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Research Article

Rationality and Scientific Thinking as Foundations for Leadership in the World of Work

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The exercise of leadership in the contemporary world is intricately linked to understanding the complexity of the current times, with an emphasis on the importance of rationality, metacognition, and scientific thinking. Among other elements, it is necessary to consider the competition between humans and machines – especially with learning machines, which are characterized by replacing rule-based programming, based on logical inference, with an approach based on pattern recognition associated with the adoption of neural networks. In this context, exploring metacognition, which transcends cognition, means prioritizing reflection on reflection – that is, focusing on learning how to learn throughout life. Therefore, the proper training of contemporary professionals implies, especially, cultivating rationality, metacognition, logic, and analytical reasoning.

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1. Machines defeating humans, machines defeating machines

In both physical and cognitive dimensions, machines have gradually surpassed human beings. In the past decade, machines based on neural networks, statistics, and pattern recognition have, through a radical change in basic assumptions in programming, surpassed traditional machines, which were modeled through logical inferences. Against this backdrop, this text analyzes to what extent machines have also developed their metacognitive abilities – that is, their abilities to continuously learn how to learn, especially by reflecting on their own learning. Based on this approach, we hope to stimulate the debate on how, by promoting an education focused on metacognition, we can try – in some way – to protect the last frontier of human superiority in the competition with machines.

In 1997, IBM's Deep Blue chess program defeated the reigning world chess champion, Gary Kasparov. This victory marked a change in basic assumptions in understanding the comparison between humans and machines regarding their cognitive abilities [1]. Less than three decades have passed, and today any smartphone processor has become powerful enough to defeat the world chess champion. However, due to the much larger number of variations in the board game Go [2], until recently, many believed that we were still far from being able to program a machine capable of defeating the great champions of this game. That is, until AlphaGo – a program developed by DeepMind (acquired by Google) – used an innovative computational model in 2016 to defeat Lee Sedol, the world's top Go player. The following year, an advanced version of AlphaGo, called AlphaZero, defeated Stockfish 8, a machine that used a traditional model and had been the champion of computer chess tournaments the previous year. A new paradigm in the field was being established [3].

The significant innovation of the occasion was based on the fact that AlphaZero started "from scratch," that is, it did not use any pre-determined heuristics or databases in its strategy, unlike Stockfish 8, which relied on pre-established rules by its developers to evaluate different moves combined with opening databases, and so on. In other words, AlphaZero initially only knew the rules of the game and learned solely by playing against itself, using the basic principles of machine self-learning. And most surprisingly, AlphaZero transformed from a complete novice to the best chess player in just four hours, without any direct human collaboration or even assistance from other machines throughout its learning process.

2. From Logical Inference to Pattern Associators in Programming

To understand the dispute between Stockfish 8 and AlphaZero, we need to understand that computer programming – a rational process by definition – does not necessarily have to be based on the insertion of a sequence of propositions, concepts, and logical inferences. Although they have been used for less than a decade, the so-called pattern associators, based on statistical calculations coupled with artificial neural networks and deep learning systems, seem to be gaining increasing prominence in solving contemporary problems (Pinker, 2021) [4]. The victory of AlphaZero over Stockfish 8 in the game of chess is just one simple example.

Currently, with the development of this modern technology, we have the alternative to capture properties of the programming/coding object through pattern associators, like interconnected neurons through synapses, instead of manipulating chains of symbols through logical rules (traditional programming). Each property is quantified and assigned a specific numerical weight, reflecting an evaluation of how good that property is for diagnosing a certain category, the object of the mission to be accomplished. Instead of focusing on the observance of logical rules, the emphasis shifts to the world of statistical distributions that determine the weights of each of the synapses involved in the complex process.

In the illustrative case of facial recognition, images are captured by a camera and sent for analysis within the system itself. It detects the presence of one or more faces and processes the collected information accordingly. The image is converted into a normalized monolithic format, to standardize it and then analyze all the relevant information. This process is called encoding, and it is through this process that the face becomes recognized (or not) in the available database [5].

Among the characteristics observed in the images are the facial measurements, also known as nodal points. In general, it is assumed that the human face has approximately eighty of these points. They include the distance between the eyes, the contour of the face, the size of the chin, the curvature and thickness of the lips, the length of the nose, as well as scars and specific characteristics. This information functions as the face's fingerprints, a kind of signature. Therefore, the system performs a cross-referencing of data and patterns, making it possible, in theory, to recognize the individual in question through a database previously registered in the system.

Artificial neural networks are at the core of this operation. Each feature of a facial item is quantified and then multiplied by a numerical weight, reflecting how much that characteristic contributes to diagnosing the desired category. The weighted values are summed, and a threshold is adopted to accept (or reject) the proposed identification. In a visual representation with two layers, a lower layer contains multiple measurable characteristics (input neurons), and in the upper layer, there is the set of available faces in the database (output neurons). Each input neuron is connected (synapse) to each output neuron via variable intensities, which can range from highly positive to highly negative, reflecting how relevant that property is in fulfilling the mission.

An important initial question is: who determines the weight to be assigned to each variable/neural connection? The surprising answer is simply no one, or if you will, through random initialization! In other words, the initialization is irrelevant. What matters is the process, the subsequent dynamics. It is the experience, based on trial and error, that gradually adjusts these patterns. This is how the network is trained, or in other words, how the machine learns. With each iteration, there is a new adjustment of the weight distribution. In other words, errors are very welcome and are inherent parts of the search or correct process.

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For more complex problems (sophisticated facial recognition being one of them), it is necessary to add more hidden intermediate layers, as well as include three or more additional dimensions, working with new categories that reflect partial similarities. In other words, the challenge of recognition can be broken down into parts, with each set of layers partially addressing an intermediate task. Deep learning systems typically involve networks with many hidden intermediate layers, enabling them to accomplish the task after as many iterations as necessary. It is worth noting that the system goes back to the beginning of the process when the partial result is not satisfactory, and new adjustments to initial weights are established. These interactions continue until an acceptable level of accuracy is achieved.

Undoubtedly, understanding this entire process in detail is an extremely challenging task that requires a lot of dedication. But, in summary, the most important message conveyed by this explanation is that the appeal to pattern associators surpasses the so-called classical artificial intelligence based on logical deductions and manual encoding. In other words, unlike classical approaches, deep learning systems theoretically dispense with preliminary concepts or even logical inferences.

3. Artificial neural networks and the human brain

It is interesting to note that when contrasting traditional logic-based computation with computation based on artificial neural networks, the latter is closer to the functioning of the human brain than the former. The brain is naturally programmed to simultaneously execute a massive number of associations and pattern combinations. Therefore, as an initial conclusion, it is worth highlighting that human cognition, although rational, is less logical than previously imagined.

Addressing this issue, Pinker (2021) emphasizes that human brains are hybrid systems. This approach sheds lighter on still obscure topics related to how human beings make inferences. Conclusions sometimes classified as intuitions or even supernatural events may be the result of reasoning linked to the functioning of neural networks, whose operations incorporate information through mechanisms that we have not fully elucidated yet. By knowing more and better about the functioning of the brain, we may be able to shed light on phenomena that we currently classify as "instinct" or "sixth sense".

Returning to AlphaZero, it is worth noting that its learning is based on artificial neural networks. The appeal to artificial neural networks expresses an attempt to make the computer function similarly to the statistical rationality dimension related to pattern association in the human brain. In AlphaZero, this process has two simple parts: (i) evaluation of the given position; (ii) evaluation of each possible legal move in the position, corresponding to a specific variant. In this case, an artificial neuron represents an amazingly simple processing unit that accepts a number of conditions, multiplying each one by a certain weight, expressing an assigned value that can be higher or lower depending on its importance.

The neural network of AlphaZero has around eighty layers and hundreds of thousands of these neurons. Coarsely simplifying, whenever AlphaZero plays and loses, it automatically adjusts the weight values of all the variants to reduce the possibility of making the same mistake that led to its defeat. In other words, in the case of AlphaZero, the iterations arise from a future predicted defeat in the game and therefore require adjustments in the weights of variants and in the initializations or intermediate steps. It is important to highlight that AlphaZero starts as a blank slate, a large neural network with surprisingly random weights.

Everything happens as if it were designed to learn how to play two-player games with alternating moves, even though it knows absolutely nothing about any game, learning over time in a limitless way. Just like us humans are born with a vast capacity to learn a language without knowledge of any language. In other words, although we are not born knowing something specific, the brain's tools are already prepared to learn any language equally. And that capacity to learn turns out to be more relevant than anything already learned.

4. Cognition and metacognition

Although our reflection started with the analysis of the advancement in machine performance in playing chess, the embedded phenomenon is part of the continuity of a challenge between, on the one hand, an absurd accumulation of accumulated information associated with the use of logical systems, and on the other hand, an extraordinary ability to continuously self-correct. With that in mind, from here on, we will explore an analogy with human learning processes. In pedagogical terms, we can associate the first model

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with the traditional process of learning based on the memorization of information and rules by the learner, and the second with the development of their ability to learn how to learn by stimulating their awareness of how and under what conditions they learn.

Undoubtedly, these two processes, "learning" and "learning how to learn," can and should occur simultaneously. However, they are not the same thing. The act of learning is connected to the development of cognition, while the act of learning how to learn is associated with metacognition. The development of cognition is linked to the act of knowing, including the mental states, and thought processes related to the acquisition of knowledge. Thus, cognition involves multiple factors such as language, perception, memory, logic, reasoning, and other elements of intellectual development.

On the other hand, there is no simple definition for metacognition. The Greek prefix "meta" indicates that metacognitive processes go beyond cognition; they are processes that reflect on cognition. The concept of metacognition is related to the act of thinking about one's own thinking, where reflection and self-awareness about how one learns become progressively as important (or even more important) than the act of learning the content itself. In this way, metacognition adds to its process the knowledge of the act of knowing. It accomplishes this task by maturing the awareness of the actors involved in the process and by using a few skills generically called socio-emotional or soft skills [6]. In summary, metacognition refers to the ability to critically reflect on one's own cognition, that is, to monitor and self-regulate cognition [7].

Here, we expand this idea by suggesting that humans are characterized by the integrated exercise of three skills: physical, cognitive, and metacognitive. Regarding the physical skill, technological advances that have enabled automation by machines, conducted at unprecedented levels, have eradicated manual labor in agriculture and industry. At the same time, new spaces have emerged or been expanded, especially in the service sector, demanding what we used to believe were exclusively human cognitive skills. However, for some decades now, we have been witnessing the progressive use of machines in this sector as well, resulting from developments in robotics and artificial intelligence. Now, the last frontier, which marked a skill exclusively human, may also be crossed. Until recently, many believed that machines could not learn how to learn. Does the example of AlphaZero show that we are also being surpassed by them in this regard?

For now, it seems that, in terms of the dimension of metacognition, we humans are still far ahead of machines. The proposed analogy above, that machines like AlphaZero have already learned how to learn, may be premature. Especially in more complex systems, in challenges characterized by novelty and focused on the resolution of future problems, our creativity cannot be surpassed by machines.

5. Educating for metacognition and possible human redemption

Given the reflection above on the competition between humans and machines, it is reasonable to assume that, for practical purposes, battles in the fields of physical and cognitive skills have been won by machines. Thus, it is in metacognitive competitions that we can still come out as winners. However, we will only surpass machines in terms of metacognitive skills if we can master such abilities. Unfortunately, in general, our metacognitive skills are lacking. In this sense, the need to advance in education for metacognition seems urgent. Moreover, this advancement is not only necessary but also urgent, given that technology has been developing at an unprecedented speed.

Unfortunately, this radical change is happening without us being able to reflect minimally on it. This lack of harmony between technological changes and people's understanding of this new reality is not an exclusive characteristic of the current revolution. However, as stated in the text, this change is much faster and more powerful than previous revolutions. Many technological revolutions, including the Industrial Revolution, generated enormous social instabilities that were resolved only after decades or even centuries. Fortunately, until now, we have always had time to seek a balance between technological advances and social progress. Now, if we do not act quickly, the destructive power of this revolution may not give us that opportunity. (Harari, 2018) [8].

But we are not sufficiently attentive to this. Especially if, as this text suggests, it is urgent for us to pay attention to learning how to learn, we still are in the initial stages. Both in the past century and currently, our education has focused on the development of cognition and not on metacognition. And this neglect of metacognitive development has occurred because,

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for a long time, training a professional meant endowing them with proficiency in certain well-defined and delimited content, as well as the main associated procedures and techniques. Developing these skills in school seemed like the right thing to do. This is because, after learning them, predictable tasks, even if sometimes highly specialized, do not require originality and could be performed by professionals who possess these rigid bodies of knowledge.

For example, the dominant Fordist/Taylorism models throughout the 20th century demanded and achieved a scale that was fully successful in what they set out to do [9]. So, until recently, the tasks of most professionals could be listed as predictable routines. Therefore, teaching methodologies focused on the transmission of knowledge and procedures (cognition) did the job.

On the other hand, when professional challenges became much more complex, characterized primarily by unpredictability, mere learned content, techniques, and procedures have proven to be limited and insufficient. In this scenario, possessing metacognitive abilities becomes the differentiating factor between success and failure. Thus, everything suggests that cognition serves the analog past while metacognition embraces the digital future.

To explore another example, let us revisit the association between the concept of metacognition and the use of soft skills mentioned earlier. In relation to this point, it is worth highlighting how the possession of resilience is fundamental in a world of constant technological acceleration and increasing impermanence of things. It is resilience that allows human beings to continue seeking updates. Thus, although resilience may not have been so necessary in the past, today it is a determining capacity for professional success. Therefore, if its cultivation used to be neglected in traditional models of education, it can no longer happen.

It is important to note that educating for metacognition requires pedagogical strategies that are distinct from those we have adopted so far. Primarily, it requires the development of the ability to deal with change and conscious adaptation processes, by establishing a minimum mental balance when facing unprecedented situations.

As mentioned above, the problem is that the world has been changing very rapidly and radically, making it difficult for educational managers and teachers to perceive and build a new educational framework compatible with this new reality. However, curiously, regarding educational processes, modern technologies can help students identify better strategies for developing their cognitive skills. In other words, such technologies can help them learn how to learn. Learning analytics, coupled with virtual learning environments, generate systematical data that enable a systematic and deep understanding of the student's main educational characteristics. From the digital footprints left by the student, it is increasingly simple to understand the characteristics associated with how the student learns. For example, through observation, it is possible to identify which media optimize learning, at what times and in what contexts the student achieves the best performance, and even which methodological approaches are most appropriate for them [10].

6. Conclusions and leadership in the contemporary world

This technological, social, and educational scenario, marked by its metacognitive emphasis, indicates a tendency towards a new rationality based on a differentiated reason, which demands predicates that contemplate the human being and their environment, especially the machines they have developed. It is as if a new Enlightenment were viable, now based on much more complex pillars than in previous centuries [11]. Throughout the 21st century, along with the flourishing of a digital society that allows everyone free access to an infinite universe of information, we have paradoxically encountered an increasing number of people susceptible to fake news, all types of denialism, and baseless conspiracy theories. Consequently, we have witnessed the rise of political polarization and extremist stances. This situation has made it difficult to build essential spaces for dialogue among people with divergent opinions in the work environment. In such a context, especially in the world of work and in the exercise of leadership within that space, rationality and critical thinking must be particularly stimulated. Thus, the proper training of contemporary professionals involves cultivating metacognition, logic (deductive, inductive, formal, informal, etc.), interpretation of texts, analytical reasoning, distinguishing causality from correlation, introducing notions of probability and statistics, and all other basic foundations of rationality and scientific thinking.

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