Is Self-organization a Rational Expectation? A Critical Review of Complexity and Emergence

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Abstract. Over decades and under varying names the study of biology-inspired algorithms applied to non-living systems has been the subject of a small and somewhat exotic research community. Only the recent coincidence of a growing inability to master the design, development and operation of increasingly intertwined systems and processes, and an accelerated trend towards a naïve if not romanticizing view of nature in the sciences, has led to the adoption of biology-inspired algorithmic research by a wider range of sciences. Adaptive systems, as we apparently observe in nature, are meanwhile viewed as a promising way out of the complexity trap and, propelled by a long list of 'self' catchwords, complexity research has become an influential stream in the science community. This paper presents four provocative theses that cast doubt on the strategic potential of complexity research and the viability of large scale deployment of biology-inspired algorithms in an expectation driven world.

Keywords: complexity, emergence, mind, biology-inspired engineering, perception, knowledge, reductionism, holism.

"To gaze implies more than to look at – it signifies a psychological relationship of power, in which the gazer is superior to the object of gaze."

Jonathan E. Schroeder

1 Introduction

The difficulty of the subject starts with the absence of a positive definition of what complexity research is, and more critical, what problem it wants to solve when it talks about self-organisation. Most, if not all involved in its research, would agree that it is anti-reductionist by nature, which implies that it does not conform to the structures and methodologies of 'conventional' science. Likewise its proponents would agree that 'conventional' science cannot possibly explain the processes far off the thermal equilibrium, characterized by abundance of multitude and a tendency to produce some strange kind of order. The reason for failure is assigned to its very methodology of

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breaking structures into well behaved and understood elements before reassembling the parts, which cumulatively equate to the whole. The reductive methodology indeed becomes cumbersome, questionable and eventually useless when the phenomena under study cannot be sufficiently isolated from the environment they are embedded in, e.g. the local weather, traffic jams, the immune system or certain aspects of a next generation ICT system. Not even the solar system, the ultimate instance of reductionist clockworks, can be predicted (in the very long run) by the knowledge conventional science brought about. The bleak prophecy concerning its limits is thus not unjustified.

The methodology of complexity research rests on a holistic view of the world and a qualitative difference between the whole and the sum of its parts is generally accepted by its advocates. What appears to be the perfect balance of natural and in particular biological processes is interpreted as the result of a yet undiscovered distributed control scheme. Since nature is believed to be a system with built-in self-organisation and sustainability, the yet undiscovered mechanisms governing this intricate balance have become a major target of complexity research. Emergence[1], the perplexing effect occurring when cause and effect of a supposedly integral process are observed in different domains of experience[2], has become its earmark and universal solution likewise, while indicating the limits of conventional science and engineering. A novel kind of (soft) knowledge is proclaimed to be its result, but what this realistically means remains entirely obscure. Little more can be added to a generic description of complexity research because, like other holistic movements, it has neither developed rigorous semantics nor a quantitative framework. In this setting, where technological progress is challenged by complexity, and complexity research by the absence of semantics, it may be informative to see what complexity research potentially has in store for us. The following four theses are meant to re-initiate a fundamental debate about complexity research. The often and for good reason voiced reproach of immunization, as e.g. generally and specifically expressed in [2], requires the 'complexity' issue to be discussed on neutral ground; the degree of semantic consistency of complexity research, i.e. the degree to which we understand what we mean when we talk about complexity, is the only practical measure that currently can be applied to judge its goals, methods and results.

2 Self-organization and Expectation Are Incompatible in Principle

The 'self' qualities we believe to find in nature are the causally unintelligible effects of non-conservatory, undirected and unpredictable processes[3]. The occasionally beautiful patterns they create are easily misinterpreted as an engineered or learnt order, whereas they are a suffering and identity-sacrificing response to changing conditions in essence. The absence of stable identity and predictability make those processes incompatible with expectation-based individual and societal pursuit.

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[1] A broad discussion and extensive bibliography concerning *emergence* can be found in [1].

[2] E.g. in significantly different dimensions of time, space, aggregation or through different modalities.

[3] The assigned non-qualities are only placeholders for the 'nothing' we know about naturalistic processes when viewed through the spectacles of the 'precise' sciences.

The roots of complexity research go back to the fifties of the last century, but only the recent societal unfolding of a romanticizing view of nature enabled the concentration of substantial efforts on the study of the processes 'used' by nature to create, develop and control its forms and processes. The difficulty of the subject has been unequivocally admitted at any time - and may yet have been underestimated in its full extent. Today, the majority of complexity research efforts are clearly directed at its commercial exploitation, i.e. at attempting to solve real world problems, for which next to emergence another monster lies in wait - purpose.

When we desire to make use of the processes that appear to self-arrange the complex interplay of the biosphere, it often goes unnoticed that we insinuate that they have been purposefully created or learnt, namely with the effect of having those 'self' qualities. Purpose and deliberate learning, however, are the domains of humans, possibly with few exceptions. They are the expression of human will to influence the future so as to make expectations more probable. Thus, what we observe in the biosphere is neither an instance of an engineered or controlled order nor a symbiotic equilibrium of 'interests' for the welfare of its 'parts', but rather a non-recurrent status quo that reflects the unique transitional balance of multiple mutual influences which is passé before it can become lawful. This status quo is neither special nor superior to any other as there is no distinguished or expected realization. On this background, biological processes cannot be explained but being predominately reactions or unconditional adaptations to changes in the environment they are inextricably entangled in. They react to changing conditions whereby producing change that causes other processes to react and so forth ad infinitum. The apparently distributed self-control of biological processes actually is a spirit-, direction- and endless chain reaction of volatile identities, rather than a locally orchestrated coexistence of systems[4]. The response to condition on the one hand and expectation on the other is what separates biological processes from machines, reaction from function and complex phenomena from actual systems. In a conscious world, explicit expectations translate into functional requirements that are prior to the system and to be observed over long periods of time and under a wide range of conditions. The ratio of the number of forbidden and granted states of such systems is near infinite - in opposition to the living world, where 'anything goes' seems to be the maxim.

Our systems and infrastructures require continuous maintenance to prevent them from falling victim to entropy, whereas the biosphere appears to be the animated equivalent of entropy and for this reason transformative but hardly destroyable. Life is, by all standards, extremely likely! It survived extreme climates, the impact of asteroids, gigantic volcano explosions and would almost certainly continue to exist after a nuclear disaster. The forms and functions developing in the wake of such a

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[4] The strength of Darwin's theory of evolution is in its Kantian epistemic conception as it intrinsically prohibits a look behind the mirror where the concepts of the mind are getting embraced by paradox. The 'blind watchmaker' (R. Dawkins) is a suitable metaphor not only at the level of the content of the theory but also at the level of its coming into the world. This higher level 'blind watchmaker' is the mind. Its raw material and touchstone are an independent and incorruptible yet unknowable reality external to our minds, against which it tests 'intelligent designs' like the theory of evolution. This is why the whole is indeed much more than the sum of parts - it contains a big deal of human ingenuity.

disaster might, however, exceed our power of imagination. For biological processes any environment is a sufficient environment and any realization is a ‘good’ realization since nothing, except some kind of replication, needs to be preserved, and if it isn’t - who cares!? The secret of nature’s ‘sustainability’ is the absence of expectation. This very absence, however, is why nature’s ‘sustainability’ is only apparent. When evolution turns a nose into a trunk or larvae convert into butterfly, there is nothing ‘sustainability’ corresponds to - except nature’s metamorphic survivability. Biological processes and purposefully engineered systems represent incompatible extremes, for expectation impairs survivability as ‘self-organization’ undermines purpose.

3 Complexity and Emergence Are No Objects of Natural Science

A US military observer summarized: ‘…in our view, complexity is a result and not a cause of confusion…[5]’. Indeed, complexity and paradox arise when a theory, model or notion is applied beyond its frame of applicability. They can therefore be interpreted as the result of our asking unfit questions, i.e. questions that have no answers under the current scientific paradigm(s). Emergence is the ultimate warning bell indicating that we are transgressing a frame of applicability. Complexity and emergence are neither natural phenomena nor potential causes that can be researched; they are the fabric of a plurality of mutually independent domains of perception shining through the appearances when we confuse our ideas of the world with the world itself.

In many decades and despite increasing efforts cybernetics, catastrophe, chaos and complexity research have not produced the expected answers, except that complex or chaotic behavior can result from simple interaction of aggregates of simple elements. Rather they have remained at a narrative, gathering and complexity (re)producing level. The chronic lack of a theoretical and quantitative framework is a strong indicator for ‘asking wrong questions’. Complexity research is often motivated by the experience of emergence that corresponds to the amazement befalling us when, for instance, we realize that there is nothing of what makes water in hydrogen and oxygen. Water, as we know it, refers to something that is and always has been part of our lives. It is visible, tangible and can be smelled and heard under certain circumstances. In other words, ‘water’ can be experienced via our natural senses and its basic qualities, e.g. its fluidity at high and solidity at low temperatures, have been derived from the interaction of what we call water with those senses. When, however, we talk about H_2O, we talk about a mental construct that nobody ever has experienced naturally. We obtain knowledge about this artificial domain through the use of a compound of real and virtual prostheses, the latter being logic and mathematics whereas electronic amplifiers, particle accelerators and powerful microscopes are examples of real prostheses. The effects of instrumentation in the sciences are discussed in [3]. What Giere calls ‘scientific perspectivism’, a selective, partial and not necessary view of the world is exemplary illustrated with regard to color vision as a human investigative activity that cannot produce absolute knowledge, not even as an

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[5] ‘Complexity: a cognitive barrier to defense system acquisition management’ Acquisition Review Quarterly, Winter 2001, George H. Perino.

ideal. He consequently takes the step Kant and Popper denied [4] - in holding that human knowledge, despite its speculative nature, asymptotically may converge toward true knowledge - and makes clear why we cannot transcend our role of observers 'however much some may aspire to a God's-eye view of the universe'. While this step does in no way simplify the enterprise of science, it may yet provide novel insight into its origin, use and limitations as well as into the immense responsibility science carries.

While biology is and has developed as a science that roots very much in the world of our natural senses and hence language, physics developed its own prosthetic senses and accordingly emancipated from natural language. On this background, the attempt to superimpose, relate or interchange the knowledge of two (or several) scientific disciplines, as often operated in interdisciplinary complexity research, appears surprising. Biology and physics, for instance, under the current paradigms, exist as independent sciences because their objects of study are complementary, 'orthogonal' or mutually exclusive projections of the same world. As 'red', 'dissonant' and 'soft' uniquely correspond to visual, acoustic and tactile experiences, and have only figurative meaning beyond, the abstract concepts of physics become meaningless when we try to relate them to the naturalistic forms and processes dealt with by biology and vice versa. The ultimate disparateness of apperception through the various natural and artificial senses may well represent the insurmountable cliffs we call emergence, i.e. disconnected clusters of aesthetic or semantic coherence. They can be interpreted as the effect of an evolutionary orthogonalisation of our sensual and semantic theories of the world making experience and talk about the experienced possible in the first place by categorically structuring and ordering our senses and theories such, that, contrary to the very paradigm of complexity research, *not everything is connected to everything*. As there is nothing of smell in vision there is nothing of physics in biology[6]. Complexity research and its networking paradigm agitate these ordering schemes - and harvest complexity.

4 'Complex' Knowledge Is Logically and Economically Unviable

Complexity research cannot escape the paradox of attempting to understand the 'whole' on the basis of its very opposite, i.e. on the basis of notions and concepts that have been stripped off the 'wholeness' in the process of reduction. It therefore has no operational ground to stand on and tries to pull itself out of the water at its own hair. Also its claim to aim at a radically novel kind of knowledge is not convincing, for it would assume revolutionary changes to brain structures genetically bestowed to us.

There are trillions of trees on this planet of which no two are identical. And yet, the notion 'tree' and the associated concept 'tree', that goes with it, allow us to talk about trees without pointing at or making reference to each or any of them. This is the

[6] Which does not mean that there are no physical effects in living beings, it means that the world is open to multiple views, each ideally expanding an orthogonal set of categories and therefore adding a 'pure' dimension of experience. Intra-categorical consistency (knowledge), however, is at the expense of the meaninglessness of inter-categorical questions.

process of reduction - or abstraction from the particular. In a creative-deductive[7] feed-back loop it *integrates* a range of phenomena which from a certain point of observation exhibit symmetries and thus invariant properties. Before notion and concept 'tree' were created in the early history of mankind, 'trees' did not exist! The advantage of this reduction is sheer immeasurable as it allows, in conjunction with other abstractions, to manipulate 'trees' in a mental process[8] before actually carrying out or having carried out a manipulation with a high rate of success, because unfit manipulations can be a priori dropped[9]. We can in fact teach others how to successfully solve classes of problems without the involved things being in reach or sight, or even exactly known. What is conveyed in the process is knowledge. Without abstraction from the particular, which is synonymous for abstraction from the whole, knowledge is impossible for economic reasons. In sharp contrast, the know-how we acquire via plain observation and imitation or trial and error cannot be integrated with other knowledge for the reason of absent semantics. Compared to knowledge, know-how is a useful blind alley. The vast number of such blind alleys we are facing today, i.e. the increasing algorithmic determination of the actions we (and machines) take, is a major source of complexity, for they are semantically unrelated, not deducible and thus incomprehensible.

As powerful the process of reduction is, it inevitably comes at the expense of the loss of individuality and hence wholeness. Knowledge is the result of selective and 'theory-laden' observation [5]. Like facts, it appears to be discrete (by notion) and possible only at the necessary renunciation of other potential knowledge, as ultimately suggested by the uncertainty principle of quantum mechanics. That quantum-mechanics' renunciation is not the effect of under-determination is discussed in [6, 7]. Knowledge of the world, involving more than one of a set of 'orthogonal' notions at a time (e.g. particle and wave, matter and life, etc.), appears to become blurred, because it cannot be consistently thought[10]. The particle-wave example shows that asking certain questions is literally unreasonable, but also that the quest for better knowledge is rationally justified as it is the sense-variant semantic illustration of the experience of an underlying stratum the true nature of which is independent of and unobservable by the ideas of the mind. This view naturally explains the anti-absolute argument of *pessimistic induction*, which describes the historical succession of successful but incompatible theories which once were believed true but eventually proved wrong.

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[7] Kant posited that a 'saltus' of the mind is needed as the first step towards scientific progress. Popper generalized the idea and made the principle, that nothing can be observed without a genetically/logically leading hypothesis the central point of his theory of speculative knowledge (see annex).

[8] In this process imagination deals with semantic systems where the system (the whole) is logically and temporally leading. It is utterly impossible to envision a system bottom-up from (its) parts. The parts of the simplistic system *bicycle,* dropped over virgin tribes land would likely be used for fishing, hunting, child play or be declared cult but not get assembled, leave alone used as a bicycle.

[9] The effects of biological evolution on mankind ceased long ago in response to the much higher efficiency of the predictive qualities of the mind.

[10] A *thing* cannot possibly be e.g. particle and wave at the same time given the classical (archaic) concepts we associate with *particle* and *wave*.

The tree in front of us is a much more complex phenomenon than the notion ‘tree’ can convey. Actually it is unique. Complexity research deliberately drives at the investigation of unique (holistic) phenomena and thus at the reversal of the process of reduction. The inevitable result is inflation, for the methodological arrow now points from the universal to the particular. Our apparatus of thinking though is based on the finite resource brain and on a categorical and hence reductive scheme of perception for economic reasons. It appears that human knowledge exists in a corridor between holistic inflation and reductive renunciation. We can comprehend only those discrete and restricted aspects which we can talk about in an economic and semantically consistent manner, those which can be explained without the need of being demonstrated, pointed at or made reference to. The pathway of the (yet) un-understood to conscience is not through the logic and semantic centers of reasoning but through the less strictly censored boulevards of emotion and impression. The latter, having served generations of scientists as the motivation to understand, i.e. make semantic, has now been declared the original subject of complexity research. Its dilemma ironically is that any knowledge it would produce would need to be reductive, because it necessarily would need to be semantic. In order to rescue its holistic claim, complexity research evades its ‘Copenhagen Convention[11]’ at all costs and instead markets the promise of a radically new kind of knowledge while, however, suppressing the unpleasant implication that it would require a novel brain.

If knowledge is out of reach of complexity research, what can realistically be expected its output to be? For weakly complex systems, which are ‘systems’ with a potentially knowable state space, the answer is anti-know-how. In fact, we, not the ‘system’, will successively learn how not to do it, since such ‘systems’ will provide services at the expense of continued ex post elimination of their undesirable states. Once all undesirable ‘system’ states have been eliminated, or equivalently, once those ‘systems’ behave according to expectation, they will emulate conventional systems via the inefficient process of state exclusion, and thus become void of any ‘self’ quality for their then severely restricted state space is no longer containing a sufficient number of ‘solutions’ to cope with the ‘unexpected’. For truly complex ‘systems’, having (near) unrestricted state space, the answer is simple: Nothing can be expected from ‘systems’ serving no expectation - by definition. In practice a third world between expectation-less ‘self-organization’ (nature) and predetermined functionality (man-made systems) may be illusionary. One might argue that humans are an example of something amid the extremes. The argument appears convincing but is nonetheless false; we cannot recycle the concepts of the mind (e.g. molecules, cells, neurons, agents, self-organization etc.) in an explication how these very concepts organize their originator - the mind. What we are ourselves does not figure among the concepts framed by the mind and therefore the argument is wrong.

5 Real Reduction of Complexity Is a Semantic Program

Processes, that are highly individual and do not underlie laws which are significantly less individual than the processes in question, are useless in trying to estimate the

[11] The Copenhagen Convention, i.e. Bohr’s principle of complementarity, made quantum mechanics empirically relevant because it implies that quantum experiments are consistently describable in classical terms involving either ‘particle’ **or** ‘wave’.

future. Human culture is largely based on the ability to estimate the future by use of a superior, semantics-based process called reasoning, capable of manipulating virtual objects and processes before releasing them to the world. Reasoning, however, needs notions which complexity research denies. 'Experience without notions is blind' (I. Kant).

Despite the high promise of biology-inspired 'self'- research it remains essentially unsatisfactory from a methodological point of view. Operationally it is fundamentalist empiricism for the reason of its self-elected detachment from the wealth of 'conventional' theoretical knowledge and its procedures of acquisition and dissemination. It is industrious with collecting (and increasingly producing) wonderful patterns and strange attractors of which we don't know what they correspond to. A microscopic turn of the wheel of the tap will cause a dramatic change of its dripping pattern - sufficient to catalogue another strange attractor. The activities of complexity research have in common that the encountered effects cannot be communicated but by describing the structure of the 'machine' or its algorithmic elements, i.e. the parts of complexity research relating to conventional science. But the very patterns they produce are not intelligible and render range and qualitative degree of the correlation of objectives and effects undeterminable, thus making complexity research incommunicado.

This muteness breaks the knowledge chain, the way we administer and accumulate knowledge. Conventional knowledge can be made the object of operations; it can be compared, transposed, permuted, integrated, and tested, for it has become knowledge (and a societal good) only after having become semantic. Moreover, the totality of knowledge or parts thereof can be abstracted from in the attempt to achieve a higher economy of reasoning that, if successful, builds theories over theories and represents the ultimate reduction of complexity. Following Kant, the forces behind this process are the regulative ideas of the *unity of mind* and the *unity of reason*. The regulative idea of unity also underlies the reflexive level of perception, provoking the integration of experience to highest degree possible. The foundation of this process are coherent and consistent models and theories. The importance of semantic consistency, enabling the concept of *'information is what creates information'*, is stressed by von Weizsäcker throughout [7]. In the absence of this precondition complexity research is highly divergent and means a different thing to anyone involved in or observing its investigation[12]. What currently remains for its proponents and opponents is a philosophical-methodological debate: The promise of radically new knowledge versus the threat of irrationalism when semantics are sacrificed and the particular is favored over the universal.

6 Conclusions

Emergence has always fascinated scientists but has remained a baffling riddle throughout the centuries. It appears to coincide with structures of apperception and

[12] Some branches of complexity research try to escape its muteness by developing hierarchies of 'systems' and rudimentary semantics. The notions they create do, however, not interface with traditional experience in any point, such that they remain without meaning. 'Notions without experience are void' (I. Kant).

reasoning rather than physical phenomena or causes. Complexity arises when we ask questions that have no answers under the current scientific paradigms, i.e. questions exceeding current linguistic potentiality. The history of science has shown that scientific paradigms are not eternal. But it has also shown that their transformation goes with dramatic changes in the meaning of apparently well established notions of apparently well established sciences, which are the shock waves of a major reduction of complexity corresponding to scientific progress. The inflationary methodology of complexity research makes it no candidate to trigger the next scientific transformation. Rather it may further the erosion of coherent and consistent communication in the sciences and the society.

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Appendix: Thoughts about Reductionism

There is evidence from various directions that reductionism is not merely a philosophical preference we can hold at liberty. Similar to the fact that we are not at free will to map our everyday experiences into other than the system of space, time and causality, we may not be at free will to acquire (anticipative) knowledge through other than reductive methods of reasoning. If so, reductionism represents the condition of the possibility of knowledge, i.e. denotes an intrinsic principle of the brain-mind complex. It would then serve a fundamental purpose which in the widest sense could be described as being of economical nature. The physical interpretation of this purpose is associated with the limited resource brain (memory and its organisation), which requires schemes that reduce the infinite number of world states to a set of rules relating objects and subjects in time. The second, psychological, interpretation is that reductionism is the observable effect of the mind's most distinguished enterprise to rescue its unity. Like physical systems involving feed-back loops need to be tightly controlled to avoid chaotic and other undesirable behaviour, the reflexive mind is in constant danger of falling apart. Panic and horror are the transient effects when the unity of the mind is severely challenged, i.e. when our role as rational observers of the world is at stake. Psychological studies speak of the *'Stalinistic Methods'* of the brain to prevent this happen and forgery of inter-subjective reality to surprising degrees has been reported. What is 'the unity of the mind'? It is its singular point of view (as a regulative idea rather than an achievable state) from where the world makes sense, from where it *appears* causal, coherent and consistent, or in brief - explainable. Explanations on the one hand need words while on the other hand an increasing number of words imply an exploding quantity of possible relations between these words (and hence meanings), such that a check of the consistency of an explanation quickly becomes difficult or even impossible. Ockham's razor is appealing to us because it is a condition of the possibility of verifying the consistency of a statement about the world. This is when reductionism may get involved as a method of theoretical verification by condensing the astronomical number of states of natural processes to a workable set of hypothetical entities and attributes, i.e. a system, which ideally represents all possible states of selected observable processes under well defined conditions. These conditions are reductions themselves and therefore reductionism presents the world-as-such by way of analogy rather than by way of convergence toward an absolute reality, which explains the paradox of factual scientific progress (in the natural sciences) in a succession of mutually exclusive theories as disconnected domains of stringent semantic coherence.

In section four the procedural elements of the reductive method have been briefly mentioned. According to Kant they consist of two fundamentally different steps that give rise to the world as we know it. First, a 'saltus' of the mind' is needed, corresponding to the fact that the novel is not deducible from current knowledge. It appears to represent its findings in phenomenal space for further elaboration by semantic processes. This first step is tentative and kind of art rather than kind of science. In a second step, the analytic capabilities of the mind come into play by trying to deduce and assess what flows from the 'saltus'. The reductive method thus creates causal *wholes* by a joint effort of the powers of imagination, logical deduction and inference, while the famous 'breaking into parts'[13] is absent in the process. If it were not, the absurdity would occur that the knowledge of the novel would be a necessary condition for its subsequent derivation in the Cartesian process of 'breaking it into parts'.

For the novel cannot be legitimated by experience, it is unlikely that 'truth' in the sense of 'conformance with experience' - as generally accepted in the sciences - is a critical concept in the logical assessment of the 'saltus'. The fact that nevertheless empirically valid theories can be the outcome of a purely mental process suggests that the involved mechanisms and in particular the role of our senses are not well understood[14]. At the same time, if the reductive scientific method is linked to an aesthetic-semantic process instead of a semantic-empirical methodology, it is not unreasonable to assume that its outputs are potentially furnished with validity prior to any empirical test. Otherwise the reductive method would not be of great value in obtaining and securing the unity of the mind. The most delicate process in the world may in fact require more sophisticated means than corporeal trial and error to establish multiple, mutually orthogonal and therefore non-conflicting world perspectives.

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[13] Descartes mentions in several places [see Bernard Williams, 'Descartes', p.15] that i) his 'method' is not obligatory and ii) the *Discours de la Méthode* is not adequately explaining it.

[14] Einstein's statement that *'…only the theory determines what can be observed'* may set the framework for a better understanding of our world perceptions.