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What is Reason?

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Abstract

This paper considers the central paradox of our time, namely, the triumphs of reason as reflected by the advances in scientific disciplines versus the seemingly inexorable increase in unreason as seen in the growth of authoritarianism and the rejection of science. The roots of this contradiction lie in a circularity in the scientific method itself, which becomes especially prominent in the project of reifying human consciousness. The crux of the problem lies in a misunderstanding of scientific rationality. I shall take another look at what is meant by the "rational process," differentiate it from formal logic, and emphasize its key dimensions of intuition and insight. Creativity is the essential aspect of the rational process. In our discussion we will argue that creativity, seen as reframing or paradigm change, is fundamentally non-algorithmic. Indeed it often finds productive uses for non-logical factors such as contradiction and ambiguity. Rationality, like science and mathematics, cannot be separated from its intrinsic connection to the human mind. Much of the damage that follows from technological advances stems from reifying human capacities and then imagining that they stand alone, independent of the human capacities that gave birth to them. Keeping human beings at the heart of scientific and technological developments will allow us to reap the benefits of these advancements and avoid the enormous downside that current social and political trends show us may be coming.

It may seem at first glance as though science is monolithic but a closer look reveals that there are two different kinds of scientific activities that differ radically in their motivation and consequences. The first is motivated by a sense of the grandeur and mystery of the natural world and its resonance in the human mind. To get a good idea of this kind of science one should read Einstein. Science of the second kind is characterized for a need to tie everything down, a need for power and control. Which kind of science will come to dominate research in AI and cognitive science? Will it be the sense of wonder or the need for control?

Which of these two attitudes will dominate depends in large part on whether or not one explicitly acknowledges that there is an essential circularity in the scientific method, namely, that the human mind is both the subject and the object of the research. In much of science this is not necessarily a problem but in AI research and in Cognitive Science it becomes a major factor. Now there is nothing intrinsically wrong with this. It is just the way it is. It is the nature of self-consciousness to be circular in this way. However, it behoves a mathematician to point out that this kind of self-reference needs to be handled with care for it leads to paradoxes and other logical conundrums. You need only think of the work of Gödel in logic and Cantor on infinite sets. On the other hand, venturing into these murky waters can lead to enormous rewards. This is where we stand today with respect to the research into the nature of mind and intelligence.

Scientific and technological progress inevitably involves a trade-off between benefits and costs. Every major scientific advance disrupts society and creates a new culture. The coming revolution of AI and intelligent machines may well be the most revolutionary change since the advent of the Industrial Revolution. Why? Because we are now dealing with the very things that make us human—intelligence, consciousness, and creativity. The stakes are enormous. The future of humanity and all life on the earth may depend on how wisely we are able to manage the transition that is fast approaching.

I am writing this article in the hope of encouraging researchers in AI to think carefully about the consequences of what they are doing. My aim is not to stop or reverse the progress of this research. That is impossible, we have gone too far down the road we are travelling. Like every previous technological change there are great benefits to be obtained for humanity from the AI revolution. Previous technical innovations produced dire warnings about possible negative consequences but, in the end, society adapted and so it will be this time around. The challenge is to get out in front of the curve recognizing that this revolution threatens to be more profound than others and that, as usual, every possible application of AI, both those with positive and with negative implications for society, is bound to be attempted. We must ask ourselves what we can do to mitigate the most negative consequences and encourage the positive. To do this we must understand the full implications of what we are doing. There is a role for individual scientists, for governments, and professional societies, and for concerned citizens. We are all in this together. It is after all our world that is in the balance—the world that we will pass on to our children and grandchildren.

1. The Paradox of Rationality

There is something very strange going on in the world today. At a time of unprecedented scientific and technological progress, a time of the greatest successes for the scientific method, and therefore for rationality, we are experiencing an explosion of irrationality in the world in the form of authoritarianism and the rejection of scientific evidence-based decision making. Our time is characterized by the simultaneous victory and defeat of reason. This stunning paradox is real and we should take some time to think about it because both sides of the paradox are connected to the future of humanity.

AI and cognitive science lie completely within the long Western tradition of rationality. Yet the world today is often in denial concerning matters on which there is scientific consensus such as the threats posed by global warming and environmental degradation. Many of our political leaders appear to live in a fantasy world which has little connection to reality. However, to only blame these myopic leaders is not enough. We must be brave enough to see the connection between populist anti-science and the hard realities of vast economic and social change that are fuelled by the ongoing technological revolution.

Liberal democracy is under attack everywhere in the world but it is to the tradition of liberal democracy and to science and rationalism that the world must look for solutions to our problems. Having said that it is still possible that we have an incomplete or inadequate understanding of the scientific method and rationality that contributes to the problems we face.

> *"Thinking involves a deep connection between logic, intuition, and insight."*

Computing devices, the Internet, and the globalization of the world's economy have certainly benefitted huge numbers of people. But they have also hurt a growing number of people whose standard of living is decreasing and who are becoming socially redundant—an underclass with little hope that they or their children will be able to ameliorate their economic or social situation. In country after country in the West these people are enraged and easy prey for manipulation by unscrupulous actors. They are open to the kind of populism that focuses their rage on some "other". We, the intellectual, social, and economic elite, tend to forget these people in our excitement with cutting edge developments in our field but their revenge may be to punish us all by attempting to bring down the very culture that has sustained scientific and technological progress.

Change can be stimulating or it can be threatening but in the short term it is often destabilizing. We are living through an unprecedented period of dramatic change and governments by and large have given little thought to the problem of helping people transition economically, socially, and psychologically. Yet the technological revolution is accelerating. The next stage, the one we are talking about will involve a total reorganization of the economic basis of society. Massive number of jobs will become redundant; millions may lose their livelihood. And this time it will not only be people who do not have higher education but will include professionals—accountants, lawyers, stock brokers, perhaps even doctors, teachers, and professors. One might argue that the new economy will produce new kinds of jobs but what about the people who are caught in the transition? How will these people live? How will they get meaning in their lives? The harbinger of what may happen can be found by looking at the first wave redundancy a good deal of which occurred in small towns and rural areas. The crisis manifested itself in a decrease in life expectancy and a growth in alcoholism and drug addiction. You cannot fail to be scared by the statistics. People are being pushed into depression, anxiety, and despair. When you are in such a state, when you are drowning, you will consider any action, no matter how radical or disruptive.

2. The Roots of the Crisis: A Misunderstanding of Reason

I propose to trace the present crisis back to the origins of our civilization—to the Ancient Greeks and their discovery of reason and rationality. Yet the Greeks also had problems with the rational. The Pythagoreans, for example, venerated a kind of literal rationality which for them meant that all numbers were rational (fractions) and that all natural processes such as musical harmony could be described and explained by these numbers. Imagine the reaction when they were confronted with the proof that the square root of two was irrational. Rational numbers and irrational numbers were, in their terms, incommensurate, and as a consequence the hypothesis of rationality had failed. This precipitated a huge cultural crisis.

Irrational numbers were a paradox and a barrier but the story has a happy ending even though it took a very long time for it to come into being. The problems of geometry were fixed up, the assumption of rationality (or commensurability) was dropped, and a new class of numbers was ultimately invented, the real numbers, that removed the problems that existed in the system of rationals. That is the kind of creative solution that we are hoping for with respect to the current cultural paradox that also flows from a flawed conception of rationality. We too have a problem with how we understand the rational process. The nature of the problem will be made clear through the consideration of the geometry of Euclid, which is one of the foundational elements of the whole scientific enterprise.

3. Euclidean Geometry

Euclidean geometry is one of the intellectual roots of the technological revolution that is about to sweep over us. I am thinking about Euclidean geometry these days because I am teaching the subject to my thirteen-year-old grandson in order to give him a little intellectual enrichment. It is not taught in schools any more but friends and colleagues who are scientists and mathematicians all concurred that the subject had been important to them in their intellectual development.

Why study Euclidean geometry? Most people regard Euclidean geometry as the prototype of a deductive system—definitions, axioms, and theorems deduced through pristine logical thought. They may believe that the subject is algorithmic so that it could be done by a computer. In other words, they imagine that Euclidean geometry could be done without human intervention in exactly the same way that some people believe that AI systems can operate independently of human beings. So is Euclidean geometry a matter of pure deductive logic?

The significance of Euclidean geometry to the mathematician goes beyond its theorems. It includes the means through which these results are obtained and these means are not confined to logic much less to algorithms. Euclidean geometry was such a significant part of the education of scientists, physicians, and mathematicians of my generation because it taught us how to think. In particular it showed us that thinking involves a deep connection between logic, intuition, and insight. It turns out that the lived reality of doing geometry is far richer than many people think.

"Doing" Euclidean geometry works like this: First of all, you have to think up some geometrical statement (or potential theorem) which is interesting and accessible on the basis of current knowledge. (This is akin to deciding which hypothesis to test in a scientific experiment.) Then one has to decide (a priori) whether the statement is true or not. If you guess 'no' you try to find a counter-example. If you guess 'yes' you try to construct a proof. Any proof is built around some idea which may turn out to be a geometrical construction. In other words, you have to know why it is true before you try to prove it. It is only at this stage that you attempt to write down a proof and this is the only step in the procedure that is strictly logical.

Thus doing geometry (and the rational process in general) involves intuition (developing the hypothesis and guessing true or false), insight or creativity (coming up with the hypothesis and the idea for the proof) and logical argumentation (for the purposes of verification and communication).

> *"The creation of the rational number system in human culture or in the mind of a child is a prototype of an act of creativity."*

All three are essential parts of a deductive system and this is how it feels to work on such system from the inside. This is how it feels to do mathematics. The further you go, the less value you ascribe to the third, logical part. As the great mathematician William Thurston said, "When the idea (behind a result) is clear, the formal setup is usually unnecessary and redundant."[1] Creative scientists are basically interested in new insights, original ideas. These comprise the essence of science. AI is just another scientific discipline and needs to be judged by the quality of the creative ideas that go into the construction of its algorithms more than by what the algorithms produce.

4. Rationality

When I talk about rationality in this paper I mean the entire process, not just one or two elements of it. To repeat, rationality involves intuition, insight, and logic. Logic is just one of the steps, not the whole ball of wax. This gives us a working definition of rationality. I further propose that we substitute "rationality" for "intelligence" whenever we can. Rationality is a process that can be verified empirically whereas intelligence is a concept that is very subtle and hard to get your hands on.

5. Intuition or Fast Thinking

Intuition is thus an essential aspect of the process of reason. The Nobel Prize winning psychologist and economic theorist Daniel Kahneman is famous for demonstrating that the economic actor is not only logical.[2] In fact according to Kahneman human beings are capable of two kinds of thinking that he calls fast and slow. Slow thinking is what many people think of as logical thinking. They forget that fast thinking, which is involved in intuition is also essential to rational thought. Fast thinking is what the leader of the free world calls his "gut" and he is a disastrous example of the damage that can occur when fast thinking is unchecked by slow. You can read the history of rational thought as the attempt to control fast thinking with slow thinking but, in my opinion, that would be a mistake for reason has room for both of these modes. AI takes slow thinking, puts it into an algorithm and uses a machine to speed it up. It remains a kind of victory of slow thinking over fast thinking but comes with a cost. Perhaps it would be better to attempt a synthesis of the two.

6. Creativity, Insight and Paradigm Change

Creativity is not to be confused with the production of what is new. It involves insight by which I mean the discovery of a new way to "see" some situation. We understand some event or situation by placing it in a context, that is, framing it. Then the most basic creative act involves reframing, that is coming up with a new way to understand a given situation or event. What I referred to earlier as “getting the idea” often involves finding the “right” point of view. In science, a frame is called a “paradigm” and reframing is referred to as a paradigm shift. I am thinking, for example, of the way Einstein reframed our understanding of gravity. But to remove the idea of creative reframing from the rarefied atmosphere of genius let me supply a more down to earth example that applies to everyone.

“Creativity transcends logic. It involves the sudden leap to a higher point of view.”

According to developmental psychologists like Susan Carey, children are born with two primitive but vastly different conceptual systems for number.[3] An early conceptual task for children consists of combining these two systems into their first learned number system—the system of the counting numbers: 1,2,3,… That development is a child’s first creative learning experience in mathematics. However, because we are concerned here with the rational, I want to focus on the next step children take a few years later—the reframing of “number” from the frame of the counting numbers to the new frame of fractions or rational numbers. Initially fractions are introduced in terms of relative areas. We all remember that two-thirds was given meaning by dividing a pie into three parts and choosing two of them. Notice that this kind of example does not yet make two-thirds into a number but merely a ratio, that is, a relationship between the numbers two and three.

The crucial question is why is 2/3 a number at all? If it is a number, then by what process does it become one? The child must come to see 2/3 as a single object, that is, she must reify the ratio of two to three into a new kind of number. When this happens with respect to two-thirds the child can do the same thing for other fractions. She has then undergone a total conceptual reorganization, a reframing of her understanding of number. Reification of pairs of whole numbers, which brings the fractions into existence, is nothing less than a paradigm shift and yet almost every child goes through this shift sooner or later. Of course we do not call it reframing, we call it learning. We have all been there but we have forgotten and so for us it is “obvious” that fractions are numbers. But there is no reason a priori that fractions should be numbers that extend the system of counting numbers. Moreover, there is no reason why the set of ratios should make up a new number system for which the old operations of arithmetic still make sense. You can see what a big deal it is when you think about the extravagant claims that the Greeks made for the rational number system and how profoundly shocked they were when confronted by the existence of irrationals as was mentioned earlier. The creation of the rational number system in human culture or in the mind of a child is a prototype of an act of creativity.

One crucial point about this example. The two number systems, counting numbers and fractions, are incompatible (or incommensurate) with one another in the following sense. If you ask a child who lives in the world of counting numbers, how many numbers there are between 2 and 3 she will say none. But a child who made the creative leap to the world of rational numbers will say that there are an unlimited number of them. And of course they would both be correct within their respective frames or conceptual systems. In other words, correct and incorrect are relative terms, relative to context, of course.

Whereas a logical system has no place for problems like contradiction or ambiguity, such problematic elements are the very things which drive paradigm change. In Greek geometry there were "unsolvable problems" like trisecting an angle and squaring a circle. To solve them, you need to change the context of the discussion, that is, reframe the problem. An even more subtle problem concerned the status of the parallel postulate in Euclidean geometry. Questioning its status as an axiom and therefore as "obviously true" leads ultimately to the development of non-Euclidean geometry.

"Rationality is the process by which human beings understand the world and themselves."

One does not leave their present paradigm willingly or easily; you need to be driven out by a problem that you cannot solve in the old system. For the move from the counting numbers to the rationals the problem might be that the division of whole numbers is not closed within the system of counting numbers. In other words, though you can divide 7 by 3 in the counting numbers (and get an answer of 2 with remainder 1), the answer is not a number in the system you started with.

This leads me to say that creativity transcends logic. It involves the sudden leap to a higher point of view. A problem that was intractable in the original frame becomes transparent when looked at in the new. One further comment is brought out by this example. In mathematics there are many kinds of numbers: counting numbers, rational numbers, real numbers, and complex numbers. This whole hierarchy is built on the primitive idea of "number". Yet "number" in the abstract is never defined in mathematics. We all have a feeling for number because even a six-month old child has two separate conceptual systems for number. Nevertheless, this "feeling for number" is informal and thus never defined explicitly. The specific kinds of numbers I mentioned are, in comparison, well-defined. In this way the conceptual world of mathematics (and physics) emerges out of an informal world. Number is not special in that regard. What I said also applies to time, space, energy, randomness, and many other concepts. In fact, all of the building blocks of science have informal roots. Mathematics lives in both formal and informal worlds. Intuition still functions in the informal world and creative reframing often has to go back there but logical processes live exclusively in the formal world where things have given explicit meanings. Now apply what I have just said to intelligence and you will see the implications.

7. Strong and Weak Subjectivity and Objectivity

The scientific method is based on the objective truth of scientific results. In this section I would like to take a few paragraphs to discuss the nature of objectivity. Most people believe in a kind of "strong objectivity" which is analogous to what is meant by "strong AI".

We sometimes say that some phenomenon is "merely" subjective meaning that it comes from personal prejudice or idiosyncratic opinion. Thus we would object to a mathematical theorem or scientific experiment being influenced by religion, race, or gender. Objective means that such matters, as well as many other cultural factors, do not influence the result. Of course some people consider mathematics itself to be a culture but within mathematics the criterion of independence from arbitrary opinion might serve as a minimal way to differentiate subjectivity and objectivity—we could call this 'weak objectivity'.

> *"To make the right choice we need a fair dose of humility and wisdom to remember that all our scientific work is a product of human consciousness, not something that does away with the need for human consciousness."*

However, there is another possible meaning of objectivity. Something is objective in this sense if it does not depend on mind. You could say that it is objective in this sense if it would continue to be true even if there were no human beings around. This must have been the idea behind putting a diagram of the Pythagorean Theorem on Voyager 1 in the hope that the truths of Euclidean geometry were universal and would be recognized by any intelligent being. Is the Newtonian theory of gravity objectively true? Most people would say that it is even if that truth is only an approximate one. Is the relativistic theory of gravity objectively true? Is it an eternal truth? Maybe it is but the jury is still out. At any rate a scientific theory is objective in this sense if the theory exists independent of the scientist who formulates or studies it. So some believe that the scientist discovers what is already there, that the rules of the universe are built-in, so to speak. Let us call this strong objectivity.

I, and others, have made the case that mathematics is objective in the weak but not in a strong sense. This implies that the truths of mathematics are human truths, not Platonic truths. So the truths of Euclidean geometry are objective in the weak but not in the strong sense. In exactly the same way one could subscribe to the hypothesis of "weak AI" and not "strong AI". Notice that the "weak" position depends on an essential connection between human beings and science; the "strong" position on the other hand holds that once the theory (or technology) is established, human beings are redundant. One holds that the process of rationality can operate independent of human beings; the other that human beings are the essential measure of rationality, for rationality is the process by which human beings understand the world and themselves.

8. Moral: Maintain an Awareness of the Human Dimension

The process of reason involves the human mind as its essential irreducible feature. Intelligence is a rational process. Thus what we normally call AI, especially as a strong, a stand-alone, algorithmic process, is not strictly speaking rational. It may be one part of a rational process depending on whether or not it is integrated with human thought processes. On the other hand, AI systems come into being through a rational process on the part of their (human) creators. It is just that the formal processes on their own cannot claim to be rational.

Negative consequences of AI arise from divorcing its achievements from their implications for human society. These implications need to be integrated into the research from the very beginning and it may even be necessary for them to be subject to approval by regulatory authorities consisting of both scientists and concerned lay people. The ultimate arbiter of technological change is its effect on humanity. As Protagoras is reputed to have said, "Man (humanity) is the measure of all things." We stand at the beginning of a new age of discovery and opportunity. Or we stand at the start of an age of chaos and social disruption. To make the right choice we need a fair dose of humility and wisdom to remember that all our scientific work is a product of human consciousness, not something that does away with the need for human consciousness.

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Notes

1. W.P. Thurston, "On proof and progress in mathematics," *Bulletin of the American Mathematical Society* 30, no. 2: (1994): 161-177.
2. Daniel Kahneman, *Thinking fast and slow* (New York: Farrar, Straus and Giroux, 2013).
3. Susan Carey, *The origin of concepts* (New York: Oxford University Press, 2011).