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Fractal Time, Observer Perspectives and Levels of Description in Nature

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Abstract: This paper reviews various approaches to modelling reality by differentiating notions of time which underly those models. Basic notions of time presupposed in physical theories are briefly described and analyzed in terms of the levels of description taken into account, the interfacial cut assumed between the observer and the rest of the world, the resulting observer perspectives and the extent to which these notions are based on temporal natural constraints. Notions of time in physical theories are secondary constructs, derived from our primary experiences of time. Therefore, we must regard our theories as anthropocentric – derived from abstractions and metaphors resulting from our embodied cognition. Theories based on the notion of fractal time and fractal space-time are generalizations or alternative descriptions which allow for a more differentiated modelling of reality. The resulting temporal observer perspectives allow for further differentiation. The notion of fractal time logically precedes those of fractal space-time, as it is based on the primary experiences of time: succession, simultaneity, duration and an extended Now. Against this background, the internal differentiation of the observer and his degree of both conscious and unconscious contextualization turn out to be vital ingredients in our reality generation game. I am fully aware of the fact that the selection of concepts presented here is neither complete nor unbiased and is coloured by my own temporal observer perspective.

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1. Introduction

"The best material model of a cat is another, preferably the same cat."[1] Most of us would probably admit that Norbert Wiener's beautiful definition can't be beat. However, limited time and resources, as well as our inbuilt desire for complexity reduction, lead us to build models to describe the physical reality we are embedded in by abstracting, i.e., by focussing on certain aspects and disregarding others. This process is steered by observer-participants whose perspectives tend to differ and whose physical make-up acts as a constraint on cognition. 2^{nd}-order cybernetics takes this fact into account by regarding the observer as a cybernetic system in its own right. 3^{rd}-order cybernetics then contextualizes the observer-participant ontologies of the 2^{nd}-order domain: The subjectivity of the observer-participant is described as the result of an embedding process.

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[1] Rosenblueth & Wiener 1945, p. 316

Contextualization of observer-participant ontologies takes account of both the system-context interface and the observer-involvement interface.[2] We thus identify the steersman who creates scientific theories as an embedded observer-participant.

This has not always been the case, however, although the role of the observer seems to have become more and more influential with changing paradigms. The Newtonian paradigm, which was based on a reductionist, linear notion of a container-like time and space, did not allow for observer frames. These were introduced with Einstein's relative concept of time. Quantum mechanics suggested that there are no independent observers, but only observer-participants who generate reality by taking a measurement which induces the collapse of the wave function. 2^{nd}-order cybernetics, synergetics and Prigogine's chronobiology recognized the need to assign different internal times to nested systems, an approach which was integrated into chaos theory and theories of complexity. Here, the phenomenon of emergence also called for a differentiation between levels of description (LODs) in terms of interfacial cuts as well as in terms of degrees and modes of involvement.

In synergetics, order parameters which enslave lower-level phenomena revealed the need to distinguish between LODs in order to describe the emergent circular causality.[3] Endophysics emphasized the need to take account of the observer's internal organization, introducing a micro-relativity.[4] The internal complexity of the observer is a constraint on our generation of reality and the perspective from which we construct models. Embodied cognition implies that we have to take account both of the observer's internal differentiation and the degree to which he is embedded into a context, i.e. his degree of involvement and participation. In order to understand the relationship between the system processes and those of the context, we need to describe interfacing in detail by simultaneously considering all process levels.[5] The concept of Fractal Time renders possible such a simultaneous description. It promises to be a useful approach to modelling reality, as it is based on a scale-relativity, which takes account of nested LODs considered, the degree of the observer's contextualization and the structure of resulting observer perspectives. Notions of fractal time are extensions, generalizations and/or re-interpretations of the concepts of time underlying classical physics, the theory of relativity, quantum theory and the notion of an internal time developed by the Brussels School.[6]

The need to regard physical theories as secondary concepts of the observer's primary experience of time, as presented by Pöppel's arguments, leads to the question as to how an observer perspective is generated.[7] My Theory of Fractal Time defines temporal observer perspectives in terms of Δt_{depth}, Δt_{length} and $\Delta t_{density}$.[8] Δt_{depth}, the density of time, is the number of compatible temporal intervals on more than one LOD: it defines simultaneity.

[2] van Nieuwenhuijze 2000.
[3] Haken 1995.
[4] Rössler 1998.
[5] van Nieuwenhuize 2000.
[6] Prigogine 1985.
[7] Pöppel 1989.
[8] Vrobel 1998.

Δt_{length}, the length of time, defines succession as the number of incompatible temporal intervals on one LOD. $\Delta t_{density}$, the density of time, is measured in the fractal dimension of a temporal interval, thus relating Δt_{depth} and Δt_{length}. My approach takes account of the observer's primary experience of time and the need to describe how an observer perspective emerges by recognizing that embodied cognition should be taken as a starting point for dealing with constraints on modelling reality. The temporal observer perspective is a result of the observer's degree of both conscious and unconscious contextualization.

A short introduction of fundamental concepts of time underlying physical theories is followed by a brief excursion into LODs and endo-/exo-observer perspectives. An overview of the observer's primary experience of time describes the notions of simultaneity, succession, the Now and duration. As physical theories are secondary constructs of those four primary experiences, definitions of observer perspectives should be based on those experiences. My Theory of Fractal Time, whose concepts are based on these primary experiences of time, is presented as an epistemological prerequisite for models of reality, including theories of fractal space-time. The last part of this review looks at the idea of taking embodied cognition as a starting point for dealing with constraints of modelling reality: The fractal temporal observer perspective is presented as the result of the observer's degree of conscious and unconscious contextualization and as a pre-requisite for notions of fractal space-time.

2. Notions of Time

Notions of time differ with respect to the ontological status assigned to time and the epistemological assumptions made. They also vary in the way possible resulting temporal relations are described. Questioning the reality of time is a fertile starting point, as it leads us to make explicit assumptions about the observer-world relationship. So, is time real? That's a toughie. If we assume that we may describe something as real if it exists independent of an observer, our approach is not a scientific one, but based on faith. Therefore, we are limited to an inter-subjective generation of inter-objective notions of time, which we derive from conceptual metaphors. As most of these metaphors are grounded in our sensory-motor system[9], embodied cognition should be taken as a starting point when we contemplate basic notions such as time, on which our physical theories are based. Subjective time is just as real to the individual observer as any inter-objective concept of time. A phenomenological approach takes account of both by describing the world as an interface reality.[10] However, this does not imply that time is a purely subjective phenomenon generated by observers. But although the observer does not generate time, he may modify its structure, which may be understood as an interference pattern resulting from the observer's embedding in a context. This idea is discussed below.

In order to solve the question as to whether the structure of time is a given ordering

[9] Lakoff and Núñez 2000.
[10] Rössler 1995, 1996, 1998.

principle or one generated by individual observers, we have to look at our options in approaching this question. Our access to the world is gained through empirical knowledge – this fact makes it difficult to address the notion of time, because we are always already embedded in the subject matter we want to define. It is logically not conceiveable that we jump out of our embedding temporal structure and describe it from an outside, a-temporal perspective. We are creatures who live in time, with embodied minds whose internal processes are of a temporal nature. Therefore, a non-circular definition of time is not possible.

Starting from our own empirical knowledge, we differentiate between familiar aspects of time, such as earlier-, later-, and between-relations (succession), phenomena we perceive as being temporally compatible (simultaneity), the extension of a temporal interval (duration), and the flow of time from the past via the present into the future, which cumulates in our consciousness of the present (the Now).

By describing change in terms of earlier-, later- , and between-relations, we refer to the time of physics, t, an inter-objective notion of time. This description reduces time to a parameter and thus lacks vital concepts which are essential to the observer's reality generation: the notions of simultaneity, duration and the Now.

The Now does not have a counterpart in the time of physics. However, it is a significant concept, as, epistemologically speaking, it is our only access to the world. In fact, the Now is all we have. Even when we remember the past and anticipate future events, we do this in the present, in our Now. Our subjective experience of time also includes the flow of time from the past through the present into the future. Events appear to be, first, in the future, then present, and, finally, in the past. This notion of time passing finds no counterpart in the time of physics either.

The notions of time we presuppose act as constraints on the development and evaluation of a scientific theory. Therefore, theories which include temporal notions such as the Now will differ from those who fail to include a temporal observer perspective.

Newton's absolute time does not allow for a privileged observer perspective defined by an individual Now, let alone for an internal differentiation of the observer. Both time and space are portrayed as container-like structures.[11]

Einstein dismissed Newton's container spacetime [12] and defines simultaneity and duration in terms of the observer's event horizon. His Special and General Theories of Relativity are based on a concept of time which cannot be conceived of independently of the observer's position. As the speed of light acts as a constraint, the concepts of simultaneity and duration are dependent on the observer frame: There is no absolute reference system. The relativity of simultaneity and time dilation are examples of the observer-centeredness which constrain statements about temporal relations. Einstein does not deny the existence of the Now, but, by differentiating between subjective and objective time, he assigns

[11] "Absolute, true and mathematical time, of itself, and from its own nature, flows equably without relation to anything external, and by another name is called duration. (...) For times and spaces are, as it were, the places as well of themselves as of all other things. All things are placed in time as to order of succession; and in space as to order of situation." (Newton 1687/1962, p.6)

[12] "The idea of the independent existence of space and time can be expressed drastically in this way: If matter were to disappear, space and time alone would remain behind (as a kind of stage for physical happening)." (Einstein 1920/1988, p. 144)

the Now a place which only exists in our consciousness. To him, subjective time is a manifestation of our consciousness in action and has no physical counterpart. His introduction of inertial systems and observer frames did allow for the notion of an observer perspective. This perspective, however, was not based on an internal differentiation of the observer, but merely on his relative position in space-time and the resulting event horizon.

Quantum Theory recognized that the observer-participants actively take part in the outcome of measurement results. The notion of an observer-participant who takes a measurement and thus causes the collapse of the wave function, allows for a differentiation of individual observer perspectives and a "private" Now.

Wheeler defines the role of the observer as that of an active, selecting questioner.[13] He sees reality as generated by our questions and the resulting selection process therefore as subjective. The subject plays a constituting role in the generation of reality. The measuring process correlates with the transition from the possible to the actual. The present, our Now, within which the decision on the way of measuring and the measurement itself is taken, may be interpreted as an indivisible whole consisting of particles and the experimental set-up. This interval of duration is indivisible, as the mere question about individual processes within that interval is meaningless. Most interpretations of Quantum Theory allow for the notion of an observer perspective which entails the generation of a Now, but regard the observer's internal differentiation as being irrelevant to the experimental set-up. It is only releveant insofar as the question posed is the result of a subjective decision-making process. Everett's interpretation, which suggests understanding the uncollapsed state vector as an objective description of the world (Many World Theory), would allow for as many simultaneous observer perspectives and Nows as there are possible interfacial cuts and measuring results.

Prigogine introduces, in addition to the astronomical time t, an internal time T, which denotes the internal age of a system. However, this internal time T, which results from the number of transformations within a system, presupposes a framework time t, as the processes which generate T *take place in time t.* The baker transformation, for example, presupposes a framework time t, within which a succession of foldings can be imagined to take place.

Prigogine did not develop his internal time T to generate an observer perspective. Rather, he conceived of it as an operator, as in quantum mechanics. (As in the baker transformation, an "average" time is defined which corresponds to the superposition of the individual partitions.) However, T may well be interpreted from within the system T describes, provided an embedded observer-participant is assumed to make that interpretation, and thus form an internal temporal observer perspective.

T is non-local, i.e., it depends on the global topology of a system and may be used to describe the internal temporal differentiation of any system undergoing change. But even

[13] "We used to think that the world exists 'out there' independent of us, we the observer safely hidden behind a one-foot thick slab of plate glass, (...), not getting involved, only observing. However, we've concluded in the meantime that that isn't the way the world works. (...) What we thought was there is not there until we ask a question." (Wheeler 1994, pp. 15/16).

if we know the internal age of a system, we cannot associate it to a local trajectory. The individual local times (partitions in the baker transformation) which result in a global internal time may or may not be fairly close to the average global time. Prigogine and Stengers present a transparent example in chronogeography.[14]

Prigogine interprets sensitive dependence on initial conditions (SDIC) as an infinite entropy barrier, which results in irreversibility. SDIC was discovered by Edward Lorentz in the early 1960s[15]. But neither Lorentz nor the pioneers of Chaos Theory, who thrived on this notion, did explicitly define a new concept of time. However, as many strange attractors happen to display a self-similar stucture, Chaos Theory actually describes temporal fractal structures in phase space. This fractality, though, is a virtual one and does not allow for the description of both succession and simultaneity, as the fractal pattern of the attractor which finally emerges no longer contains the information of the successive vectors from which it evolved. Succession is lost in a phase space portrait. (In contrast to the phase space portrait representation, the notion of fractal time introduced in the second part of this paper takes account of both succession and simultaneity.)

3. Levels of description: The Endo and Exo-Perspective

One way of comparing different approaches to modelling reality consists of considering the number of LODs taken into account by a model. The notion of LODs was discussed in detail by Hofstadter[16] in the context of holism vs reductionism, tangled hierarchies and the inviolate level. For the sake of brevity, I shall not get into detail on his notions of LODs. In the present context, it shall suffice to point out that LODs come in two disguises we are not necessarily aware of: Either or both as abstractions within a fixed coherent perspective and/or as interfacial cuts between the observer and the rest of the world (the endo- and exo-perspective).

Descartes' interfacial cut between *res cogitans* and *res extensa* created two LODs on which physical theories thrived for centuries. However, recent advances in cognitive science[17] suggest that the Cartesian Cut is not helpful, as it disregards the fact that the mind is embodied, i.e., that most of our cognitive performances are limited by perceptual constraints and conceptual metaphors, which are grounded to a large extent in our sensory-motor system. All abstractions we perform are constrained by such conceptual metaphors.[18] Therefore, taking the Cartesian Cut between *res cogitans* and *res extensa*

[14] "When we look at the structure of a town, or of a landscape, we see temporal elements interacting and coexisting. Brasilia and Pompeii would correspond to a well-defined internal age, somewhat like one of the basic partitions in the baker transformation. On the contrary, modern Rome, whose buildings originated in quite different periods, would correspond to an average time exactly as an arbitrary partition may be decomposed into elements corresponding to different internal times." (Prigogine & Stengers 1985, pp. 272-273)

[15] Lorentz 1963.

[16] Hofstadter 1980.

[17] e.g. Storch et al 2006.

[18] Lakoff & Núñez 2000.

seriously, prevents us from accessing the foundations of our cognitive performances.

The Newtonian paradigm is based on the exo-perspective. Like Laplace's demon, an observer is considered to have, theoretically, at his disposal all information which is necessary to compute and predict the future development of a system. The act of observation, including the observer's perspective and internal organization, is regarded as having no impact on the measured results. Einstein introduced observer frames, defined their boundaries, and thus introduced the observer's relative position as a vital notion which determines his perspective and measuring results. However, he did not take account of either the observer's internal differentiation nor the interference the act of observing implies. Quantum mechanics took this step but did not consider the observer's internal make-up when setting the Heisenberg Cut.

Prigogine introduced the internal time T (as an operator), the internal age of a system, which differs from the astronomical time t. This made it possible to describe the internal differentiation of a system undergoing change. Although the internal time T depends on the global topology of the system, it is also an exo-physical model, as it does not describe T from the perspective of an embedded extended observer. Thus, the above models set differing interfacial cuts, none of which explicity take account of the impact of the observer's internal differentiation on the measuring result.

Rössler's microconstructivism states that we have to take into account the microscopic movement within the observer when we model reality.[19] The embedded observer is confined to an endo-perspective, as he has no access to the thing-in-itself: All the endo-observer may talk about is the world as it appears on his interface – a purely phenomenological account. The exo-perspective remains inaccessible to mortals – it is an idealization which implies the idea of a bodyless super-observer such as Laplace's Demon. Rössler's differentiation between the endo- and exo-perspective reveals yet another Gödel limit embedded observers face: our Now manifests itself as our interface reality, a very private event horizon, generated by the microscopic movements within the observer. The more an observer is aware of his internal structure and dynamics, the more differentiated is his Now, his temporal interface. And the Now is our only access to the world. The setting of the interfacial cut determines the notion of time we presuppose when modelling reality.

However, there is a limit to our potential awareness of not only the microscopic processes within the observer, but also to his cognitive structures. Most of our thinking is inaccessible to conscious introspection, as we cannot monitor it on low-level thought processes which shape our observer perspectives.[20]

[19] Rössler 1995, 1998 and personal communication.

[20] Metzinger suggests that this inaccessibility is a result of the fact that the perspective-generating mechanisms are transparent to us because they occur on time scales which are far too fast for us to be accessed consciously. Metzinger 2006.

4. Simultaneity, Succession, Duration and the Now: Physical Theories are Secondary Constructs of Our Primary Experiences of Time

The concepts of time presented above vary significantly with respect to the significance given to the observer's internal differentiation and perspective. However, according to Pöppel, they are all secondary constructs, derivatives of our primary experience of time.[21] In order to provide a basis for our primary experience of time, natural scientists come up with natural laws whose implicit concept of time is compatible with our perspective and our description of Nature. This implicit concept of time must, however, be appreciated as a derivative: Pöppel's argument essentially consists of the fact that we, as human beings, have to cosider *a priori* the performances carried out by our brains when considering all theories and concepts we have generated. Therefore, all physical theories are necessarily anthropocentric.[22]

Hence, he concludes that all physical concepts of time are secondary constructs we have developed, as we can only approach time and duration through the filtering processes which result from the limitations of our perceptual apparatus and the integrative performances carried out by our brains. Pöppel describes his approach as neuro-scientific, taking the subjective experience of time as a starting point. In this context, he differentiates between simultaneity, succession, the Now and duration. These constitute our primary experience of time, which, he suggests, precedes the physical and semantic concepts of time.

a. Simultaneity

Our senses both render possible and limit our experience of simultaneity. The differing ways of experiencing simultaneity correlate with various sensory perceptions. We perceive signals we hear as non-simultaneous if they are separated by an interval of approx. 6 milliseconds. Below this threshold, signals are perceived as being simultaneous. Our visual senses show a different sensibility to simultaneity. Here, impressions which are separated by an interval of 20 to 30 milliseconds are experienced as non-simultaneous. If that separating interval is shorter, impressions are perceived as simultaneous. Our tactile sensibility is settled in between the audio- and visual threshold for simultaneity, roughly at 10 milliseconds.

The simultaneous perceptions via various senses means that these are temporally nested, as the acoustic and optical spaces are not congruent in terms of their smallest perceivable temporal units. Our brains make up for this incongruence and integrate

[21] Pöppel 1989, 2000.

[22] For physical concepts of time, this entails that "... the search for the conditions of rendering possible any experience of time in the real world is determined by mechanisms of our brains, which condition our experience of time. It is not possible to conceive of a theoretical concept of time in physics (e.g. Newton's 'absolute' time), which pretends to exceed experience of time. Therefore, I suggest to regard the physical concepts of time (be it the Newtonian one, that of Einstein or Prigogine) as a *secondary construct* derived from our primary experience of time." [my translation, Pöppel 1989, p. 380]

acoustic and visual inputs into a gestalt. Pöppel defines a simultaneity horizon, which spans at a radius of 10 – 12 meters from the observer (this distance varies slightly for different observers). This is the distance at which audio and visual signals are perceived as being simultaneous. He suggests that this horizon is probably also a constraint on our world view. (Note that, at this distance, the non-congruence of audio and visual signals does not result from the difference of the speeds of light and sound – it is a constraint inherent in our perceptual apparatus.)[23]

b. Succession

The experience of succession is a little more tricky, as individual events need to be identified before they may be put into some successive order. Events must be separated by at least 30-40 milliseconds to be perceived as being successive. To explain this phenomenon, a qualitative jump is necessary, which connects the processing of a stimulus by our sensory organs to the processing which goes on in our brains – the point where we knock sense into what we have heard or seen.

c. Duration and The Now

The experience of the Now is based on yet another performance carried out by our brains, namely integration. Impressions are experienced as present when our brain assembles them into perception gestalts. Pöppel exemplifies this idea with an example from language[24] which is reminiscent of Husserl's example of hearing a succession of musical notes as a tune (Husserl's example is described below in the context of the notion of fractal time): Pöppel's definition of something being present is based on a clustering of perception-related experiences which are based on meaningfulness, i.e., perceptual gestalts are constructed by our brains. From this, we may conclude that the duration of the individual present depends on the mental capability of the person who experiences an event. The richer and more differentiated the language, the more complex are the perceptual gestalts this person may construct and, as a result, the more extended this person may define his present. In order to render possible the experience of duration, two components are necessary: firstly, the "identification and integration of perceptual gestalts"[25] and, secondly, memory, by means of which time may be skipped and even be overcome through reflexion by providing past experiences to our reflective consciousness.[26] Pöppel's rod for measuring duration is situated within ourselves: the smallest frequencies define the shortest temporal extension of events, which may be generated

[23] Pöppel 2000, pp. 38-42.

[24] "Successive events are perceived as being present only up to a certain limit. An example from language: the word "now" is is made up of successive phonetic events. But when I hear the word "now" now, I perceive the whole word now and not a succession of individual phonetic entities. This indicates another performance of brains at work, namely the *integration* of temporally separated events in perception gestalts, which, in each case, are present, i.e. constitute the Now. The upper limit to this integration of perception-related experience ranges between two and four seconds. (...) What we *experience* as being present is not a point without extension on the time axis of classical physics but meaningful events which have been integrated into gestalts." Pöppel 1989, p. 372 (my translation)

[25] Pöppel 1989, p. 374

[26] Pöppel 1989, p. 375

into perceptional gestalts by means of integration – a subtle performance carried out by our brains, of which we are unaware.

Gestalts are indivisible constructs per definitionem. However, if they display internal differentiation, and therefore, temporal extension, they define a certain duration, albeit an indivisible one. The notion of an indivisible Now was introduced by Henri Bergson, half a century before the term gestalt was coined. Bergson's term *durée* denotes a non-divisible whole.[27] The Bergsonian concept of *durée* does not accept succession within the non-divisible whole of the duration, although it does contain the past.[28]

Below, the term Now is used in Husserl's sense, insofar as it implies the properties of an extended present which exhibits deep nesting of protentions and retentions. The notions of the prime and time condensation, which will be introduced in my Theory of Fractal Time, are based on the Bergsonian concept of duration, which defines a present which implies the past *and* is, at the same time, indivisible. (Fractal time not only nests past events into the present but also includes the notion of anticipation, which adds the idea of the future being embedded into the Now.)

The four elementary experiences of time briefly described above constitute our primary experience of time. Our experience of time thus turns out to be something given and becomes the starting point of philosophical questions concerning the conditions which render experience of time possible. These conditions are generated in different ways, depending on the underlying belief system. Pöppel showed that both physical and semantic approaches, and, therefore, physical theories, are anthropocentrical and thus derivatives of our subjective experience of time.[29] The same is true for mathematics: Lakoff & Núñez described how mathematical concepts are derived from embodied cognition.[30] The idea that physics should be based on neuropsychology is also supported by Fidelman's work.[31]

[27] "Let us therefore rather imagine the image of an infinitely small elastic band, contracted, if it were possible, into a mathematical point. We slowly start stretching it, so that the point turns into a line which grows continuously. Let us focus our attention not on the line qua line, but onto the action of pulling it. Notice that this action is indivisible, given that it would, were an interruption to be inserted, become two actions instead of one and that each of these actions is then the indivisible one in question. We can then say that it is not the moving action itself which is ever divisible, but the static line, which the action leaves under it as a trail in space." Bergson 1909, p. 8 (my translation).

[28] "The internal duration is the continuous life of a recollection which extends the past into the present, so that the present may clearly contain the perpetually expanding image of the past (...).Without this continuing existence of the past in the present, there would be no duration, only the existence of the moment." Bergson 1909, pp. 27-28 (my translation).

[29] "As our brain has only one perspective on the world (whose extent we cannot possibly imagine) as a result of its evolutionary history, all physical theories are necessarily a view through only one (namely our) window to the world. As a result, physical theories are necessarily anthropocentric." Pöppel 1989, p. 380 (my translation)

[30] Lakoff & Núñez' 2000.

[31] Fidelman 2002, 2004 a,b,c and personal communication.

5. Fractal Time

Any physical theory should thus take account of the fact that its assumptions and observations are secondary constructs based on our primary experience of simultaneity, succession, the Now and duration. Below, my fractal notion of time is introduced, which is based on our experience of time, in particular on our experience of duration and the Now. It defines the primary experiences of time as a prerequisite for modelling reality. Simultaneity is generated by our brains by integrating events which are connected by during-relations, and we generate succession by integrating incompatible perceptional gestalts, i.e., events which cannot be connected by during-relations, on specific LODs. Against the background of my notion of fractal time, perceptional gestalts may be defined as temporal natural constraints.

Most existing notions of fractal time are really defining concepts of a fractal space-time which differ with respect to the way LODs are taken into account and interfacial cuts are set. In his pioneering work on fractals, Mandelbrot coined the terms *fractal* and *fractal time* and introduced a differentiation resulting from taking into account nested LODs, temporal intervals within a time series as defined by their degree of resolution.[32] He thus provided a way of measuring and comparing time series with respect to their temporal density. This he achieved by assigning a fractal dimension to spatio-temporal structures. The arbitrary choice of the measuring rod applied by an observer determines the outcome of the measurement, which depends on how much detail is taken into account. He made explicit that the role of the observer is crucial to the extent that he defines the measuring rod and the LODs taken into account when observing or measuring a time series. However, Mandelbrot's observer's perspective is an external one, as there is no internal observer, let alone constraints on such an observer's perception, so our primary experiences of time do not play a role.

Some theories of fractal space-time which have been developed in recent years do take account of our primary experience of time. They are intriguing as they define fractal space-times which render possible essentially new approaches and ways of modelling reality. Nottale's Theory of Scale Relativity, which extends Einstein's principle of relativity to scale transformations, assumes a continuous but non-differentiable fractal space-time whose geometry is resolution-dependent.[33] He actually applies the notion of fractality to the geometry of space-time itself. Space-time resolutions are inherent to the physical description and therefore of universal status. Thus, Nottale's approach, which aims for a full scale-relativistic physics, describes a differentiation of LODs which both implies and exceeds differentiations within the measuring chain. The principle of scale co-variance requires that the equations of physics are invariant under scale transformations. Nottale's theory allows for far-reaching conclusions in almost any branch of science, be it biological, inorganic or economic phenomena. He makes the appealing suggestion that evolutionary analogies between phylogeny and ontogeny (cell differentiation, tissue and organ build-

[32] Mandelbrot 1982.
[33] Nottale 2001.

ing, etc) may be manifestations of an underlying memory phenomenon which expresses itself on each level of description, at each scale of organization.[34] Together with Timar[35], Nottale focusses on temporal structures from the endo-perspective, which takes account of the fundamentally scale-relativistic character of our perception of time.[36] Their approach includes an extension of Boscovitch's co-variance principle to scale-invariance and may be applied, among other fields, to the description of certain mental disorders as a temporal incommensurability between observers as well as between an observer and his environment.[37]

El Naschie's Cantorian space-time is a fractal structure inherent in space-time itself.[38] It is based on a Peano-like Cantorian geometry, which has also been suggested by Ord (a Peano-Moore curve).[39] Among many other physical phenomena, Young's double-slit experiment may be re-interpreted by the Cantorian space-time model by assuming that the wave interference is a result of the geodesic waves of space-time itself. El Naschie's e-infinity, a discrete hierarchical fractal space-time with infinite dimensions, allows for the description of both relativity and quantum particle physics.

Dubois' anticipatory systems contain a model of themselves and are thus fractal structures, in essence.[40] The present state of a system is calculated not only on the basis of its past but also depends on its future (or, potentially future) states. Dubois differentiates between weak and strong anticipation. Weak anticipation, which is based on prediction, is generated from an exo-perspective, whereas strong anticipation, which implies that the anticipatory faculties are inherent in the system itself, is the result of computing from an endo-perspective. While exo-anticipation is generated when a system models a time series which describes external systems, endo-anticipation is based on the system's eigen dynamics – it is a property embedded in the describing system itself. Examples of strong anticipation are Dubois' notions of incursion and hyperincursion which define a computational method that takes into account the future states of a system in order to calculate its present state. Dubois' approach is an example of the idea that any complex system which is capable of reflecting and steering its own behaviour must be able to generate a model of itself and map this model onto itself.

The fractal approach has also been applied as a method of analyzing time series. Flicker-noise spectroscopy (FNS), a method developed by S.F. Timashev to measure time series on several LODs simultaneously, employs the idea of using a fractal measuring chain in order to recognize fractal structures in a chaotic signal.[41]

[34] Nottale et al 2002.
[35] Timar 2003.
[36] Nottale 2002.
[37] personal communication
[38] El Naschie 1995, 2004.
[39] Ord 1983.
[40] Dubois 1988, 2001.
[41] The primary idea of FNS is to disclose information hidden in correlation links which are present in a sequence of various irregularities (spikes, jumps, discontinuities in derivatives of different order) that occur in the measured dynamic variables at all levels of spatiotemporal hierarchy of systems under study. Timashev 2006.

The theories and methods described above all imply the idea of scaling structures, either as a property of the fabric of our universe, a generation mechanism or a fractal measuring method. These approaches open up fundamentally new ways of interpreting physical phenomena and have produced a wealth of concepts which explain the underlying structure of the manifestations of reality in a new way. But to link these approaches to our primary experiences of time, we have to fall back onto notions conceived of nearly 80 years ago.

The first person to develop a theory of fractal time which takes account of our primary experiences of time was the German phenomenologist Edmund Husserl.[42] Although he did not use the term *fractal*, he implicitly introduced this notion half a century before Mandelbrot's seminal book appeared. Although Husserl failed in his attempt to show that time is generated by the subject (which was the purpose of his treatise on the phenomenology on the inner consciousness of time), he implicity described the notion of fractal time by introducing a nested model of the Now. His model is based on the observer's perceptions and the resulting temporal observer perspective.

Husserl's notion of the Now is based on the modes of empirical knowledge *retention*, *consciousness of the present*, and *protention*. As the potential cumulation point of all retentions and protentions, the consciousness of the present represents future events by anticipating them and past events by reflecting them, in a modified way, in the Now. A present which hosts both retention and protention must exhibit extention. Husserl shows that it is necessary to assume the concepts of retention and protention in order to understand how we perceive change, exemplified by our skill to perceive not only a series of isolated notes, but a tune[43]. When we listen to a tune, we hear a succession of musical notes. But how come that we do not perceive simply a succession of unrelated notes – that we are able to hear a tune? We connect the note we have just heard with the present one and the tone we anticipate to follow it, all within our extended Now. By repeatedly remembering a tone (*retention*) and anticipating the next tone (*protention*), we generate a nested temporal pattern within the Now. Thus, the observer creates a simultaneity of retension, the consciousness of the present and protention. This simultaneity shapes our nested Now.

If we had no memory of the preceding note and no anticipation of the next one, we would only perceive a succession of isolated, uncorrelated notes. However, as we *are* able to perceive a tune and not just a succession of isolated notes, we must assume the Now to be extended and provide for *both* succession and simultaneity. Reiterated nestings of successive overlapping and simultaneous events within the Now generate a nested, fractal structure. This is true for any perception of change: We have to assume a nested structure of the Now to explain our ability to perceive a tune or any other time series as a meaningful entity.

I therefore assumed a nested structure of the Now which contains overlapping events which add the dimension of simultaneity to that of succession. Without simultaneity, no

[42] Husserl 1928.
[43] Husserl 1928.

before and after relations, no correlated succession, would be conceivable, as simultaneity creates the framework time which connects otherwise isolated events into a before and after relation. Husserl failed to show that time is created by the subject.[44] However, his nested model of the Now remains convincing. Below, I shall describe how the observer, although he does not generate time, does, through his choice of nestings, generate the structure of the Now.

In my Theory of Fractal Time, I have adopted Husserl's notion of a nested Now.[45] The concepts of duration, succession and simultaneity are based on our primary experiences of time. One aim of my theory was to provide a means of quantifying the internal stucture of the observer's interface by differentiating between the length of time, $\Delta t_{length,}$the depth of time, Δt_{depth}, and the density of time, $\Delta t_{density}$. These concepts allow us to describe a nested temporal perspective and the structure of our temporal observer interfaces.

Δt_{length} is the number of incompatible events in a time series, i.e., events which cannot be expressed in terms of during-relations (simultaneity). Δt_{length} defines the temporal dimension of succession for individual LODs.

Δt_{depth} is the number of compatible events in a time series, i.e., events which can be expressed in terms of during-relations. Δt_{depth} defines the temporal dimension of simultaneity and provides the framework time which allows us to structure events in Δt_{length} on individual LODs.

$\Delta t_{density}$ is the fractal dimension of a time series.[46] It describes the relation between compatible and incompatible, i.e., successive and simultaneous events, the density of time.

N.B.: Δt_{depth} logically precedes Δt_{length}, as there is no succession without simultaneity.

As an example for a fractal time series, consider any multi-layered signal. To illustrate the idea with audio signals, imagine the frequency ratios of musical notes which are played simultaneously. The least complex frequency ratio between two musical notes is 2:1, which defines the interval between them as an octave. The note A played on an oboe, for example, has a frequency of 440 Hz. The next higher A played on this musical instrument would have a frequency of 880 Hz, and so on. The nested overtones generate a cascade of embedddings, whose structures are translatable into each other, as the overtones are integer multiples of the fundamental frequency.[47]

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[44] Bieri shows that Husserl's approach is contradictory, being based, on the one hand, on the timeless character of the subject but, on the other hand, describing reflexion in the consciousness of the present as a succession: "One will not be able to avoid interpreting this 'succession' as a real time structure. This is because it is phenomenologically inconceivable that a formally possible thought of a consciousness first constructs a succession and then places itself into that very succession and only in doing so manages a temporal presentation of its data." (Bieri 1972, p. 197, (my translation).

[45] Vrobel 1998, 2004, 2006a.

[46] There are many ways of determining fractal dimensions, among them the Hausdorff dimension, Mandelbrot's self-similarity dimension and Barnsley's box-counting method. The latter provides the most general approach, as even a plane-filling structure may be described in terms of a fractal. Barnsley shifts the notion of fractality into the observer perspective. This allows a description of a fractal perspective as the result of re-iterated Nows nested by the observer. (Mandelbrot 1982, Barnsley 1988).

[47] Vrobel 2006e.

It is possible to provide a translation between the individual nested LODs if the pattern displays a self-similar structure, i.e., if the embedded LODs host structures which are identical to those of the embedding LODs, albeit of different extension in Δt_{length}.[48] The resulting commensurability gives rise to our notion of consonance.[49] In the musical example of nested overtones, consonance is created by overlapping frequencies which are easily translatable into each other in terms of Δt_{length} and Δt_{depth}. The notions of Δt_{length} and Δt_{depth} suffice to define a temporal observer perspective. $\Delta t_{density}$ is implicit in the idea of a temporal perspective, as it describes the relation between the number of nestings and the successive events on their respective LODs. These two temporal dimensions (Δt_{length} and Δt_{depth}) must be assumed in order to explain our perception of a multi-layered signal.[50] The Newtonian metric of time may be defined as a special case

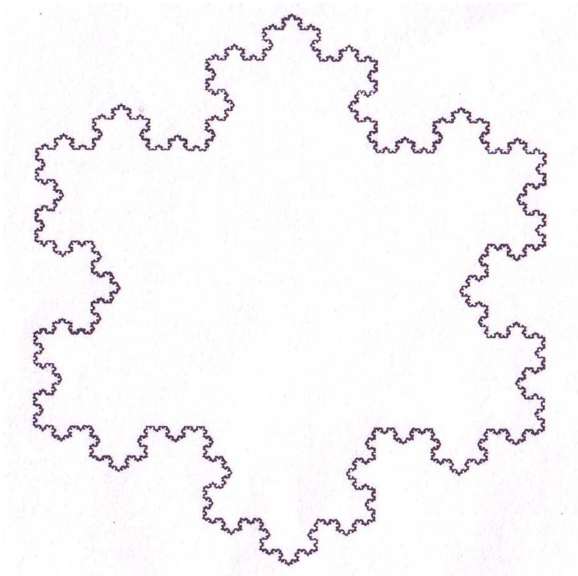

Fig. 1

of fractal time metrics. Imagine a fractal clock (as exemplified by the triadic Koch island, see Figure 1) which is run by an infinite number of pointers attached to the perimeter of the triadic Koch island, with all pointers ticking away simultaneously, each at its own speed. This fractal clock ticks away just like any ordinary clock, except that there is an infinite number of pointers instead of just two (or three). The infinitely nested structure of the triadic Koch curve exhibits an infinite number of intervals, which the pointers of a fractal clock have to tick away. While pointer no. 1 ticks only three times (per lap), pointer no. 2 is ticking 12 times, pointer no. 3 is ticking 48 times, and so on, ad infinitum (see Figure 2). If projected onto a one-dimensional straight line, the infinitely nested structure of the triadic Koch curve forms a continuum, and thereby, a Newtonian

[48] This assumes that the observer's internal make-up is capable of differentiating between these LODs.
[49] "The idea of consonance is ultimately grounded in the notion of commensurability, an essential in Greek mathematics. We recognise consonance when we perceive a certain number of vibrations of one frequency exactly matching a certain number of another frequency." (Fauvel et al 2003).
[50] such as the Risset scale (cf Vrobel 2006d)

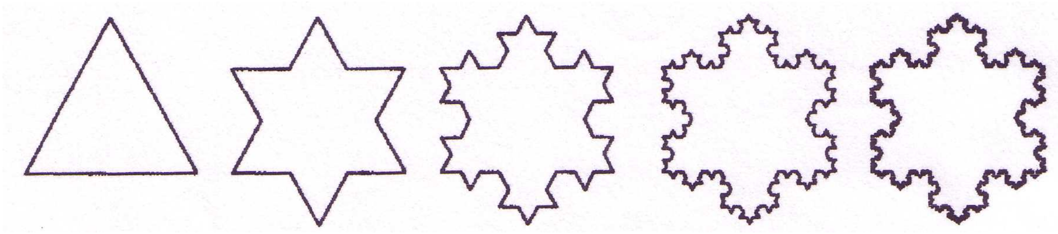

Fig. 2 Δt $_{depth}$: 3 ticks **during** 12 ticks **during** 48 ticks **during** 192 ticks **during** 768 ticks **during** ...

metric: the set of points generated in this way is the set of rational numbers. Therefore, the Newtonian metric may be defined in terms of fractal time, as Δt $_{length}$ of the nesting level ∞, i.e., $\Delta t_{depth} = \infty$.

6. Temporal Natural Constraints

The choice of the Koch curve as an example of a fractal clock is only for the didactic purpose of illustrating the nested structure of this fractal, be it spatial or temporal. Scaling behaviour in nature is usually limited by upper and lower boundaries between which a fractal and possibly self-similar domain manifests itself.[51] I have introduced the concept of temporal natural constraints, with the Prime being the smallest interval in a temporal nesting cascade. The Prime is defined as an interval which cannot host further nestings: it is a nesting constraint. It defines the smallest interval within a nesting cascade, a gestalt which is indivisible in the Bergsonian sense.[52] No limit to more extended, embedding length scales is assumed, as a phenomenological model of nested Nows describes individual observer perspectives whose depth is determined by the observer's embedding performances. For as long as the observer is capable of embedding new Nows, the nesting cascade has no upper limit.

If the structure of the Prime, which recurs on all LODs within a nesting cascade, is set as a constant, a scale relativity emerges: time is "bent" with respect to the Prime Structure Constant (PSC).[53] The distortion of the PSC allows us to formulate internal relations within a nested structure and thus translate between LODs. The "bending" of time in relation to the Prime requires congruence on all or several LODs. If such congruence is achieved, say, by an observer who registers the PSC only and disregards the lengths of the interval that structure "covers", condensation occurs[54].

[51] Cramer points out that objects we define fractals in Nature, such as coastlines, deltas, ferns, etc., exhibit only a limited scale-invariance: "The concept of the fractal dimension and self-similarity is, to begin with, a mathematical one. For real physical and chemical objects, diffusion curves, surfaces of crystals or proteins, self-similarity will never be fully realized for all scales of length. There is an upper and a lower limit for it." Cramer 1988, p. 172 (my translation). Cf. also: Olsen et al 1987.
Nottale equates such an impassable lower length-scale with the Planck scale and the upper one with the cosmic length scale which is related to the cosmological constant. (Nottale 2001).
[52] Cf.: Bergson 1909.
[53] Vrobel 2005a, 2006e.
[54] Vrobel 1998, 2000.

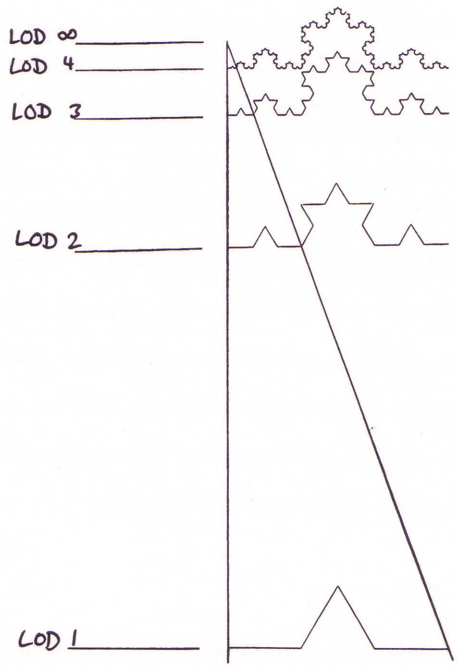

Fig. 3

Condensation is a property generated by congruent nestings. It can be measured by the quantities of condensation velocity v(c) and condensation acceleration a(c). The basic quantities for the determination of v(c) and a(c) are Δt_{depth} and Δt_{length}. The quotient of Δt_{length} of LOD 1 and Δt_{length} of LOD 2 equals the condensation velocity v(c) for LOD 2 $\odot$ LOD 1[55] (provided the units of both LODs can be converted to one another). For scale-invariant structures Figure 3[56] such as the Koch curve, v(c) is identical with the scaling factor s. Thus, for Figure 3, the condensation velocity v(c) for the Koch curve is LOD1 (4/3) / LOD2 (4/9) = 3; LOD2 (4/9) / LOD 3 (4/27) = 3; ...etc. The condensation acceleration is constant: a (c) = 1. There are TNCs on possible embeddings, generated both by physical structures of the outside world and the observer's internal differentiation. As Pöppel showed, some of these constraints on our experience of time and duration result from the limitations of our perceptual apparatus. TNCs may be selection effects. Limitations to the structurability of time by the observer are very likely a success story, as they render possible communication, travel, trade and science.

Without such constraints, no boundaries could have been set up within which limited entities may be defined. Within the framework of my notion of fractal time, LODs and primary experiences of time may be conceived of as TNCs. More complex structures such as metaphors and gestalts also act as TNCs, as they are pre-attentively generated indivisible wholes and thus not accessible to introspective analysis.[57]

[55] $\odot$ denotes *nested in.*

[56] Vrobel 1998, p. 45.

[57] Vrobel 2006f.

7. Observer Perspectives: The Fractal Temporal Interface

The terms succession and simultaneity, duration and the Now are not absolute concepts, but relative notions which presuppose an observer perspective, as the truth values of statements like "A happens before B", "A is simultaneous with B" or "A covers the same temporal interval as B" are context-dependent, i.e., they only make sense if defined for a particular observer perspective. Therefore, the temporal nesting of events shifts the property of fractality (simultaneity) to the eye of the beholder, the observer-participant.

An observer constructs a perspective by generating depth. This is true for both spatial and temporal perspectives. By representing objects at different distances from the observer as being of different sizes, he generates an invisible reference frame. For temporal intervals, the temporal perspective is generated by the nesting of multi-layered signals and the reiterated retention and protention performances the observer carries out. The notion of perspective presupposes simultaneity of different subsets. No perspective would arise if we observed the contents of different subsets successively, as no Δt_{depth} would be generated.[58]

With this in mind, observer types may be described. A non-fractal observer perceives only isolated notes in a tune or isolated events in a time series, and is thus only be able to observe successive events. He cannot generate Δt_{depth}, as simultaneity and memory formation would be unknown to him. Therefore, he is not capable of generating a Temporal Fractal Perspective through reiterated nesting performances.[59] A non-fractal observer lives in an eternal succession of unconnected Nows, in which no learning or reflection can take place. A fractal observer, in contrast, is capable of perceiving events on a number of LODs, and therefore able to generate a Temporal Fractal Perspective. A fractal observer experiences succession and simultaneity of events directly, in real time.

Unless an observer is impaired, e.g., by a neurodegenerative disease, he generates both succession and simultaneity. But although most of us are fractal observers, our awareness of our nested perspective is limited. The suspicion that there are both nested and non-nested perspectives dawns on us when we face situations in which our expectations are not met or in which we stumble over linguistic curiosities. One such curiosity is the name of the *yesterday-today-tomorrow* shrub. The colour of its blossoms changes within days from deep violet-blue to a light blue and finally to white. However, as this slow fading of the colour is staggered, the shrub displays blossoms of all three colours for a longish period of time. Whoever coined the name *yesterday-today-tomorrow* shrub seems to have observed it during this period of time on at least two LODs: on *both* that of the plant as a whole and that of its individual blossoms. It was an observer with a fractal temporal interface, generated by nested Nows. A non-fractal observer would not come up with a name like *yesterday-today-tomorrow* shrub, as he would have looked at the individual successive colour change of the blossoms on one LOD only. In order to refer to the past, the present and the future in one Now, it takes a nested interface which provides for both

[58] Vrobel 2006d.

[59] Vrobel 2005b.

simultaneity and succession. Although our Temporal Fractal Perspective is invisible, it is possible to deduce its existence from examples such as the the name of a shrub.

Simultaneity is a dimension generated by nesting temporally compatible events, with every embedding performance adding a level of description. The term simultaneity assumes an interfacial cut between an observer and the rest of the world. Simultaneity between events may be seen as the result of successful integration efforts carried out by the observer's brain. In general, fractal observers may be described as agents whose ability to contextualize determines the outcome of their measurements. This also affects our notions of the passage of time and entropy. I have suggested that the arrow of time we perceive (as the passage from the past to the present and into the future) cannot be explained by an increase in entropy, as the latter is an LOD-dependent measure, which depends on both the observer's position, his available time window for carrying out a measurement and his interfacial cut. For an observer situated inside a universe which consists of alternatingly nested ice cubes and hot water bottles, entropy may increase or decrease, depending on his position. As this observer cannot determine whether the outermost layer is an ice cube or a hot water bottle, he cannot conclude whether entropy will eventually increase or decrease (assuming such an outer layer exists). All he could use as a measure of change are progress units, which would increase in any case, describing a private arrow of time which does not necessarily correspond to the notion of entropy.[60] Against the background of my Theory of Fractal Time, the arrow of time runs from the inside towards the outside of a nesting cascade of Nows (with, in each case, the current Now hosting all previous Nows) rather than from the past via the present into the future.

Condensation is not affected by the arrow of time, as it does not imply the notion of succession. It may be experienced by an observer if his internal differentiation matches that of incoming signals from the outside world on nested LODs. This matching of internal and external LODs must occur between scale-invariant nestings in order to render possible translation via a known scaling factor. In nature, scale-invarinace usually occurs in the shape of a statistical self-similarity, such as 1/f noise. Exact scale invariance is an artefact which must be generated both for the observer and his embedding context. For such exact scale-invariance on both the observer's side of the interfacial cut and that of the structure of the embedding context, non-temporal cognition of temporal structures is conceivable. However, also statistical correlations such as 1/f noise, which abound in nature, both within our brains and bodies and in the outside world, generate scaling patterns.[61] (It should be noted that the patterns we describe as being part of the outside world are really inter-subjectively established mental constructs. However, as the naive realism implied in a clear division between inside and outside matches our metaphors, I refer to these concepts for didactic purposes. But the reader should keep in mind that the outside world is a mental construct generated by the observer.) In a condensation scenario, time is "bent" with respect to the PSC. This allows the observer to catch a glimpse beyond his immediate present: As a result of the structural congruence of his

[60] Vrobel 1996, 2006b.

[61] van Orden et al 2005.

nested LODs, his Now is extended. This glimpse involves no duration, i.e., no extension in Δt_{length} - its only extension is in the dimension of Δt_{depth}. This reduction of time to simultaneity within the observer's temporal interface renders possible a non-temporal access to cognition of temporal structures (for scale-invariant nested structures).[62]

The complexity an observer's temporal interface thus displays is a relative measure which results from the interaction of that observer with his context. The structure of the interfacial cut may be measured in terms of interface complexity, which relates internal and external scale-invariances in terms of the number of simultaneous one-to-one mappings.[63] The higher the number of simultaneous matchings on the respective internal and external LODs, the less complex the interfacial structure. The scalability of observation is based on pattern recognition of the shared process dynamics of the object, the interface and its context.

8. Participation: Temporal Embedding

An important change in perspective from classical science to relativity was the inclusion of the boundary in the shape of the event horizon. Quantum theory defined this boundary as an interface in which and through which the processes of a system are linked with the those of its context. As the linking of processes requires a matching of their metrics and dynamics, their internal temporal structures need to be made explicit. Van Nieuwenhuijze notes that the fractal perspective implies that we not only include the interface in our description of how an object is linked to its context, but we also regard the interface itself as being extended.[64] Internal and external process dynamics are linked within the interface, whose extension may be described in terms of $\Delta t_{length,}\Delta t_{depth}$, and $\Delta t_{density}$. Together, these define the dynamics of temporal distortions, i.e., dilation and contraction. The notion of fractal time allows us to render explicit the relation between an object and its context by zooming in on the boundary, the interface where they connect. An analysis of the temporal organization of the observer participant and his context reveals how the part relates to the whole. There is a direct relationship between the way we define an object and our degree of participation. The latter determines the position of the interfacial cut. Our selection of a specific LOD (or, in the fractal perspective, a number of LODs) determines the processing level(s) on which we distinguish an object from its context. This we tend to do on the basis of our own internal process dynamics, which determines the degree of observer involvement and observer attachment. Observation thus requires process coupling.

Van Nieuwenhuijze's approach also takes account of our primary experiences of time. His model conceives of reality as an interference pattern which results from the observer's interaction with the context he is embedded in. This requires differentiating between nested LODs within the observer which correspond to possible ways of interacting with

[62] Vrobel 1995.

[63] Vrobel 2006c

[64] van Nieuwenhuijze 1998, 2000, and personal communication.

our context. He renders explicit the observer's involvement and states that we need to include this factor as part of our formulations of observation. Every scientific formula thereby needs to contain a component which specifies our degree of involvement. Our capacity of relating to embedding LODs determines the way we make sense of the world and may interact with our surroundings. Conversely, it determines the way we function.[65] Therefore, the development of viable physical theories is determined by our capacity to generate a nesting cascade of successful contextualizations and to be aware of our degree of involvement.

The need to distinguish between observer types in terms of their internal differentiation and the position of their interfacial cuts results from the degree of contextualization an embedded observer generates. In the next section, I shall describe the idea of an extended observer to illustrate the arbitrariness of the setting of the interfacial cut. Identifying misattributions is a non-trivial task, as individual or collective observer perspectives can only be judged from an exo-perspective, an idealized position and degree of participation. The notion of sheer simultaneity turns the observer into a mere participant, who, in a state of total immersion, loses the capacity to observe.

TNCs Revisited: Embodiment

Gestalts and metaphors we use in constructing of our models of reality are complex structures. However, we do not perceive them as such, as they are part of the invisible reference frame within which we perform logical inferences. In fact, they are the indivisible building blocks of our observer perspectives. As TNCs, primary experiences of time belong to this domain. Also our interpretations of background/foreground (or the trajector/landmark relation[66]) create abstractions and metaphors on which we base our models. These interpretations result directly from the limitations of our embodied cognition. Differing degrees of nestings in an observer perspective, which manifest themselves as perceptions of simultaneous contrasts or the failure to contextualize, also form TNCs. [67] The observer types introduced in this review (fractal and non-fractal) are defined by "given" constraints, i.e., limitations we are not aware of.[68] We will probably never be able to shed light on the preconditions which form our observer frames. However, we may realize how vulnerable our own observer perspectives are if we consider observers with unusual interfacial cuts, i.e, whose ability to distinguish what is part of them and what belongs to the rest of the world appears to be significantly distorted from that of the norm.

In his Berkeley lecture, Metzinger described such extreme observer types.[69] On the one hand, there are individuals who deny that part of their bodies belong to them. For example, a person may claim that one of his legs does not belong to him, although he can

[65] van Nieuwenhuijze 2000.
[66] Lakoff & Núñez 2000.
[67] Dakin et al 2005, De Grave 2006, Tschacher 2006.
[68] Vrobel 2006f.
[69] Metzinger 2006.

clearly see that it is attached to his body. This condition is well documented under the term "neglect"[70]. On the other hand, there are observers who assign parts to themselves of what most other individuals would describe as belonging to the outside world. They set an interfacial cut which leads them to believe that they are the whole world in the sense that all events are controlled by their volitional acts. Metzinger describes a patient who spends all day staring out of the window, making the sun move across the sky. This may sound like an extreme case, but then many managers and politicians also delude themselves into being in control of their organizations or their economies.

There are less extreme and more familiar examples of extended observers. Think of how men perceive their cars as physical extensions of their bodies: A man in a Ferrari acts differently from one in a VW Beetle. Observer extensions are all around us. They range from clothes, glasses, hearing aids, cyber-goggles, fierce dogs and guns to microscopes, telescopes, gravitational lenses and more complex selection effects such as social and linguistic conventions.[71] The extended observer is an important concept, as our perception and description of reality significantly varies, depending on where we set the interfacial cut. The rubber hand illusion illustrates this convincingly[72]: A subject is sitting at a table, with his left arm resting on it. His hand is screened off from view and a rubber hand is placed in front of him. The subject is asked to stare at the rubber hand while both the rubber hand and his own hand which is resting on the table are stroked with paintbrushes simultaneously. The visual feedback links the visual and tactile perceptions (neurons that fire together wire together), so that after a while, the subject reported that he felt his own hand was being stroked, even if only the rubber hand was touched by the paintbrush: The intermodal matching sufficed for self-attribution. This conditioning effect has changed the subjects' perspective by shifting the location of the interfacial cut between the observer and the rest of the world. In this context, Metzinger defines the concept of mineness: all representational states which are embedded into the currently active self-model gain the additional higher-order property of phenomenal mineness.[73]

Whether or not the observer's perspective generated between mineness and non-mineness (or self and non-self) is based on a misattribution is not always easy to reveal. Some misattributions may become hardwired as a result of continuous positive feedback. This may result in rigid observer perspectives and which manifest themselves as educated incapacity, religious fanaticism, paranoid tendencies and scientific paradigms. The setting of the interfacial cut generates our observer frame and determines the way we interpret experiences.

Simultaneity generates gestalts which may become hard-wired as the result of a conditioning effect. Sheer simultaneity creates a super-gestalt, with the observer incorporating the whole world. In this case, the observer perspective is lost and replaced by mere participation.[74] These gestalts are the TNCs which shape our temporal observer per-

[70] Metzinger 2006.
[71] Vrobel 2006b.
[72] Botvinick & Cohen 1998.
[73] Metzinger 2003, 2006.
[74] Vrobel 2007.

spectives within the framework of which we try to generate a consistent interface reality for ourselves and construct scientific theories. Although it is a start, the fractal observer perspectives described above are only partly subject to introspective analysis, e.g., in terms of observer embeddedness, the setting of the interfacial cut and the complexity of the observer's Now. This is also true of the temporal perspectives of the scientists whose theories generate the prevailing paradigm.

9. Conclusion

The notion of fractal time described in this paper takes account of our primary experiences of time. An endophysical perspective such as the one implied in my Theory of Fractal Time takes account of the incompatible temporal extensions of succession and simultaneity and defines observer types in terms of their temporal fractal observer perspective. In order to account for our primary perceptions of time, the Now must be assumed to be extended and display a nested structure.

The ontological implications of the concepts of time presented in this review differ with respect to the observer perspective and the attainability of endo- and exo-perspectives. A strong case can be made in favour of a fractal model of time, as it is a generalization which includes both the Newtonian continuum and relativity as special cases. The notions of time implied in these theories, as well as those assumed in quantum theory and Prigogine's internal time T, are secondary constructs which are based on our embodied primary experience of time.

My Theory of Fractal Time describes some of the invisible constraints which govern our observation.[75] The observer position, the number of LODs taken into account and the setting of the interfacial cut all determine the outcome of a measurement (an observation). In general, it may be stated that any attempt to analyze a time series, in fact, any modelling of reality, must take account of constraints on our embodied cognition which come in the shape of LODs such as interfacial cuts, our internal differentiation and our degree of conscious and unconscious contextualization, which generate our temporal observer perspectives. Therefore, the notion of time introduced in my Theory of Fractal Time may be seen as a prerequisite for theories of fractal space-time.[76]

The structures of time and space are mental constructs.[77] They emerge as the result of the circular causation generated by embodied interaction and cognition.[78] Our theories are thus anthropocentric and are limited by constraints resulting from our cognition, which has evolved to optimize the survival of our bodies, not to catch a glimpse of the Platonic realm of ideas.

As we have no access to the thing-in-itself, the *noumenon*, a phenomenological description of the world, based on the gestalts and metaphors our embodied cogniton has

[75] Vrobel 1999.
[76] "More generally speaking one could say that a 'fractal time' (cf. [Vrobel 1995]) serves as an explanation of fractal space-time."
[77] Lakoff and Núñez 2000, Storch et al 2006, van Nieuwenhuijze 1998.
[78] Storch et al 2006.

generated, is all we can build our models on: interface reality. The rest is faith and speculation.

However, there is no need to despair. If we agree that our models of reality are limited by TNCs resulting from embodied cognition and that our inter-subjectively generated reality does not describe the *noumenon*, we may happily continue to indulge in naive realism. As Metzinger pointed out, naive realism is an extremely useful perspective for our phenomenal selves to deal with the world.[79] After all, it is the result of a long selection process. And as long as it works, we may as well stick with it. We may never be able to access the preconditions of perception and processing, let alone access the *noumenon*. But as long as we are aware of the fact that interface reality is all we may talk about, we may as well enjoy the limitations of our *condition humaine*:

"I am plagued by doubts.
What if everything is an illusion and nothing exists?
In that case, I definitely overpaid for my carpet."[80]

[79] "... naive realism has been a functionally adequate assumption for us, as we only needed to represent the fact 'there's a wolf there' (...) not 'there's an active wolf representation in my brain now'." (Metzinger 2006)

[80] Woody Allen 1986.

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