this task? It is possible that a further in-depth study for the answer to these questions may concern the philosophy of AI text generators.

6. A still open question

Each season of the research on AI is grounded on the prediction of the achievement of certain results; the failure to achieve these goals has led to a phase of retreat and frustration. A lot of AI researchers maintain that their researches cannot be assessed following the traditional standard of logic and scientific research, since do not concern nature but new artificial objects. Sixty year after the rise of AI, the exceptional nature of AI still continue since there are no criteria of falsification, etc.
However, we can observe that AGI is still a test case which AI has not yet passed. AI cannot afford themes such as creativity, without providing a definition, and subjectivity (for example, reduced to a dictionary). As a matter of fact, AI challenges subjectivity and this is the reason why there is a difficulty with self-ruled creativity also if AI technologies are a powerful tool for each kind of human creativity.

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