Making science relative to a cognitive subject

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1 Introduction

Judged from inside, the effectiveness of mathematics in physics has appeared 'unreasonable', and is a matter of wonder, not explanations.

I propose to 'solve' the problem by 'dissolving' it instead of trying to break it by brute force; I offer to build a framework from basic elements in which this singularity simply disappears in the background.

The intuitive idea is that if the problem is gnawing, it can be seen as a stable singularity of our thought system. If it remains, and resists, it is an invariant of our explanatory framework. Attacking it head-on is to wager it will break like a shell under direct force, which, taken completely *a priori* is perfectly possible. This however should not deprive us of examining other options. An in principle scenario is that once immersed in an appropriate perspective, the problem unfolds, it becomes possible to reason about it, it is *reasonable*.

It is worth observing that the proposed theme implies a reflective look at the activity of elaboration of a science, in particular physics, and mathematics (were it considered as science or not). In fact the nodal point lies exactly there, and to approach it scientifically implies to produce a formalisation for such a reflective view.

The general process proposed here follows the tendency towards a general principle of relativity: that statements be explicitly related to reference frames (Galilean, special, general, as for the well-established ones). One perhaps less evident and spectacular aspect of this tendency is the careful record of the conditions of every observation, or experiment, and the more thorough making explicit of every theoretical, formal hypothesis and manipulation by writing its mathematics. It can however, be seen as an extension of the concept of a frame of reference, and a possibility to consider those many processes in a single framework of generalised relativity.

It happens precisely that there is a very early hypothesis to which all physics is relative, well worth making explicit and, hence, reconsidering, for fruitful consequences. But first let us make a recall on axiomatisation —the stage an accomplished theory in physics should reach—, and a detour through some abstraction in symmetry and relativity.

2 Axiomatising science as an aim

The ideal outcome of physics as it has evolved now is to formulate axioms, and then rebuild upon them a (partial) representation of the world, whose predictions you can confront to experiments results. Nearly all sciences have yearned after this model and more or less successfully, and uncomfortably tried to mimic this physics' strongly mathematised model.

When this stage is reached, the contents of the 'predictive engine' are as explicit as they can be, and can be checked thoroughly for internal consistency. That part of the theory is pure mathematics.

Not all is said here: if the outcome is well characterised (formal), how are derived the concepts that lend themselves to such treatment, in particular those that obey principle is left in the shadow —'unreasonable'. They are not intuitive; every physics teacher has seen enduring reasonings in the form of the impetus, or explanations like "the one pushing harder is having the other moving back", quietly negating Newton's third law after mentioning it the line above. Galileo writings reflect similarly 30 years of struggle back and forth against his own stated principle.

3 Some abstraction: Symmetry and relativity

Let me borrow and extend some of Rosen's [5.] insightful reasoning, the best treatment I know of symmetry, in the most general form needed here. (I shall depart, however, from his use of absolute statements such as 'laws of nature'.)

Rosen aptly summarises the essence of symmetry in one sentence: symmetry is immunity to a possible change. It is easy to check this definition against all the common cases of symmetry that come to mind. It also matches the concept of invariance under a mathematical transformation. For instance, geometrical properties are characterised by their invariance under the transformations of the principal group. Hence a geometrical object is not as in the casual sense a particular appearance of, say, a triangle, but the orbit of all the appearances it may display through the available transformations.

If I want to establish a symmetry, I must be able to measure a change. This means I need a frame of reference, and change will be relative to that frame. For instance, for a spatial displacement, I need to be able to determine that I advance. If I use a tape measure, it must be graduated and numbered, so that I can determine the displacement. If I were trying to use a tape measure invariant under displacement, that is, without marks, as a reference, it would not work. This means that the frame of reference must be affected by the change I want to observe. Hence, establishing a symmetry implies breaking that symmetry. Any observed symmetry is relative to an asymmetrical frame of reference. (An now we leave Rosen, for new statements.)

This concerns any relativity.

Any measurement displays such relativity, were it length, mass, time, etc., since the property is abstract and general. A length measurement is made relatively to a standard yardstick, by comparing their length. (This explanation describes the process, but does not reveal, nor define what a length is, to the reader.) Typically you place the long object to be measured and the yardstick side by side coinciding at one end, then you proceed to concatenate the yardstick that the resulting length is still shorter after n operations, and longer after $n + 1$. (The careful reader will see implied relativities in this concatenation, which threaten to end up in finite regression, or circularity.) Hence there is no absolute length, just length relative to a reference stick.

In this light, Mach's statement that "It is utterly beyond our power to measure the changes of things by time. Quite the contrary, time is an abstraction at which we arrive through the changes of things" is perfectly clear. And Poincaré's remark that we use periodic movements as a measure of time but calling them periodic supposes being able to measure time points at the circularity noted above.

The necessary symmetry breaking inherent in immunity to a possible change shows various faces: phenomenon-frame of reference, variant-invariant, is quite universal. In mathematics for instance, we say that a structure is completely characterised by its invariants; you cannot define a structure without invariants, that would be an impossible 'perfect symmetry'. The observation in the next section that the basic hypothesis of physics implies a blind spot is identical. We pick again the symmetry thread (with reference frame, measurement, etc.) in the following sections.

4 The basic hypothesis in physics, that permeates all thought

The number one, rarely stated, hypothesis in physics is that we can separate nature into two parts, the observer and the observed. But not only: we then proceed as if there were no observer at all, as if science could be a viewpoint from nowhere. Nagel [3.] has reported how this has come to permeate all science, yielding a general belief in absolute knowledge, much as that of an omniscient god. The feeling is entrenched because this approach has been so distinctively successful in building predictive theories, so blurring a vision of the reason of its strength, and of its inherent limitations.

In the extreme, an absolute viewpoint means static: no time of any kind that recognises that things happen.

In fact this observer-observed split and subsequent immediate observer disappearance goes well beyond physics and pervades all science, even all modern thought. With this initial axiom embark intrinsic limitations —invariants—, that always remain as dead angle, an inaccessible horizon to its theories' reach [10.].

5 Perception, at the blind spot resulting from the basic hypothesis

Perception is a horizon in the present frame of thought: it is the limit, never attained, always moving of our investigation. One can even consider that our view of the world is always and entirely made of horizons, skylines, moving at the surface of the world at every sort of our changes in position. These are the lines where our sight stops and cannot go further. Their shape reveals something of the world, but the thickness is not accessible [10.].

Perception is the core issue of a blind spot for all contemporary science. At any considered scale, perception is an encounter: Subject and event, sensory organ and object, sensory neuron and stimulus, receptor and its matching molecule or excitatory energetic signal. You need both.

Bach-y-Rita's experiment [8.] will help us point the key issue of perception. In this experiment, blind people lean against the back of an armchair which bears a matrix of 400 vibrating sticks connected to a camera. Provided the subject has the possibility to move himself the camera and possibly get other feedback sources, he learns in a few hours to "see with the skin of his back", differentiate objects, even recognising an object coming forward (the invariance of the image by change in size).

Subjects initially report confused feelings in their back (an amorphous space, see α in the next section), then soon come to perceive things, which emerge. A striking observation is that in usual conditions, the skin does not see, not because its sensory neurons are less able than in the retina, but because they do not encounter patterns of signals with the corresponding invariants; once the camera and the matrix offer them, the skin's neurons promptly identify, synthesise them (at lower resolution than the retina of course). Thus neuronal chains show universal abilities; sensory afferences are not labeled ('vision' or 'touch') by metadata, everything is in the excitatory pattern; and the experiment opens the path to many sorts of sensory substitutions. It also points that the crucial part that must be accounted for in a theory of perception is the emergence of a new object out of a muddle; a form, a structure out of the amorphous. Creating something anew: learning, which routine situations tend to obliterate.

The daily situations that recall this crucial fact of perception are, of course, infrequent. For instance, ambiguous figures (e.g., Necker's cube) provoke two mutually excluding interpretations, making thus palpable the same core phenomenon by their repeated birth and death of a perceptory object.

Hence a theory of perception should explain the appearance of an object in the perceptual field. Most 'perception' theories are physics of what takes place during perception (again, fruitful): We drop the subject, and describe transduction on the sensory cell, conduction on the nerve, projection on cortical areas… Cognitive science has criticised this process as pushing the homunculus that eventually perceives always further away in the brain, never arriving at perception, proper. The process would converge, and reconcile the split, if and only if we were able to synthesise a living subject, from the initial axioms. Although that has been artificial intelligence's promise, there is still no sign of that. Other, completely opposite attempts have started from the subject. Those who have truly tried this option rigorously have been unable to reach the world: prove its existence, or synthesise it from the subject alone by pure reasoning. The extreme, logical, but unfruitful outcome is solipsism.

A reasonable conclusion is: Since the central phenomenon is an encounter, it is fair to have both the world and the subject given. The challenge is to propose a formal framework (as it should be) where something new may appear —not a theorem that was not evident from the onset, not something undecidable, something *else* that what was given initially. That sounds like a pure paradox, since provided the restrictions just made, there is nothing new that can be expected to come out of a formal system, that is its 'function'. However a formal model to represent novelty is possible [2.]. It is not absolutely necessary to expose it here for the present aim, so let us proceed directly to our cosmology.

6 A cosmology based on subjective relativity; the α world

To rebuild a full representation of the whole world, we start from the cognitive situation, that of empirical knowledge: science, as perception, is an act of a subject, talking about the world he perceives. The subject states himself by Descartes' certitude "I think, therefore I am"; however, 'I am' not alone, there is a world that I know. Jacques Schlanger [9.] has called it the cognitive situation: a subject knows something about something —the world. Both are given as axioms at the onset. I am therefore the one describing in formal terms the world and the way I am inside it.

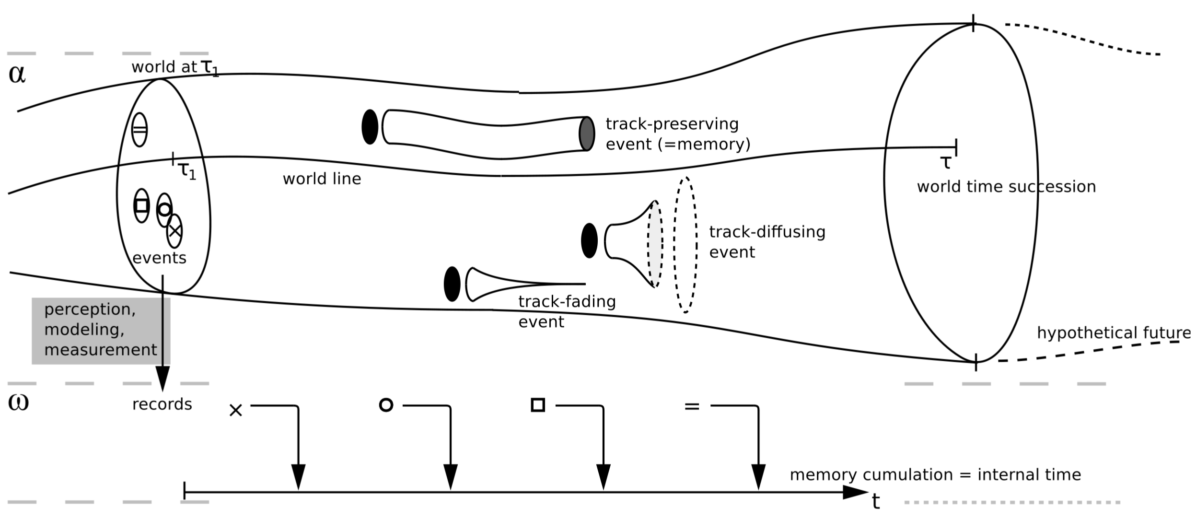

Figure 1: The world α and the ω domain (memory).

In Figure1 the world α is entirely the set of perceived events at a given instant, represented as a Venn diagram. This is our basic space, with no more *a priori* structure; an amorphous set. This statement already contains that what we call 'past events' are not accessible, not anymore: there is only 'now'. (And concerning 'future events', they are pure fiction, not accessible either —if that could have any sense, since it would imply effective world-access to fictional facts.) We return later to define what to understand by 'past events'.

To be more definite, and dispel any ambiguity, *perceived events means not merely perceptible*, which would be unclear, and *not by everyone* either, but by the one specific subject I am considering (myself, to begin with, at this stage). By hypothesis, by construction, events are fixed points, invariants. This is what is usually termed irreversibility: no access to past events. The present is experienced as in continual change (how change is formalised comes later).

To remove another possible confusion, those perceived events are in no way atoms of the world, whatever means you use to acquire these events. 'True' atoms of the world is not a possible concept in empirical knowledge. This is by decision of the model, not a statement about what are real position is, though I do believe that absolute statements have the burden of proof on their side.

In contemporary Occidental culture, it is customary to say that we go from past to future, and, since Arthur Eddington, that an arrow of time points in that direction. From the Ancient Greeks comes the different metaphor of time as the flow of a river, which is not devoid of ambiguities, since whether we go down the flow or stand on the bank is not indicated; in the latter case, the arrow to the future likely points upstream, which counters the idea that time flows to the future. In short this metaphor is unstable; it lacks a clear frame of reference, like so many errors seen in basic classes of physics. These views are not unique, nor universal either. Robert Pirsig writes that the Ancient Greeks would regard time as the future coming from behind you, and the past receding away to the horizon before you, and in the Aymara language and cultural gesture, it is similarly reported that the future is figured behind oneself [4.].

What is time? There is no arrow of time in this diagram.

Time, in the described situation, cannot be conceived of without memory: past events exit only in memory. Which means in fact that time is memory. How can I possibly draw this diagram? I am at its present end, the current set of perceived events. Every other set is figured as a slice of space-time, each a different present I have had the experience of living in a (ordered) sequence. This sequence has a beginning, the birth of memory (which is not to say that it is necessarily accessible). Hence in fact, if I have called the space-time diagram 'α world', only the actual present set of perceived events is 'the world', all the preceding sets are drawn only from memory traces, reconstructions from records of 'past present worlds'. At first sight, they are included in the figure erroneously, but for the ease of understanding. However, this is not so much the case, because the present set of events is not very different, it is also the result of a perceptory record, not the 'world itself', but 'the world in our conscience', to use common words. The actual world, which I will not name, is not accessible in its being, or absolutely; only through interaction, that take place in action-perception loops: inducing or witnessing a transformation, and recording the corresponding events.

Only the cumulation in my memory allows me to conceive of and draw this diagram, with its time line (a sequence of sets) τ. Time, irreversible by every experience, is equated to memory, and formalised as a cumulation, an (ordered) sequence of records.

That time is represented by memory fits exactly with the current definition of a unit of time in metrology. A unit of time is a time interval, which cannot be measured without cumulating the record a first event, then of a second one, were they periods of a radiation corresponding to a precise transition of a nuclide, or the hand of a clock passing in front of marks. There is no absolute measurement of time, only comparisons of time intervals, as already noted. How can one objectivize, time, if not by records? There is no alternative. It offers a very convenient formalisation. (And, to anticipate, records will of course be formalised as text —in any alphabet of symbols of your choice.) Prigogine was seeking to define time as an operator [6.]; time as cumulated records is the simplest form of such an operator.

Thus this diagram is very different from any sort of space-time diagrams which have become classic since Minkowski. There is no sort of absolute time, all the more not going forever in the direction of an arrow. Even less a space provided with a geometry at the onset, were it Euclidean, Riemannian or other.

This α world diagram reflects exactly that the knowledge of the world is relative to a subject: the subjective relativity. (In effect, subjective relativity requires that we describe the symmetry of moving memories from one subject to another. Clearly, the only way is of course communication, and would deserve, and demand much room. However it should be clear that this is feasible from the current framework.)

7 Events in the α world and building space —structure— from time

How can I be, cognitive as I know myself, in that world? Some events are evanescent: in a short time, they thin down to a point and disappear, or, like a perfume spray, they vanish in the volume, as represented in the figure. Others are events that leave a trace, a long-lasting track. They appear like tubes in the figure: observing a slice at a moment —e.g., the event of a footprint— implies the event of a step in the mud in retrospect. It is *interpreted* as such.

I relate what I see now to what I have witnessed happening in the past, that I still have in memory.

Here we have extended the use of the term event, from a fixed, elementary entity in space-time (punctual but still, like any perceived thing, appearing with some thickness, some grain, so that it would not be faithfully represented as a point on the real line), to cover a series of events in time, thereby connected. This causes no confusion and is natural, but deserves more making explicit: events are connected because in my own reference frame, I see non-changing things among changing ones (a symmetry).

These tubes are the basic appearance in the world of the faculty of memory I am endowed with. Thus the world keeps memories about itself, traces, and forgets too: it erases traces. There is a permanent symmetry breaking between perceivable memory-keeping and erasing.

Obviously, a space with a rich structure, Euclidean or other, as we mean it usually is to be a cognitive edification in our model, since we started with only an amorphous space, offered to a cognitive individual. It is therefore constructed in memory. And as memory equates time in the sense that time can be accessed only through memory —or, to ease understanding with an image, memory is sedimented time—, space is sedimented time.

What we have called traces, and pictured symbolically as tubes in the figure, are sedimentations of events.

They can be described from an adequate viewpoint as invariants through (most events in) time (and up to now). Examples are all the sorts of fossils or traces, remains, one can conceive of —so long as no erasing event comes to pass in the meantime. Less obvious examples stem from the observation that a given time, our sensory field is generically made of, or more exactly seen as, lasting events, not short-lived, transient ones which we eventually simply neglect, consciously or not. Thus we are biased towards lasting events. 'So much that' we tend to permanently seek ways of building new ones out of a scrambling of changes, as illustrated in Bach-y-Rita's experiment.

8 Working in the ω (memory) domain

To interpret a trace in the world, e.g. a footprint means someone having stepped, I *refer* in some way to a situation where I have seen an event leaving a trace that I judge 'same' in some way that is, analogue to the trace I see. This operation is done in memory, from my recorded traces of events.

To state it precisely, this analogy means that the situation is changed, but some aspect, properly extracted, can be seen identical: it is a symmetry. Just by the same token, repeatability, reproducibility (can you obtain the 'same' result by reproducing the 'same' experiment in your lab?), and predictability are well modeled as symmetries. They make clear the connection between perception, modeling, measurement, mentioned in the diagram and above.

All involve some idea of analogy, or classification (what has been referred to as categorisation in cognitive psychology), which has naturally been recognised as a founding feature of cognition.

To draw the connection back to perception, Uexküll is notable for putting forward the idea that any animal by his living builds a world of signs, completely different worlds of action and perception — that of the tick, the bee. . . —, foreign to one another, parallel though they share common surroundings [7.]. Uexküll is now considered as having originated biosemiotics [1.] . Not surprisingly, his thought shares similar premises with the present essay: "Whoever wants to stick to the conviction that living beings are only machines, abandons any hope of ever considering their *lived* world." [7., p.13]. And certainly there is nothing wrong in modeling living beings as machines, as long as the inherent limitation of this stance are kept clear. "Otherwise one forgets that from the onset was suppressed what is the most important, to wit the *subject*, who uses means, in his perception and action" [7., p.14]. The mechanising tradition connects, e.g., Descartes, Condillac —and all the modern 'theories of perception'—, but also, on another thread of theorising in probabilities the bet that every perception purports to, Laplace, Bayes, Bernoulli, Jaynes.

While we are at seeing that classifications and predictions are symmetries, it is worth noting that any prediction, by nature, operates on partitions of the set α, it organises it notably by confusing, assimilating the elements of the same classes: there is inherent approximation, or reduction, simplification in the process; the corresponding law compresses the image of the world, and it can only be useful to this extent. Hence no law of interest can be 'complete', in the sense of exhausting the world.

To assimilate situations, is, etymologically, to make them same, to say that whatever happens, they are considered unchanged. It of course not an absolute operation. It is more an interpretation, one among a whole set of possible other interpretations. Only pragmatic confrontation to en eventual usefulness, as a predictor, will invite the subject to maintain it and try it on other occasions.

Time as experienced in α is irreversible; writing in ω gives reversible (read) access to any recorded event. Thus the internal cumulation time t is reversible, breaking symmetry with τ, though parallel. Writing irreversibly and irrevocably allows reversibility, that is, all the possible prognostications of cognition.

9 The possibility of a universal reference frame

What is the most general possible form of reference frame, in this framework? (What is the most general conceivable phenomenon-catcher?) It should be able to account for any sort of non-changing phenomena, invariants built by reencoding in probably extremely convoluted ways the (records of) elements of α, and, to extend this set as much as possible, with all possible measurement and investigation apparatuses. Hence it should be able ultimately to display a change to serve as a frame of reference. That will be ultimately an internal change, at least to know the before and the after. This means having the capacity to write into one's memory, independently of what goes on in the world. This is exactly what a living individual is able to do. He appears as defining some closure with a number of degrees of freedom inside, that he can use to keep on writing into his memory, laying the basis of cognition.

This stage was omitted in the previous discussion of measurements: a more complete model of measurement necessitates that the steps of measurement be explicitly written into memory, so that the symmetry a measurement is, is reflected in a recorded change in the subject.

For instance, how do I know that time elapses, when nothing happens, no change is visible around me? I keep on writing in my memory, and this is a change that occurs —simply being alive. (This also implies that an individual is not unitary, it has several instances inside —exactly what psychology describes—; which is exactly what was grossly approximated by the expression "degrees of freedom" above. The subject is cognitive, he has room for deliberations about the world and himself.) All these considerations are not additions to my axioms, just more detailed descriptions of the given initial terms.

Thus in different words, a universal frame of reference would be able to display a change, whatever goes on in the world. This means, a *controlled* change. So it should be individualised, made to a great extent independent of the world (to the extent that it is possible). That exists in our world, there is the possibility that parts of it individualise, we have called one the subject. A natural formal representation of this is writing. (A practical approximation of which can be made by using enduring events of our surroundings.)

Of course this in principle universal possibility is limited by those practical actions the subject can induce without compromising his integrity. Because of his nature (that we account for partially in terms of structures), there are changes he can endure, and changes he cannot. This is precisely what makes every action-perception a bet; the individual implies a 'risk to live', why prediction is central to perception and to science, why envisioning possible outcomes or options and probabilities plays such a central rôle in science.

Observe that since I have taken the subject as the initial source of any scientific statement, it is in fact no surprise that once made precise the notion of a reference frame, the subject appears as its most general form. This was an expected horizon. In addition note that the modeled individual is a universal, but in no way an absolute reference frame.

10 Conclusion

Physics can be defined as the part of sciences of nature that has accomplished axiomatisation, or is on that way. The concepts in physics did not come spontaneously, they were painfully selected over the centuries. In particular, it was found that adequate concepts were those responding to principles, which in retrospect appear nothing but rules for easy calculation, hence a development in parallel with mathematics. However in many phenomena of interest, the principles from physics appear quite remote, and no clear path to deriving others is showing.

A pass trough abstraction opens on a different and pleasant landscape. Departing from perhaps the most basic hypothesis of physics, it is possible to build an alternate theory, no less consistent, with reflective characteristics —once bootstrapped, it gives to a broad extent the ability to analyse its own processes—; in particular the rôle of mathematics can be interpreted straightforwardly, and it lends itself to applications outside the current domain of physics, e.g., in biology.

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