

## THE NATURE OF TIME AS A CONSEQUENCE OF HOW WE CONSTRUCT THE WORLD

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**Abstract:** In classical physics there was a clear understanding of what physical space and time are: physical space is the theatre of the collection of all events that are actual at a certain moment of time, and physical time is the parametrization of the flow of time. 3-dimensional space and 1-dimensional time have been substituted by 4-dimensional time–space in relativity theory. But if reality is the 4-dimensional time–space manifold of relativity theory, what is then the meaning of ‘change in time’? We investigate this problem of relativity theory by following an operational approach originally elaborated for quantum mechanics. We show that the contradiction between a geometric view and process view of reality is due to a misconception in the interpretation of relativity theory. We argue that it is not time which is space-like, with the inevitable paradoxical situation of a block universe as result, but on the contrary, it is space which is time-like. This ‘dynamic’, ‘time-like’ conception of space answers the question of the meaning of ‘change in time’ within the 4-dimensional reality of relativity theory, and puts forward a new view on other aspects of the theory.

**Keywords:** Time – Space – Reality – Relativity Theory – Quantum Mechanics

### 1 Introduction

*Henceforth space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality.*

Hermann Minkowski

*The scene of action is not a three-dimensional Euclidean space, but rather a 4-dimensional world, in which space and time are linked together indissoluble. However deep the chasm may be that separates the intuitive nature of space from that of time in our experience, nothing of this qualitative difference enters into the objective world which physics endeavours to crystallise out*

*of direct experience. It is a 4-dimensional continuum, which is neither 'time' nor 'space'. Only the consciousness that passes on in one portion of this world experiences the detached piece which comes to meet it and passes behind it, as history, that is as a process that is going forward in time and takes place in space.*

Hermann Weyl

What is reality? What is space? And what is time? These are three questions that we want to investigate. Our intuitive pre-scientific conception of the world in relation with these three notions is not very precise but could be summarised as follows.

- Reality is everything that exists now in the present. The past has been real but is no longer and the future is what shall become real but is not yet.
- Space is the theatre where reality is in. It englobes all of reality.
- What is real changes continuously and time describes and parametrises this change of reality.

Till the birth of relativity theory all physical theories were compatible with this intuitive scheme. But when relativity theory entered the scene, these intuitive conceptions of space and time, and what is less recognised even till today, also the conception of reality, has got into problems. We deliberately state the revolution that happened in the beginning of this century in this vague way, because we believe that the trouble that relativity theory has brought to our understandings of space, time and reality has still not been resolved. It has not even been identified fully, because in many textbooks about relativity theory the impression is given that we fully understand this strange theory and its implications on the nature of space, time and reality. Perhaps historically this is due to the fact that very shortly after the conceptual earth-quake that was generated by relativity theory, quantum mechanics appeared on the scene. The conceptual problems introduced by quantum mechanics, also related to the fundamental nature of space, time and reality, were much bigger still. And partly because of this reason — many brilliant young theoretical physicists started to work on quantum mechanics struggling with the multitude of conceptual and technical problems that appeared there — relativity theory started to

get considered more and more as a well understood physical theory. The problem with the interpretation of quantum mechanics was, and partly still is, also a problem related directly to the question ‘What is reality?’. Many investigations stimulated by this question have been undertaken in relation with quantum mechanics, and many aspects have been clarified meanwhile. In this paper we shall use some of the insights that have been gained about the three fundamental questions that we have put forward by the investigations on the interpretation of quantum mechanics — more specifically the progress that has been made to axiomatise quantum mechanics in an operational way [1]–[19] — and apply them to relativity theory. We shall be able in this way to understand certain fundamental questions about time, space and reality [20]–[25]. As a rather amazing result we will show that physical reality is 4-dimensional, as presented in [20, 21, 22], or 3-dimensional, depending on whether we accept the Einsteinian or Lorentzian interpretation of relativity theory. The way in which this 4-dimensionality shows itself is however fundamentally different from the way imagined by Minkowski and Weyl. The reflections and results presented in this paper are a continuation of the material exposed in [16, 18], but we have written the paper in such a way that it is self-contained.

## 2 What is Reality? An Operational Criterion

If we repeat our intuitive conception of time - formulated as ‘Time describes and parametrises the change of reality’ - it becomes obvious that we cannot understand the nature of time until we have obtained a clear understanding of the nature of ‘reality’. Therefore, before coming to our analysis of the concept of time in modern physics, we will concentrate on the concept of reality. Let us again repeat our intuitive notion of reality as ‘everything that exists now in the present’ and then put forward the way in which we shall analyse this concept in a rigorous manner. Here we use the idea of ‘now’ and ‘present’. If we would like to define also these concepts, we would come into a circular situation, needing time to define reality. Therefore, and also because it seems to us the most profound approach, we will consider as a primary — and hence undefined — concept the concept of ‘present experience’.

### 2.1 Experiences

We consider an experience to be an interaction between a participator — we consciously use here the word ‘participator’ instead of the word ‘observer’ to indicate that we consider the cognitive receiver to participate creatively

in his or her cognitive act — and a piece of the exterior world. When the participator lives such an experience, we will say that this experience is present, and we will call it the present experience of the participator. When we consider the situation of a measurement then we conceive this as the experimentator and his experimental apparatus together being the participator, and the physical entity under study to be the piece of the exterior world that interacts with the participator. The experiment is then the experience. Let us give some examples of experiences. We consider the following situation: I am inside my house in Brussels. It is night, the windows are shut. I sit in a chair, reading a novel. I have a basket filled with walnuts at my side, and from time to time I take one of them, crack it and eat it. My son is in bed and already asleep. Paris ‘by night’ exists and is busy. Let us enumerate the experiences that are considered in such a situation:  $E_1$ : *I read a novel*,  $E_2$ : *I experience the inside of my house in Brussels*,  $E_3$ : *I experience that it is night*,  $E_4$ : *I take a walnut, crack it and eat it*,  $E_5$ : *I see that my son is in bed and asleep*,  $E_6$ : *I experience that Paris is busy*.

The first very important remark I want to make is that obviously I do not experience all these experiences at once. On the contrary, in principle, I only experience one experience at once, namely my present experience. Let us suppose that my present experience is  $E_1$ : *I read a novel*. Then a lot of other things happen while I am living this present experience. These things happen in my present reality. While ‘I am reading the novel’ some of the happenings that happen are the following:  $H_1$ : *the novel exists*,  $H_2$ : *the inside of my house in Brussels exists*,  $H_3$ : *it is night*,  $H_4$ : *the basket and the walnuts exist, and are at my side*,  $H_5$ : *my son is in bed and is sleeping*,  $H_6$ : *Paris exists and is busy*. All the happenings, and much more, happen while I live the present experience  $E_1$ : *I read a novel*.

Why have I ordered the collection of my possible experiences in such a way that what I am just saying is evident for everybody (and therefore shows that we are not conscious of the specific ordering that is behind this evidence)? Certainly it is not because I experience also these other happenings. My only present experience is the experience of reading the novel. But, and this is the reason for that I have chosen fruitfully to order the collection of my possible experiences in this way, I could have chosen to live an experience including one of the other happenings in replacement of my present experience. Let me put down the list of these experiences that I could have chosen to experience in replacement of my present experience:  $E_2$ : *I observe that I am inside my house in Brussels*,  $E_3$ : *I see that it is*

night,  $E_4$ : *I take a walnut, crack it and eat it*,  $E_5$ : *I go and look in the bedroom to see that my son is asleep*,  $E_6$ : *I go to Paris and see that it is busy*.

This example indicates how we have started to model reality. First of all we have tried to identify two main aspects of an experience. The aspect that is controlled and created by me, and the aspect that just happens to me and can only be known by me. Let us introduce this important distinction in a formal way.

## 2.2 Creations and happenings

To see what I mean, let us consider the experience  $E_4$ : *I take a walnut, crack it and eat it*. In this experience, there is an aspect that is an action of me, the taking and the cracking, and the eating. There is also an aspect that is an observation of me, the walnut and the basket. By studying how our senses work, I can indeed say that it is the light reflected on the walnut, and on the basket, that gives me the experience of walnut and the experience of basket. This is an explanation that only now can be given; it is, however, not what was known in earlier days when the first world models of humanity were constructed. But without knowing the explanation delivered now by a detailed analysis, we could see very easily that an experience contains always two aspects, a creation aspect, and an observation aspect, simply because our will can only control part of the experience. This is the creation aspect.

For example, in  $E_1$ : *I read a novel* the reading is created by me, but the novel is not created by me. In general we can indicate for an experience the aspect that is created by me and the aspect that is not created by me. The aspect not created by me lends itself to my creation. We can reformulate an experience in the following way:  $E_4$ : *I take a walnut, crack it and eat it* becomes  $E_4$ : *The walnut is taken by me, and lends itself to my cracking and eating* and  $E_1$ : *I read a novel* becomes  $E_1$ : *The novel lends itself to my reading*.

The taking, cracking, eating, and reading will be called creations or actions and will be denoted by  $C_4$ : *I take, crack and eat* and  $C_1$ : *I read*. The walnut and the novel will be called happenings and will be denoted by  $H_4$ : *The walnut* and  $H_1$ : *The novel*.

**Statement 1 (Creation, Happening)** *A creation is that aspect of an experience created, controlled, and acted upon by me, and a happening is that aspect of an experience lending itself to my creation, control and action.*

An experience is determined by a description of the creation and a descrip-

tion of the happening. Creations are often expressed by verbs: to take, to crack, to eat, and to read, are the verbs that describe my creations in the examples. The walnut and the novel are happenings that have the additional property of being objects, which means happening with a great stability. Often happenings are expressed by a substantive.

**Statement 2 (Experience)** *Every one of my experiences  $E$  consists of one of my creations  $C$  and one of my happenings  $H$ , so  $E = (C, H)$ .*

A beautiful image that can be used as a metaphor for our model of the world is the image of the skier. A skier skis downhill. At every instant he or she has to be in complete harmony with the form of the mountain underneath. The mountain is the happening. The actions of the skier are the creation. The skier's creation, in harmony fused with the skier's happening, is his or her experience.

### **2.3 *The most basic modelling of the world: reality, present, past and future***

Let us again consider the collection of experiences:  $E_1$ : *I read a novel*,  $E_2$ : *I observe that I am inside my house in Brussels*,  $E_3$ : *I see that it is night*,  $E_4$ : *I take a walnut, crack it and eat it*,  $E_5$ : *I go and look in the bedroom to see that my son is asleep* and  $E_6$ : *I go to Paris and see that it is busy*. Let us now represent the basic model of the world that is made out of this small collection of experiences.  $E_1$ : *I read a novel* is my present experience. In my past I could, however, at several moments have chosen to do something else and this choice would have led me to have another present experience than  $E_1$ : *I read a novel*. For example:

- One minute ago I could have decided to stop reading and observe that I am inside the house. Then  $E_2$ : *I observe that I am inside my house in Brussels* would have been my present experience.
- Two minutes ago I could have decided to stop reading and open the windows and see that it is night. Then  $E_3$ : *I see that it is night* would have been my present experience.
- Three minutes ago I could have decided to stop reading, take a walnut from the basket, crack it, and eat it. Then  $E_4$ : *I take a walnut, crack it and eat it* would have been my present experience.
- Ten minutes ago I could have decided to go and see in the bedroom whether my son is asleep. Then  $E_5$ : *I go and look in the bedroom to see that my son is asleep* would have been my present experience.

- Two hours ago I could have decided to take the plane and fly to Paris and see how busy it was. then  $E_6$ : *I go to Paris and see that it is busy* would have been my present experience.

**Statement 3** *Even when they are not the happening aspect of my present experience, happenings ‘happen’ at present if they are the happening aspect of an experience that I could have lived in replacement of my present experience, if I would have decided so in my past.*

The fact that a certain experience  $E$  consisting of a creation  $C$  and an happening  $H$  is for me a possible present experience depends on two factors: (i) I have to be able to perform the creation, (ii) The happening has to be available. For example, the experience  $E_2$ : *I observe that I am inside my house in Brussels* is a possible experience for me, if: (i) I can perform the creation that consists in observing the inside of my house in Brussels. In other words, if this creation is in my personal power, (ii) The happening ‘the inside of my house in Brussels’ has to be available to me. In other words, this happening has to be contained in my personal reality.

**Statement 4** *The collection of all creations that I can perform at the present I will call my present personal power.*

**Statement 5** *The collection of all happenings that are available to me at the present I will call my present personal reality.*

I define as my present personal reality the collection of these happenings that are available to one of my creations if I would have used my personal power in such a way that at the present I can fuse one of these creations with one of these happenings. Happenings can happen at once, because to happen, a happening does not have to be part of my present experience. It is sufficient that it is available, and things can be available at once. Therefore, although my present experience is only one, my present personal reality consists of an enormous amount of happenings all happening at once. This concept of reality is not clearly understood in present physical theories. Physical theories know how to treat past, present and future. But reality is the order that we find in the ‘possible’. We describe it by means of a modelization of the experiences that I could have lived but probably will never live.

#### **2.4 Material time and material happenings**

From ancient times humanity has been fascinated by happenings going on in the sky, the motion of the sun, the changes of the moon, the motions of the planets and the stars. These happenings in the sky are periodic.

By means of these periodic happenings humans started to co-ordinate the other experiences. They introduced the counting of the years, the months and the days. Later on watches were invented to be able to co-ordinate experiences of the same day. And in this way material time was introduced in the reality of the human species. Again we want to analyse the way in which this material time was introduced, to be able to use it operationally if we analyse later on the paradoxes of time and space.

My present experience is seldom a material time experience. But in replacement of my present experience, I always could have consulted my watch, and in this way live a material time experience  $E_7$ : *I consult my watch and read the time*. In this way, although my present experience is seldom a material time experience, my present reality always contains a material time happening, namely the happening  $H_7$ : *The time indicated by my watch*, which is the happening to which the creation  $C_7$ : *I consult* is fused to form the experience  $E_7$ .

We can try to use our theory for a more concrete description of that layer of reality that we shall refer to as the layer of ‘material or energetic happenings’. We must be aware of the fact that this layer is a huge one, and so first of all we shall concentrate on those happenings that are related to the interactions between what we call material (more generally energetic) entities. We have to analyse first of all in which way the 4-dimensional manifold that generally is referred to as the ‘time–space’ of general relativity theory, is related to this layer of material or energetic reality. We shall take into account in this analysis the knowledge that we have gathered about the reality of quantum entities in relation with measurements of momentum and position.

### 3 Relativity and Reality

We consider now the set of all material or energetic happenings, and following our analysis in the foregoing section, this set represents physical reality. Let us try to find out now ‘what reality is taking into account relativity theory?’. We’ll make a rigorous analysis using our criterion of reality.

#### 3.1 *The nature of reality taking into account relativity theory*

Let us suppose that I am here and now in my house in Brussels, and it is December 28, 2004, 4 PM exactly. I want to find out ‘What is the material reality for me now?’. Let us consider a place in Paris, for example at the entrance of the Eiffel Tower, and let us denote, the centre of this place by  $(x_1, x_2, x_3)$ . I also choose now a certain time, for example December



28, 2004, 4 PM exactly (always referring to Greenwich time), and let me denote this time by  $x_0$ . I denote the happening that corresponds with the spot  $(x_1, x_2, x_3)$  located at the entrance of the Eiffel Tower, at time  $x_0$  by  $M$ . I can now try to investigate whether this happening  $M$  is part of my personal material reality. The question I have to answer is, can I find a creation of localisation  $L$ , in this case this creation is just the observation of the spot  $(x_1, x_2, x_3)$  at the entrance of the Eiffel Tower, at time  $x_0$ , that can be fused with this happening  $M$ . The answer to this question can only be investigated if we take into account the fact that I, who want to try to fuse a creation of localisation to this happening, am bound to my body, which is also a material entity. I must specify the question introducing the material time co-ordinate that I co-ordinate by my watch. So suppose that I co-ordinate my body by the 4 numbers  $(y_0, y_1, y_2, y_3)$ , where  $y_0$  is my material time, and  $(y_1, y_2, y_3)$  is the centre of mass of my body. We apply now our operational definition of reality. At this moment, December 28, 2004 at 4 PM exactly, my body is in my house in Brussels, which means that  $(y_0, y_1, y_2, y_3)$  is a point such that  $y_0$  equals December 28, 2004, 4 PM, and  $(y_1, y_2, y_3)$  is a point, the centre of mass of my body, somewhere in my house in Brussels. This shows that  $(x_0, x_1, x_2, x_3)$  is different from  $(y_0, y_1, y_2, y_3)$ , in the sense that  $(x_1, x_2, x_3)$  is different from  $(y_1, y_2, y_3)$  while  $x_0 = y_0$ . The question is now whether  $(x_0, x_1, x_2, x_3)$  is a point of my material reality, hence whether it makes sense to me to claim that now, December 28, 2004, 4 PM, the entrance of the Eiffel Tower 'exists'. If our theoretical framework corresponds in some way to our pre-scientific construction of reality, the answer to the foregoing question should be affirmative. Indeed, we all believe that 'now' the entrance of the Eiffel Tower exists. Let us try to investigate in a rigorous way this question in our framework. We have to verify whether it was possible for me to decide somewhere in my past, hence before December 28, 2004, 4 PM, to change some of my plans of action, such that I would decide to travel to Paris, and arrive exactly at December 28, 2004, 4 PM at the entrance of the Eiffel Tower, and observe the spot  $(x_1, x_2, x_3)$ . We could give many concrete ways to realise this experiment, and we will not give here one in detail, because we shall come back to the tricky parts of the realisation of this experiment in the following example. But hence the answer is indeed affirmative: I could have experienced the spot  $(x_1, x_2, x_3)$  at December 28, 2004, 4 PM, if I would have decided to travel to Paris somewhere in my past. Hence  $(x_0, x_1, x_2, x_3)$  is part of my reality. It is sound to claim that the entrance of the Eiffel Tower exists right now. And we remark that this does not mean that I have to be able

to experience this spot at the entrance of the Eiffel Tower now, December 28, 2004, 4 PM, while I am inside my house in Brussels. I repeat again, reality is a construction about the possible happenings that I could have fused with my actual creation. And since I could have decided so in my past, I could have been at the entrance of the Eiffel Tower, now, December 28, 2004, 4 PM.

Until this moment one could think that our framework only will confirm our intuitive notion of reality but our next example shows that this is certainly not the case. Indeed, let me consider the same problem, but now consider another point of time-space. I consider the point  $(z_0, z_1, z_2, z_3)$ , where  $(z_1, z_2, z_3) = (x_1, x_2, x_3)$ , hence the spot we envisage is again the entrance of the Eiffel Tower, and  $z_0$  is December 29, 2004, 4 PM exactly, hence the time that we consider is, tomorrow 4 PM. If I ask now first, before checking rigorously by means of our operational definition of reality, whether this point  $(z_0, z_1, z_2, z_3)$  is part of my present material reality, the intuitive answer here would be ‘no’. Indeed, tomorrow at the same time, 4 PM, is in the future and not in the present, and hence it is not real, and hence no part of my present material reality (this is the intuitive reasoning). If we go now to the formal reasoning in our framework, then we can see that the answer to this question depends on the interpretation of relativity theory that we put forward. Indeed, let us first analyse the question in a Newtonian conception of the world to make things clear. Remark that in a Newtonian conception of the world (which has been proved experimentally wrong, so here we are just considering it for the sake of clarity), my present material reality just falls together with ‘the present’, namely all the points of space that have the same time co-ordinate December 28, 2004, 4 PM. This means that the entrance of the Eiffel Tower tomorrow ‘is not part of my present material reality’. The answer is clear here and in this Newtonian conception, my present personal reality is just the collection of all  $(u_0, u_1, u_2, u_3)$  where  $u_0 = y_0$  and  $(u_1, u_2, u_3)$  are arbitrary. The world is not Newtonian, but also if we put forward an ether theory interpretation of relativity theory (let us refer to such an interpretation as a Lorentz interpretation) the answer remains the same. In a Lorentz interpretation, my present personal reality coincides with the present reality of the ether, namely all arbitrary points of the ether that are at time  $y_0$ , December 28, 2004 4 PM, and again the entrance of the Eiffel Tower tomorrow is not part of my present material reality. For an Einsteinian interpretation of relativity theory the answer is different. To investigate this I have to ask again the question of whether it would have been possible for me to decide

in my past such that I would have been able to make coincide  $(y_0, y_1, y_2, y_3)$  with  $(z_0, z_1, z_2, z_3)$ . The answer here is that this is very easy to do, because of the well known, and experimentally verified, effect of 'time dilatation'. Indeed, it would have been sufficient that some weeks ago in my past, let us say November 28, 2004, 4 PM, I would have decided to step inside a space ship that can move with almost the velocity of the speed of light, such that the time when I am inside this space ship slows down in such a way, that when I return with the space ship to planet earth, still flying with a speed near the velocity of light, I arrive in Paris at the entrance of the Eiffel Tower while my personal material watch indicates December 28, 2004 4 PM, and the watch that remained at the entrance of the Eiffel Tower indicates December 29, 2004 4 PM. Hence in this way I make coincide  $(y_0, y_1, y_2, y_3)$  with  $(z_0, z_1, z_2, z_3)$ , which proves that  $(z_0, z_1, z_2, z_3)$  is part of my present material reality.

First we have to remark that in practice it is not yet possible to make such a flight with a space ship. But this is not a crucial point for our reasoning. It is sufficient that we can do it in principle. Indeed, we have not yet made this explicit remark, but obviously if we have introduced in our framework an operational definition for reality, then we do not have to interpret such an operational definition in the sense that only operations are allowed that actually, taking into account the present technical possibilities of humanity, can be performed. If we would advocate such a narrow interpretation, then even in a Newtonian conception of the world, the star Sirius would not exist, because we cannot yet travel to it. What we mean with operational is much wider. It must be possible, taking into account the actual physical knowledge of the world, to conceive of a creation that can be fused with the happening in question, and then this happening pertains to our personal reality.

### ***3.2 Einstein versus Lorentz: has reality 4 dimensions?***

We can come now to one of the points that we want to make in this paper, and that clarifies the paradox of time that makes the difference between an ether interpretation of relativity (Lorentz) and an Einsteinian interpretation of relativity. Why would we come to a different result concerning the foregoing question, depending on whether we advocate an Einsteinian interpretation of relativity theory or an ether interpretation? To see clear in this we have to come back to the essential aspect of the construction of reality of our framework, which is the difference between a creation and a

happening. We have to give first another example to be able to make clear what we mean.

Suppose that I am a painter and I consider again my present material reality, at December 28, 2004, 4 PM, as indicated on my personal material watch. I am in my house in Brussels and let us specify: the room where I am is my workshop, surrounded by paintings, of which some are finished and others I am still working on. Clearly all these paintings exist in my present reality, December 28, 2004, 4 PM. Some weeks ago, when I was still working on a painting that now is finished, I could certainly have decided to start to work on another painting, a completely different one, that now does not exist. Even if I could have decided this some weeks ago, all of you will agree that this other painting, that I never started to work on, does not exist now, December 28, 2004, 4 PM. The reason for this conclusion is that the making of a painting is a 'creation' and not a happening. It is not so that there is some 'hidden' space of possible paintings such that my choice of some weeks ago to realise this other painting would have made me to detect it. If this would be the situation with paintings, then indeed also this painting would exist now, in this hidden space. But with paintings this is not the case. Paintings that are not realised by the painter are potential paintings, but they do not exist.

With this example of the paintings we can explain very well the difference between Lorentz and Einstein. For an ether interpretation of relativity the fact that my watch is slowing down while I decide to fly with the space ship nearly at the speed of light and return at the entrance of the Eiffel Tower while my watch is indicating December 28, 2004, 4 PM and the watch that remained at the Eiffel Tower indicates December 29, 2004, 4 PM, is interpreted as a 'creation'. It is seen as if there is a real physical effect of creation on the material functioning of my watch while I travel with the space ship, and this effect of creation is generated by the movement of the space ship through the ether. Hence the fact that I could observe the entrance of the Eiffel Tower tomorrow December 29, 2004 4 PM, when I would have decided some weeks ago to start travelling with the space ship, only proves that the entrance of the Eiffel Tower tomorrow is a potentiality. Just like the fact that this painting that I never started to paint could have been here in my workshop in Brussels is a potentiality. This means that as a consequence the spot at the entrance of the Eiffel Tower tomorrow is not part of my present reality, just as the possible painting that I did not start to paint is not part of my present reality. If we however put forward an Einsteinian interpretation of relativity, then the effect on my watch during

the space ship travel is interpreted in a completely different way. There is no physical effect on the material functioning of the watch, but the flight at the velocity nearly the speed of light ‘moves’ my space ship in the time–space continuum such that time co-ordinates and space co-ordinates get mixed. Certainly if we take into account that most of the time dilatation takes place not during the accelerations that the space ship undergoes during the trip, but during the long periods of flight with constant velocity nearly at the speed of light. This means that the effect of the space ship travel is an effect of a voyage through the time–space continuum, which brings me at my personal time of December 28, 2004, 4 PM at the entrance of the Eiffel Tower, where the time is December 29, 2004, 4 PM. And hence the entrance of the Eiffel Tower is a happening, an actuality and not just a potentiality, and it can be fused with my present creation. This means that the happening  $(z_0, z_1, z_2, z_3)$  of December 29, 2004, 4 PM, entrance of the Eiffel Tower, is a happening that can be fused with my creation of observation of the spot around me at December 28, 2004, 4 PM. Hence it is part of my present material reality. The entrance of the Eiffel Tower at December 29, 2004, 4 PM exists for me today, December 28, 2004 4 PM.

If we advocate an Einsteinian interpretation of relativity theory we have to conclude from the foregoing section that reality is 4-dimensional. This conclusion will perhaps not amaze those who always have considered the time–space continuum of relativity representing the new reality. Now that we have however defined very clearly what is the meaning of this, we can start investigating the seemingly paradoxical conclusions that often are brought forward in relation with this insight.

### *3.3 The process view confronted with the geometric view*

The paradoxical situation that we can try to solve now is the confrontation of the process view of reality with the geometric view. Often it is claimed that an interpretation where reality is considered to be related to the 4-dimensional time–space continuum contradicts another view of reality, namely the one where it is considered to be of a process-like nature. By means of our framework we can now understand exactly these two views and see that there is no contradiction. Let us repeat now what is the meaning in our framework of the conclusion that reality is 4-dimensional. It means that, at a certain specific moment, that I call my ‘present’, the collection of places that exist, and that I could have observed when I would have decided to do so in my past, has a 4-dimensional structure, well represented mathematically by the 4-dimensional time–space continuum. This is

indeed my present material reality. This does not imply however that this reality is not constantly changing. Indeed it is constantly changing. New entities are created in it and other entities disappear, while others are very stable and remain into existence. This is as much the case in all of the 4 dimensions of this reality. Again I have to give an example to explain what I mean. We came to the conclusion that now, at December 28, 2004, 4 PM the entrance of the Eiffel Tower exists for me while I am in my house in Brussels. Then this is not a statement of deterministic certainty. Indeed, it is very well possible that by some extraordinary chain of events, without me knowing about these events, the Eiffel Tower had been destroyed, such that my statement about the existence of the entrance of the Eiffel Tower 'now', although almost certainly true, is not deterministically certain. The reason is again the same, namely that reality is a construction of what I would have been able to experience, if I would have decided differently in my past. The knowledge that I have about this reality is complex and depends on the changes that go on continuously in it. What I know from experience is that there do exist material objects, and the Eiffel Tower is one of them, that are rather stable, which means that they are into existence without changing to much. To these stable objects, material objects but also energetic fields, I can attach the places where I could observe them. The set of these places has the structure of a 4-dimensional continuum. At the same time all these objects are continuously changing and moving in this 4-dimensional scenery. Most of the objects that I used to shape my intuitive model of reality are the material objects that surround us here on the surface of the earth. They are all very fixed in the dimension indicated by the 0 index, usually referred to as the time-dimension, while they move easily in the dimensions indicated by the 1, 2, and 3 index, called the space dimensions. Other objects, for example the electromagnetic fields, have a completely different way of being and changing in this 4-dimensional scenery. This means that in our framework there is no contradiction between the 4-dimensionality of the set of places and the process-like nature of the world. If we came to the conclusion that the entrance of the Eiffel Tower, tomorrow, December 29, 2004, 4 PM exists also for me now, then our intuition reacts more strongly to this statement, because intuitively we think that this would mean that the future exists also and hence is determined and hence no change is possible. This is a wrong conclusion which comes from the fact that during a long period of time we have had an intuitive image of a Newtonian present, that would be determined completely. We have to be aware of the fact that it is the present, even in the Newtonian sense, which is not determined at

all. We can only say that the more stable entities in my present reality are more determined to be there, while the places where they can be, because these places are stable with certainty, are always there.

### ***3.4 The singularity of the reality construction***

We want to come back to the construction of reality in our framework that we have confronted here with the Einsteinian interpretation of relativity theory. Instead of wondering about the existence of the entrance of the Eiffel Tower tomorrow, December 29, 2004, 4 PM, I can also question the existence of my own house at the same place of the time-space continuum. Clearly I can make an analogous reasoning and come then to the conclusion that my own house, and the chair where I am sitting while reading the novel, and the novel itself, and the basket of wall nuts beside me, etc..., all exist in my present reality at December 29, 2004 4 PM, hence tomorrow. If we put it like that, we get confronted even more with a counter-intuitive aspect of the Einsteinian interpretation of relativity theory. But it is a correct statement in our framework. We have to add however that all these objects that are very close to me now December 28, 2004, 4 PM, they indeed also exist in my present reality at December 29, 2004, 4 PM, but the place in reality where I could have observed them is of course much further away for me. Indeed, to be able to get there, I have to fly away with a space ship at nearly the velocity of light. We now come to a very peculiar question that will confront us with the singularity of our reality construction.

Where do I myself exist? Do I also exist tomorrow December 29, 2004, 4 PM? If the answer to this question would be affirmative, we would be confronted with a very paradoxical situation. Because indeed, I myself, and this counts for all of you also, cannot imagine me to exist at different places of time. But indeed our framework clarifies this question very easily. It is impossible for me to make some action in my past such that I would be able to observe myself tomorrow December 29, 2004 4 PM. Indeed, if I would have chosen to fly away and come back with the space ship such that I observe now, December 28, 2004, 4 PM on my personal watch, the inside of my house tomorrow December 29, 2004, 4 PM, then I can do this, and as we remarked already, it proves that this inside of my house tomorrow is part of my present personal reality. But I will not find myself in it. Because to be able to observe my house tomorrow December 29, 2004 4 PM, I have had to move out of it. Hence, in this situation I will enter my house, for myself being still at December 28, 2004, 4 PM, but my house and all things in it, being at December 29, 2004, 4 PM. This shows that there is no paradox.

#### 4 Conclusions: What about Time, Space and Reality?

We have shown that relativity theory, interpreted as advocated by Einstein, forces us to conclude that reality is 4-dimensional. More specifically, the collection of objects (happenings in our framework) that exists is spread over a structure of places that has 4 degrees of freedom and hence is 4-dimensional. When this was claimed by scientists as Minkowski and Weyl it seemed to entail an intrinsic paradox. Indeed, how can ‘the future’ already be ‘real’? How then can there be any ‘becoming’? After our analysis the situation presents itself in a completely different way. Indeed, our actual present experience is always only at one spot in the 4-dimensional time-space manifold. It is by means of the operational construction that we have put forward here that we can see that the ‘places’ in the 1, 2 and 3 coordinates of which we suppose their simultaneous (not simultaneous in the sense of Einstein, but in the sense of our construction) existence, do not exist more simultaneous, than the places in the 0 coordinate of which we suppose their simultaneous existence. It is because we have such a strong intuitive feeling about the simultaneous existence of the places in space, that we have psychological difficulties to consider the places in time at the same level of existence. Hence to be able to cope with the situation we have to see the real meaning of the simultaneous existence of places in the 1, 2 and 3 coordinate and then understand that this is the same as for the places in the 0 coordinate. But, and this is an important result of our analysis, time still indicates and co-ordinates the changes that take place in reality, it indicates these changes for pieces of reality that are spread out in a 4-dimensional region. This means that if we accept physical reality to be represented by the 4-dimensional time-space continuum, we do not have to conclude that there is no becoming in this reality. It is only such that the becoming takes place in 4 dimensions.

Another result of our analysis that is worth mentioning is the following. Time-space defined as the collection of places that exist simultaneous with our present experience, in the sense defined in this article, namely that it would have been possible to substitute our present experience with an experience involving one of these places, is in fact primarily ‘empty time-space’. Let us explain what we mean. In Newtonian physics, when talking about ‘space’, this meant in principle, ‘empty space’. Indeed, ‘space’ was considered to be the substratum with the capacity of being able to contain physical entities, and hence ‘space’ itself is empty for Newton, because it is the collection of the places that can be occupied by physical entities. That is the reason that mathematically space was described by a 3-dimensional



Euclidean manifold, empty in its normal state, and being able to be filled up with physical entities. In this sense it was said that each of these physical entities occupies a part of space.

Since in the beginning days of relativity theory operationalism, not only as a method, but also as a philosophical conception, was very much in fashion, together with the profound problems concerning the conception of reality, time and space, which we considered in this article, it was often claimed that relativity theory did away with the idea of empty space, *i.e.* 'empty time-space'. We point out that it is the same confusion that we investigated in this article that is at the origin of the conviction about the operational non-validity of the notion of 'empty time-space'. Indeed, a place is per definition 'empty', since it is the substratum that can contain any physical entity. If the physical entity occupies a certain place, then there is 'no longer place', which explains well that with 'place' we mean 'empty place'. Since time-space is the collection of all 'places' it is empty. This is a very important aspect, since it allows the mathematical representation of 'time-space' by means of a 4-dimensional manifold. But also philosophically it is an important aspect to put forward. The operational construction that we outlined in this article arrives at the notion 'place' as its only completely stable substratum in time. Hence the statement 'A place does not change in time' is a correct statement within our operational approach to relativity theory. And as a consequence 'time-space' itself does not change in time. What changes in time are the physical entities contained in 'time-space', hence what changes in time is the 'reality' contained in the 4-dimensional 'time-space'.

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