DOES THE THEORY OF RELATIVITY RELATIVIZE EXISTENCE AS WELL?

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For more see Is There an Alternative to the Block Universe View? (paper) and Relativity and the Nature of Spacetime (book).

ABSTRACT

The issue of the ontological status of Minkowski spacetime is revisited. It is shown that when the question of dimensionality of reality is taken into account in the analysis of relativity of simultaneity it follows that reality can be three-dimensional only if its existence is relativized. Therefore special relativity poses a clear dilemma - the view regarding reality as three-dimensional can be preserved only if existence is relativized; if existence is absolute, reality is four-dimensional with time as the forth dimension. The existing attempts to make the concept of objective becoming (or objective flow of time) compatible with special relativity fail to answer a crucial question - what is the dimensionality of reality in that case. It is argued that existence - the most fundamental "attribute" - cannot be relativized. In such a case relativity of simultaneity does imply that reality is a four-dimensional world whose events are equally existent and therefore are not objectively divided into past, present, and future.

KEY WORDS: Minkowski spacetime, simultaneity, existence, dimensionality of reality, time flow, twin paradox, conventionality of simultaneity, consciousness

INTRODUCTION

In 1908 H. Minkowski [1] gave a four-dimensional formulation of special relativity (SR) by uniting space and time into a single entity - a four-dimensional spacetime (also called Minkowski space or Minkowski spacetime). An essential question arising from here is whether this four-dimensional (4D) spacetime is only a convenient graphical representation of reality which we consider to be an evolving three-dimensional (3D) world or it is a mathematical model of a real 4D world with time as the forth dimension. The answer to this question may have profound implications for our understanding of reality and our place in it.

What is at stake in the debate on the ontological status of Minkowski spacetime constitutes perhaps the greatest intellectual challenge the human race has ever faced: if reality is a 4D world then the time dimension, like the space dimensions, is entirely given which means that all moments of time are given. As all events of spacetime are equally existent there is no objective (ontological) difference between past, present, and future events; therefore our lives are predetermined and free will is nothing more than just a persistent illusion.

According to the pre-relativistic view of reality, based on our common sense ideas of existence, reality is believed to coincide with the present since the present is all that exists. As the present is all that exists now, the future is all that will exist, and the past is all that did exist, this view, also called presentism, often causes confusion and creates the impression that the very use of language (tensed or tenseless) has some significant role to play in the concept of reality. In order to show that this is not the case presentism can be formulated in terms of the dimensionality of reality: the present is the ordinary 3D world of our everyday experience evolving in time and existing only at the constantly changing moment "now". In this view past and future clearly do not exist since they are respectively only previous and forthcoming STATES of the existing at the present moment 3D world. The constant transformation of future into present and of present into past is viewed as an OBJECTIVE becoming or objective flow of time. As the future is ontologically undetermined in the presentist view we possess the free will to be the masters of our own fate.

The problem with this view becomes immediately clear when the concept of the present is closely analyzed. It turns out that simultaneity plays a crucial role in that concept since the present is the set of all events occurring SIMULTANEOUSLY at the present moment. As an event in SR is a 3D object, a field point or a space point all considered at a given moment of time, the present is defined as everything - all 3D objects, fields, and points of space - which exist SIMULTANEOUSLY at the moment "now". Therefore, the view that it is only the present that is real implies absolute (observer-independent) simultaneity since the set of simultaneous events that constitutes the ONLY existing present is common to all observers. However, one of the major results of SR is the relativization of simultaneity. This means that two observers, A and B, in relative motion have different sets of simultaneous events and therefore different presents (different 3D worlds) [see Figure 1].

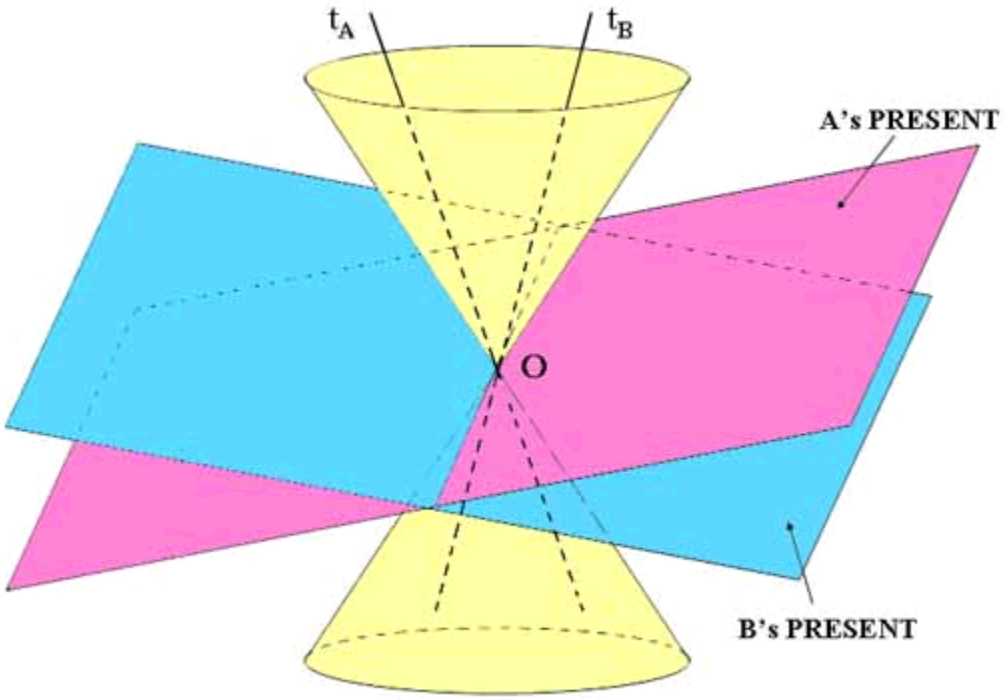


Figure 1. The lines t_A and t_B represent the worldlines of observers A and B in relative motion. The red and blue planes (lying outside the lightcone) represent A's and B's presents, respectively.

The relativity of simultaneity and its consequence that two observers in relative motion have different 3D realities have two possible explanations. It seems quite tempting to assume that SR relativized not only motion, space, time, and simultaneity, but existence as well [2]. This means that we can continue to regard the present as the only reality which, however, does not possess an absolute existence - what is real becomes relative or observer-dependent. In Figure 1 only the present of observer A (his 3D world) is real from his point of view. Part of B's present (lying to the left of the event O which is the crossing point of A's and B's worldlines) lies in A's future and therefore does not exist for A; the other part of B's present is in the A's past and does not exist for A either. Observer B reaches the same conclusion regarding A's present. Therefore, the view that the present is the only (3D) reality and that the flow of time is objective can be reconciled with SR only if existence is relativized; this would mean that the concepts of the present and time flow would become observer-dependent.

The other explanation of the relativity of simultaneity is based on the assumption that existence is such a fundamental "attribute" that cannot be relativized. If existence is absolute (i.e. observer-independent), then the 3D worlds of A and B (i.e. A's and B's presents) should be real for both A and B. However, this is obviously not possible if reality is a single 3D world. Once it is explicitly assumed that existence is absolute it becomes evident that the relativity of simultaneity and its consequence that observers in relative motion have different 3D worlds require that reality be a 4D world. Otherwise no relativity of simultaneity would be possible - if reality were a single 3D world, it should be common to all observers in relative motion, which would mean that they have a common present and therefore a common set of simultaneous events; hence simultaneity would turn out to be absolute. There is a straightforward explanation of the relativity of simultaneity in an absolutely existing spacetime - the observers A and B of Figure 1 regard as their presents (i.e. their sets of simultaneous events) two different 3D slices of spacetime. Those slices, however, are not more existent than the other events of spacetime; simply A and B describe the 4D reality in terms of our traditional 3D language.

It should be noted that both dimensionality of reality and flow of time depend on how existence is regarded. Reality is a 3D world only if existence is relativized; in this case the flow of time is objective but also relativized (observer-dependent). If existence is absolute, reality is the 4D world of Minkowski spacetime. Often this 4D world is called a block universe since all of its events are equally existent which means that there is no objective flow of time. In the next section we shall examine several attempts to reconcile our traditional view of time flow with SR and shall show that they do not address an issue that is crucial in this debate - the dimensionality of reality. The last section deals with arguments demonstrating that existence cannot be relativized and therefore reality is represented by Minkowski spacetime.

IS THERE ANY ALTERNATIVE TO THE 3D - 4D WORLD DILEMMA?

One may wonder why such a dramatic situation - preserving our common sense idea of a 3D reality only at the expense of relativizing existence - should be pictured. There have been different attempts to show that some kind of objective becoming (flow of time) still can exists in Minkowski spacetime. One of the most outspoken critics of the attempts to demonstrate that Minkowski spacetime represents a 4D reality is H. Stein. In two papers [3, 4] he tried to refute an argument by Rietdijk [5, 6], Putnam [7], and Maxwell [8, 9] that Minkowski spacetime leaves no room for objective time flow (or becoming). In order to analyze Stein's objections let us briefly summarize the argument he criticized. The worldlines of two observers A and B in relative motion are shown in Figure 2. There is a third observer C whose worldline is vertical which means that A is approaching C whereas B is receding from C. Two events M and N happen with C at different moments of his proper time. As event M is simultaneous with event O according to A and therefore lies in observer A's present, both events O and M are equally real for A (according to Putnam) or equally determinate for A (according to Rietdijk). Event N is simultaneous with event O in B's reference frame; that is, it belongs to observer B's present. This means that both events O and N are equally real and determinate

for B. Since Putnam and Rietdijk implicitly assume that the reality and determinateness of an event is absolute (observer-independent) they arrive at the conclusion that if event N is real (determinate) for observer B, it should be as real (determinate) for observer A (and for all observers including C) as well. Therefore, observer C's fate is predetermined since events N and M are equally real and equally determinate - when he is at event M he does not have the choice (he firmly believes he has) to decide what he will do when event N becomes his moment "now".

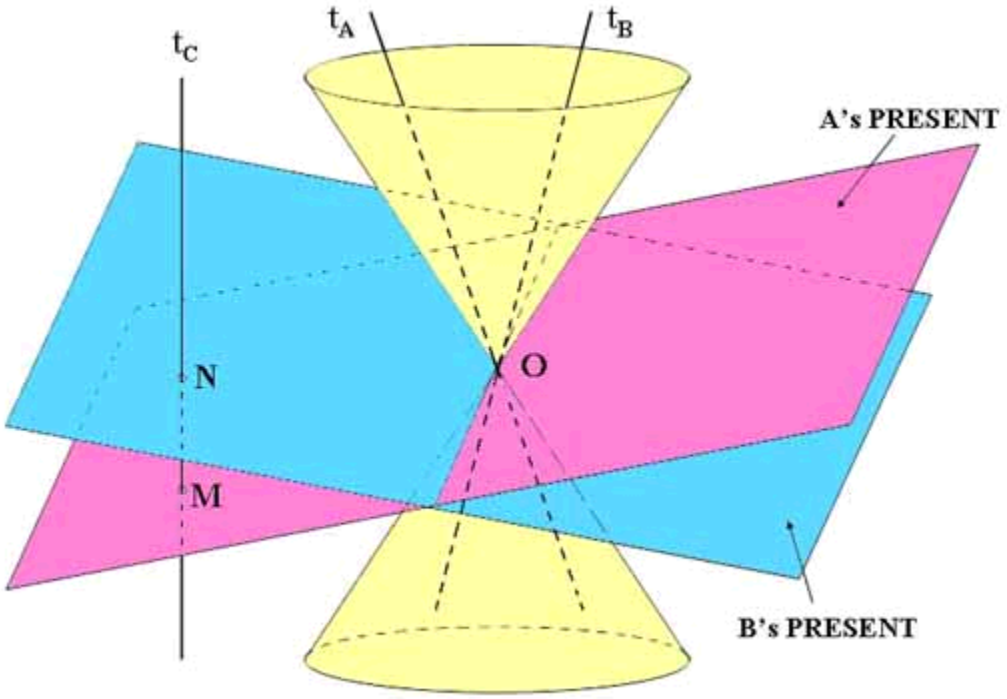


Figure 2. The events M and N are happening with an observer C whose worldline is represented by the vertical line in the figure. Event M lies in observer A's present and is therefore simultaneous with event O according to A. Event N belongs to observer B's present which means that it is simultaneous with event O in B's reference frame.

H. Stein's major objection against the argument of Rietdijk and Putnam - that two distant events experience the same present - is given in both of his papers: "there is of course no such "experience": the fact that there is no experience of the presentness of remote events was one of Einstein's basic starting points [3, p. 16], [4, p. 155].

In order not to deviate from the purpose of the paper I shall leave aside (i) the question whether Einstein claimed such a thing, and (ii) Stein's criterion that an event is real (or has become) for an observer (at a given moment of his time) only if the event can in principle influence the observer (at that moment).

For Stein "in the theory of relativity, the only reasonable notion of 'present to a space-time point' is that of the mere identity-relation: present to a given point is that point alone - literally 'here-now' " [4, p. 159]. Here I will leave aside one more question - Stein's claim that in Minkowski spacetime there exist objectively privileged events that can be regarded as present ones (points here-now); not only in SR, but also in any physical theory there does not exist even the slightest hint that one moment of time is somehow privileged. The major problem of Stein's criticism is that by reducing what is present to an event (here-now) he did not answer the obvious questions "What is reality then?" and "What is the dimensionality of reality?"

If Stein had tried to answer these questions he would have ended up with the dilemma - to claim that existence should be relativized (to preserve the concepts of objective becoming and time flow) or to accept the arguments of Rietdijk and Putnam. As Stein avoids the issue of joint reality of distant events it can be demonstrated that he would have faced that dilemma by utilizing his criterion of determinateness in SR: "for any event E, what is definite (besides E itself) is just its 'causal past' " [4, p. 165], i.e. all event that lie in E's past light cone.

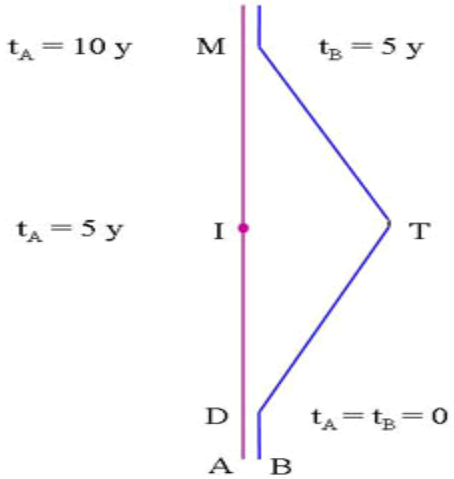
Consider event M in Figure 2. It lies in the past light cone of event N and is therefore determinate for N. However, M does not lie in the past light cone of event O and is therefore not determinate for O. Determinateness turns out to be relative if Stein's criterion is used. Relativization of existence would have inevitably followed if Stein had offered a criterion for the reality of remote events that is consistent with his rejection of Putnam's argument.

There exist other attempts to reconcile SR with the concept of objective becoming (objective time flow) [10], [11]. Any such concept that is compatible with SR, however, presupposes two things: (i) some privileged events, and (ii) observer-dependence (or worldline-dependence) of becoming. As the status of the privileged events ultimately refers to their existence a relativization of existence is unavoidable in those attempts as well.

A RELATIVIZED EXISTENCE IS NOT COMPATIBLE WITH RELATIVITY

As we have seen in the previous sections if we ask the natural question "What is the dimensionality of reality according to SR?" we arrive at the dilemma - (i) reality is 3D if its existence is relativized, or (ii) if existence is absolute, reality is 4D. It is difficult even to imagine that someone might subscribe to the view of relativization of existence. As Kurt Gödel put it: “The concept of existence … cannot be relativized without destroying its meaning completely” [12, p. 558]. Although it is worth analyzing whether or not existence can in principle be relativized [13] the purpose of this paper is to show whether such relativization is compatible with all consequences of SR.

We have seen that the option of relativizing existence appears to follow from the relativity of simultaneity. In order to determine whether this is really the case - whether SR implies that existence should be relativized - let us consider the twin paradox which is an absolute effect with no relativity of simultaneity involved. The worldlines of twins A and B are depicted in Figure 3. Initially A and B are at rest with respect to each other - their worldlines are parallel before the event D at which twin B departs, and after turning back at event T meets again A at the event M. Twin A's worldline is a straight line which means that it is he who does not change its state of motion.



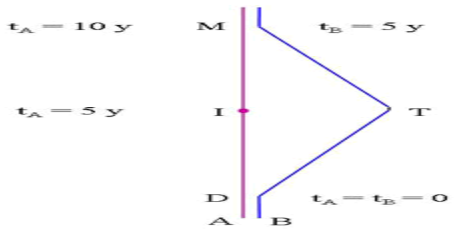
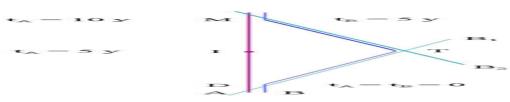


Figure 3. Twins A and B initially at rest with respect to each other separate at event D (departure) and meet again at event M (meeting).

In Euclidean geometry the straight line is the shortest distance between two points. In the pseudo-Euclidean geometry of Minkowski spacetime, however, among all worldlines connecting two events the straight worldline is the longest. As the proper time of an observer is measured along his worldline the time that has elapsed between events D and M according to twin A is greater than the time as measured by twin B - A's worldline between D and M is longer than B's worldline between the same events (in Figure 3 it is the opposite since the diagram is drawn in the ordinary Euclidean geometry).

Let us assume that when A and B meet at M five years have passed for B and ten years for A. Both twins agree that more time has elapsed for A - they directly compare their clocks at M. The time difference between A and B is an ABSOLUTE effect - no relativity of simultaneity is involved and no relativization of existence is necessary to explain it. Not only is the option of relativization of existence unnecessary for the explanation of the twin paradox, but also its analysis when the issue of dimensionality of reality is explicitly taken into account shows that this effect is only possible if the worldlines of the twins are REAL 4D objects [14]. This result demonstrates that it is not necessary to go outside SR and to look for philosophical arguments to resolve the issue of relativization of existence. We arrived at that issue when we tried to explain the meaning of relativity of simultaneity; an analysis of the meaning of two other relativistic effects - time dilation and length contraction - also leads to the dilemma of relativized versus absolute existence since those effects are based on the relativity of simultaneity. However, it is quite natural to try to resolve an interpretation dilemma within the framework of SR first before seeking outside assistance.

To see that the "twin paradox" effect is only possible in a 4D reality in which the twins' worldlines are real 4D objects, let us start from the opposite view - that their worldlines are not real, that the twins exist as ordinary 3D objects that evolve as time objectively flows. In such a case both A and B should exist in the event M - otherwise what kind of a meeting it would be if they are not both present there. The only way A and B can explain the time difference of five years is to assume that B's time has somehow "slowed down" during his journey. As the only difference in the states of motion of A and B is the acceleration that B has undergone during the journey it follows that it should be responsible for the time difference. Also, it is the acceleration that showed the asymmetry between the twins and demonstrated that the twin paradox was not a paradox, but a real effect. However, it has been shown that the acceleration does not cause the slowing down of B's time (see for example [15]). Most convincingly this can be demonstrated by the so called three-clock version of the twin paradox (Figure 4). Instead of twin B who accelerates four times during his journey consider two clocks B1 and B2 which move with constant speeds. At the event D the readings of clock B1 and A's clock are set to zero (when B1 passes A). When B1 reaches the turning point at T, it is intercepted by the second clock B2 and the readings of the two clocks are instantaneously synchronized. The readings of clock B2 and A's clock are compared at M at the instant B2 passes A. The calculations show that the difference in the readings of B2 and A's clock at M will be again five years. As the acceleration does not cause the slowing down of B's time and since no other hypothesis for that slowing down has ever been proposed it appears virtually certain that B's time is not affected in any way.



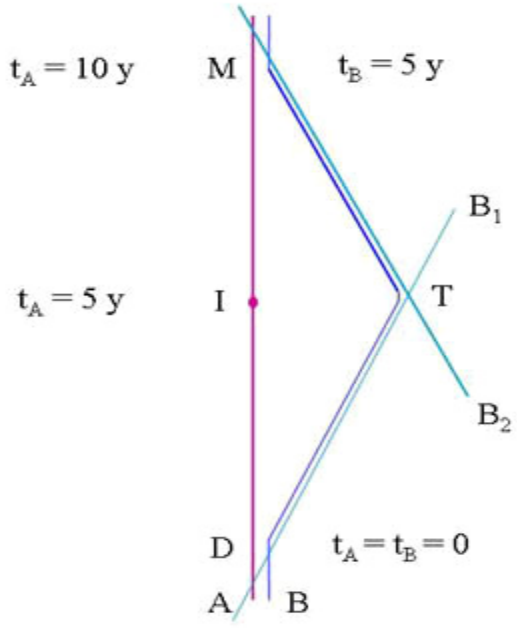


Figure 4. Three-clock version of the twin paradox where no acceleration is involved.

That A's and B's times flow in EXACTLY the same way rigorously follows from the fact that A's and B's clocks measure PROPER times. And as there are no privileged inertial observers their proper times do not differ in any way. Although it is not correct to talk in terms of time flow in SR, sometimes the time dilation effect is interpreted as slowing down of the time of a moving clock. However, what appears to be slowing down in this case is NOT the proper time measured by the moving clock (say clock 1), but the OBSERVED time between two events happening with clock 1 as measured by another clock (say clock 2) with respect to which clock 1 moves. The proper times of clocks 1 and 2 flow in exactly the same way.

As it is now certain that A's and B's times flow in the same way (since the clocks of A and B measure proper times), it is immediately seen that the twin paradox is not possible. For one who does not take seriously the representation of the twin paradox in Figure 3 the same flow of A's and B's times will mean that when A and B meet, there will be no difference in their age. For one who accepts what is depicted in Figure 3 (but still believes that the twins' worldlines are not real 4D objects) the situation is different. As A's and B's times flow in the same way if five years have passed for B (when he exists at event M), five years would have elapsed for A as well and he would exist at event I. Therefore A and B could not meet at all (see Appendix). The impossibility of the twin paradox shows the incorrectness of our initial assumption - that A and B exist only as 3D objects subjected to an objective flow of time.

As discussed above the twin paradox is consistently explained if A's and B's worldlines are real 4D objects; then twin A exists not only at event M (where he meets with B) and event I (where he should be if some kind of time flow still takes place - see Appendix), but at all events comprising his worldline. The role of the acceleration is also naturally explained - it is the acceleration of B that curved his worldline and as a result it became shorter than A's worldline. But this does not mean that the acceleration is the ultimate cause of the time difference of five years. As shown in Figure 4 what accounts for that time difference is that B's time is measured along a curved worldline no matter whether it is a single worldline that is curved by acceleration or it is composed of two straight worldlines with no acceleration involved.

The analysis of the twin paradox convincingly shows, I believe, that the twins' worldlines are real 4D objects which means that reality is correctly modelled by Minkowski spacetime. This in turn shows that existence is absolute and the relativity of simultaneity is possible only in a 4D reality. As existence is absolute if reality

were a single 3D world all kinematic consequences of SR would not be possible as shown above for the relativity of simultaneity and the twin paradox; time dilation and length contraction would not be possible either, if the relativity of simultaneity were impossible. SR demonstrated that in order for something to be relativized there should be something else that remains absolute. Space, simultaneous events, and the existence of 3D objects appear relativized but in fact these are merely 3D slices of an absolutely existing 4D reality. If reality were a 3D world no relativization would be possible.

The arguments that existence is absolute which means that Minkowski spacetime represents a 4D reality also shed light on the debate [16-19] on whether or not the simultaneity of distant events is a matter of convention. When one tries to prescribe a procedure for synchronizing two distant clocks (by light signals or by a slow transport of a third clock) a logical circle is reached - to synchronize the clocks we need the one-way velocity of light (or of the slowly moving clock [20]), but in order to measure the one-way velocity, the clocks should be synchronized beforehand. The very existence of a logical circle demonstrates that either there is an error in our reasoning or the logical circle is a hint that we may have started with some misconceptions.

As an undisputable error in the reasoning leading to the logical circle has not been identified for several decades of debate, the other option increasingly appears to be the way out. The logical circle is reached when it is assumed that the simultaneity of distant events and the one-way velocity of light are something objective which is not therefore a matter of convention. This becomes especially clear if the question of conventionality is also formulated in terms of the dimensionality of reality. As discussed above the present is the set of all SIMULTANEOUS event at the moment "now". Therefore the simultaneity of distance events can be objective if (i) the only reality is the present, or (ii) the events of a 3D slice of Minkowski spacetime are objectively privileged. Only in these two cases there exists an objective motion of 3D objects and the concept of velocity has an objective meaning.

However, we have seen that those two cases either lead to a direct contradiction with the relativity of simultaneity (if the existence of the present and the privileged state of a set of events of Minkowski spacetime are absolute) or to a relativization of existence. As the analysis of the twin paradox excludes the option of relative existence it follows that in SR the conventionality of distant events is a matter of convention. Indeed, in a 4D world the conventionality of simultaneity becomes both obvious and trivial [16]. As all events of spacetime are equally existent it is really a matter of convention which 3D slice an observer will regard as his set of simultaneous events. In Minkowski spacetime there is no motion of 3D objects - all such objects are presented by their worldlines there. And as we are free to choose from all existing events a 3D slice (our 3D space) which forms an angle (not necessarily a right one) with the time axis of our reference frame we can get different one-way velocities of light.

CONCLUSION

If the relativity of simultaneity is explicitly discussed in terms of the dimensionality of reality, the fact that observers in relative motion have different sets of simultaneous events can be explained either by assuming that existence is also relativized (preserving the views of the present and objective becoming) or by considering existence absolute which means that reality is a 4D world. Although the option of relativizing existence appears completely unacceptable from a philosophical point of view, that option is eliminated within the framework of SR by demonstrating that the twin paradox would not be possible if existence were not absolute.

APPENDIX

Although the twin paradox is correctly explained with the existence of the twins' worldlines, there is still something missing. The fact that SR implies a 4D reality is so hard to accept not only by philosophers who continue to struggle to come up with some concept of objective becoming compatible with SR, but by anyone who realizes what a 4D reality means. Most attacks against regarding Minkowski spacetime as adequately representing reality are based on the apparent contradiction between the equal existence of all events of spacetime and the fact that we realize ourselves only at the moment "now" and believe that it is without any doubt privileged.

No one can seriously question the fact that we realize ourselves at the present moment. But it does not immediately follow from here that we, as material objects, exist only at this moment. Years ago H. Weyl fully realized the apparent contradiction between what Minkowski spacetime is representing and what our senses are telling us and proposed a resolution:

> *"The objective world simply IS, it does not HAPPEN. Only to the gaze of my consciousness, crawling upward along the life line of my body, does a certain section of this world come to life as a fleeting image in space which continuously changes in time"* [24].

Although Weyl's resolution formed the basis of the view of minddependent flow of time it has not been generally accepted. And indeed at first it appears to be self-contradictory since Weyl assumes that the consciousness (leaving aside the question of what the consciousness itself is) moves in Minkowski spacetime where no motion is possible. There would be a contradiction if it is assumed that either consciousness "operated" at the macro level of reality modelled by Minkowski spacetime or Minkowski spacetime were applicable to all levels of reality. However, it does not appear realistic to expect that any MACRO concept (such as Minkowski spacetime) will be applicable to ALL levels of reality. At some level lying "beneath" the macro level of our everyday experience the properties of reality will inevitably be quite different from what we now know; we have already started to observe such discrepancies at the quantum level. With this in mind it is natural to expect that the consciousness "operates' at a sub-micro level where the frozenness of our macro reality does not hold any more [25].

As Weyl put it everyone's consciousness crawls upward along their worldline realizing the information from their senses stored in the brain, but incorrectly interprets this information in a sense that a constantly changing 3D world exists. Even if we forget about Minkowski and relativity and try to analyze rigorously what we see we will arrive at the conclusion that the 3D (in fact, 2D) images we realize allow two ontologically different interpretations: (i) they represent a 3D world, or (ii) they are only images from a higher dimensional world.

Now we are in a position to complete the explanation of the twin paradox depicted in Figure 3. The twins exist at all events of their worldlines but each of them realizes himself only at a single event when his consciousness reaches and realizes that event. There should be no difference in the mind-dependent flow of time of the twins (the advancement of the consciousness of each of them along his worldline); at least there is no MACRO reason as we have seen above that can cause any change in the time flow for one of the twins. Then when five years have passed for twin B and his consciousness reaches the event of the meeting M he will be happy to meet his brother. However, this will be a very strange meeting - twin B will be meeting his brother from his future. As twin A's consciousness moves in the same way as B's consciousness five years have elapsed for A as well and his consciousness realizes event I; so his consciousness is five years behind B's consciousness. When twin A realizes event M he will be meeting his brother from his past; B's consciousness will be five years ahead.

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