A Study on Invariance of Temporal Coincidence

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Abstract. This paper presents an attempt to define temporal coincidence starting from the first principles. The temporal coincidence defined here differs from Einstein's simultaneity for it is invariant across inertial frames - not relative. The meaning and significance of temporal coincidence is derived from axioms of existence and it somehow relates to Kant's notion of simultaneity. Consistently applied to the Special Theory of Relativity framework, temporal coincidence does not in any way create mathematical contradictions; however it allows looking at some common relativity claims with a dose of scepticism. Time, as derived from Lorentz transformations, appears to be conventional in order to match the postulate of constancy of the speed of light. The relative simultaneity is only apparent due to that convention. There are insufficient grounds to claim that inertial systems moving relatively to each other have their own different temporal realities. Overall, the innate temporal logic we have is not erroneous and does not need to be replaced contrary to the claims of some relativity educators.

Keywords Absolute Simultaneity, Relative Simultaneity, Relativity of Time, Temporal Coincidence

1 The Purpose and the Scope

The purpose of this study is to present from the point of view of scientific realism and primitive ontology the evidence that relative simultaneity described in 1905 by Einstein (1 pp. 38-40) and later works is the result of convention, hence it differs from rationally defined Temporal Coincidence.

I shall argue that Temporal Coincidence of distant events can be given a unique meaning so it is consistent with "ordinarily perceived simultaneity". It is applicable to Special Theory of Relativity (STR) if analytic geometry is applicable within coordinate systems the theory operates in.

In the broader context, the purpose of this study is also to demonstrate that, contrary to widespread claims, the mathematical representation of the STR does not change the traditional notion of "now", and one does not have to forfeit the innate temporal logic in order to embrace the benefits of the theory. In the most general context, the purpose is also to demonstrate that the temporal common sense humans posses is not as bad as it has been portrayed since the 1905 science revolution.

To say that this study fulfils this purpose or that it makes sense to state such purpose is rather a controversial claim. However, to the best knowledge and ability of the author, it has been accomplished to a degree that it can be presented to public critique, for any progress made in science is through controversial claims, even through ones that can be refuted.

By no means does this study claim to be authoritative, but its conclusions may be useful for reviving new interest in and discussions on the matter of simultaneity, which is not yet settled.

This study makes no attempt to negate, redefine or stretch the STR to fit the stated purpose. There is also no attempt to advance the problem into the General Theory of Relativity (GTR) because understanding fundamental properties of time as we know it is possible within the simple framework of the STR.

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2 PRESENTATION METHOD, PRINCIPLES AND ASSUMPTIONS

This study is not a historical overview: it focuses more on presenting the author's ideas and less on the broad overview of previously published materials on simultaneity, unless it is absolutely necessary to emphasise contradictions or to support presented arguments. There is currently no better overview of the subject than the work of Jammer (2).

The presentation of the subject takes into account a number of principles, assumptions and constraints described further in this section. The arguments are ordered hierarchically starting from general ontology and ending with detailed calculations in accordance with the STR.

The author's opinions and postulates are expressed in the first-person singular grammatical form in order to distinguish from those believed to be objective truths, scientific facts or common knowledge.

2.1 General Principles

1. Separation of concerns.

To the best ability, the discussion is divided into segments of text that are separately dealing with:

a) Commonsense informal reasoning,
b) Experimental and practicality issues,
c) Discussion exclusively operating in the domains of logics, philosophy, theoretical physics and mathematics.

Note 1: This principle results from the necessity of presenting a clear sequence of thoughts within a consistent domain in which the problem is analysed. It is often the case that mathematical arguments are intertwined with experimental concerns and it is hard to make judgements about precedence and relations of elements from different domains. The intention is to introduce assumptions and a mathematical framework that is applicable to physical problems under consideration. Once this is accepted, there is no need to intervene into this domain with experimental concerns. This can be done separately without disturbing the flow of the arguments.

2. Existence of time.

As much as possible, I refrain from ascribing the status of existence or non-existence to "time".

Note 2: "Time" is a linguistic term to describe a wide range of physical, philosophical and common concepts often meaning different things, all under the same name. I can only say as much about time as can be represented by measurements turned into mathematical abstractions. Specific aspects of "time" will have distinct or descriptive names such as "duration" or "time interval", "elapsed time" and the like. To avoid circularities, I chose to impartially judge appearances related to various aspects of time as they are known, measured or understood rather than seeing them as a manifestation of an existing a priori time in itself. Finally, I accept Einstein's refined definition of time given in Princeton Lectures in 1921(3 p. 28) for the sake of discussion and consistency with the STR. This definition is in fact in accordance with this principle since it only describes time as an ensemble of indications of clocks rather than postulating the existence of a potentially superfluous entity. Interestingly, contrary to this definition other claims in the name of relativity are made, where time abstraction is given the status of existence through the postulate of existence of space-time continuum.

3. Rules of Reasoning

The following rules of reasoning from Newton's *The Principia* (4 p. 320) are followed to the best ability:

> Rule I.
> We are to admit no more causes of natural things than such as are both true and sufficient to explain their appearances.
>
> Rule II.
> Therefore to the same natural effects we must, as far as possible, assign the same causes.

2.2 General Assumptions

1. Ideal rest.

It is assumed consistently with the STR that there exists an inertial system constructed from physical objects at rest relatively to each other that can be regarded as non-moving or by other name as "stationary".

In such a system statically determined locations remain constant and persistent and all Euclidean geometry rules are valid. The clocks in such systems run at the same rate everywhere and can be synchronised by methods yet to be presented. The stationary system is recognised by the STR to the extent that it is not unique but every inertial system may consider itself as being in ideal rest.

There is no objection to the possibility of existence of uniform rectilinear motions, translations of ideal rigid bodies, material points including those moving at the speed of lights.

2. Physical and idealised motion.

When talking about motion I assume the following:

a) Behaviour of real moving physical objects can be meaningfully represented in the form of explicit or differential equations in terms of monotonically increasing parameter attributed to time, which needs to be defined first for that purpose.
b) Motion can also be represented in a timeless manner as a position of one object as a function of position of another.
c) Only ideal inertial systems and the associated framework of Cartesian coordinates are considered in this study.
d) Notwithstanding recognition of the speed of light limiting any direct action at a distance, Cartesian coordinate systems that include time as a coordinate can be validly used even though the same coordinate time for all points in space could be interpreted as an instantaneous signal. The result is that one can associate the same time coordinate for all points in space but the meaning of this association is outside the scope of pure mathematics.

3. Special Theory of Relativity to be taken as scientific fact.

Notwithstanding critical analysis of some of the STR implications, the approach here is to accept and apply the STR with its postulates, its coordinate systems framework and transformation equations as appropriate in order to construct and analyse models of plausible physical scenarios.

It is expected that after transformation from one inertial system to another the mathematical result is representative of some real behaviour or observation of the transformed entity.

4. Limitations of the STR not significant when discussing the concept of time and simultaneity.

Only the General Theory of Relativity (GTR) has the power to describe complex processes involving accelerations and gravity. However, it is the STR that has displaced the classical view on time and changed the view on simultaneity. Traditional concepts pertaining to time have been changed and justified using the STR, then later extended and incorporated into the GTR. For that reason, limiting discussions to the STR domain is deemed adequate at this stage. The following considerations then do not take into account any scenario where gravitational or acceleration effects may influence clocks.

5. Mathematical framework used in Einstein's 1905 paper is adequate.

The choice of this approach comes from the fact the approach chosen by Einstein (1) is naturally linked to classical Newtonian physics without a fully developed concept of a four-dimensional space-time continuum. Still, all essential features of the STR have been derived and demonstrated. To add the space-time concept to this discussion would be going beyond Newton's Rule I. Also, the postulate of existence of the space-time continuum is not necessary to describe some relativistic phenomena and the role and properties of time at an elementary level. It was certainly adequate for Einstein in his groundbreaking publication. This is not to say that there is something wrong with combining space and time into one four-dimensional system to simplify mathematical operations.

2.3 Specific Assumptions

1. Einstein's definition of time is accepted.

The following formulation derived from the Princeton Lectures definition (3 p. 28) is assumed to represent the original:

Time is defined as the ensemble of the indications of similar clocks, at rest relatively to an inertial frame, which register the same simultaneously.

2. Single time value as a determinant of common reality.

From the above definition of time I tentatively assume*:*
The same instant or moment of reality applicable to all locations in space can be designated by a single value of time indicated by properly synchronised clocks at rest in an inertial frame, that is also by the clock located at the origin. This depends on the proper synchronisation of the clocks and the meaning of the term "simultaneous", otherwise equal times would link different periods in history as contemporaneous.

This assumption comes from a belief that one of the purposes of clock synchronisation is to have one parameter designating the common state of physical reality. Secondly, if one insists on a privileged rest frame, this is a natural assumption. If one assumes historical integrity within an inertial system, there can be only one possible system-wide clock synchronisation that makes the same time indication, correctly relating the current reality moment at different locations, as opposed to relating various moments in history.[2]

From this point onwards, I shall call that time obtained from clock readings as "indicated time". This an analogy to "indicated airspeed" (used in aviation) as opposed to "true airspeed"[3]. This is to show that clocks are instruments that have to be calibrated and synchronised and the empirical indicated time can be shadowed from the "a priori time in itself", which is a matter of belief.

The term "simultaneously" in Einstein's definition of time is treated here as a placeholder for the temporal relation that is adequately defined. Simultaneous events were defined in Princeton Lectures (3 p. 28), however I shall argue that an alternative definition of simultaneity that better matches reality is possible (Temporal Coincidence).

3. Einstein's definition of simultaneity is under discussion.

Arguments for a definition alternative to Einstein's will be presented. In this study I will consistently use the expression "Temporal Coincidence".

4. Coordinate systems consistent with the STR.

All details and conventions regarding coordinate systems are understood as per Einstein's 1905 work (1 §3). This abstraction is thought to be representative to a high degree for an assembly of physical objects away from gravitational sources.

5. Lorentz transformation.

Lorentz transformation equations represent the essence of the STR and this is all that is needed to discuss kinematics, simultaneity and time within the scope of this study. No alternative verifications from quantum theories or other branches of physics are attempted.

3 TEMPORAL COINCIDENCE

In the following sections I shall discuss the concept and define Temporal Coincidence. This expression is often used as a synonym of simultaneity. For example, Jammer (2 p. 13) provides the following description:

> [..] we define "simultaneity" as the "temporal coincidence of events." Assuming we have two clocks we regard the coincidence of their hands with certain numbers on their dials as an event. Then we can say that the clocks are "synchronized at a certain moment of time" if and only if at that moment of time the hands of the two clocks are in the same position, that is, they indicate the same time.

Because the purpose of this study is to rectify the concept of simultaneity and because this term is loaded with traditional meanings, I have instead chosen the expression "Temporal Coincidence", so that there is no

[2] From this statement any conventionalism of simultaneity any synchronisation should be ruled out. As it is a very controversial issue more analysis is required.

[3] Indicated airspeed is the airspeed of an airplane as indicated on the airspeed indicator: This is the airspeed in an atmosphere of standard sea level density that would give raise to a dynamic pressure equal to the encountered (13).

ambiguity whether I am referring to the traditional or my own interpretation of simultaneity. This is also a more descriptive term.

3.1 Clocks, Simultaneity and Time

There is almost no escape from circularity when trying to define simultaneity. As stated above, simultaneity of two events at two separate locations seems to imply the necessity of the same numerical values of indicated time when and where they happen. But to synchronise remote clocks, distant simultaneity has to be understood and defined.

Two simultaneous events co-located with one clock temporally coincide with the same clock indication. This is a unique relation where none of the two events can be earlier or later than the other. This is a natural non ambiguous concept. The same kind relation between events is expected when they are spatially separated at fixed distance. This would be however a wishful thinking if there was no concept of how to determine the relative order of remote events. As two distant events cannot be instantaneously verified we are left with indirect methods.

Remote clocks producing uniform intervals at the same rate can be synchronised in an infinite number of ways. Synchronisation can be made by ad hoc rule or by a convention. There are some difficulties with both synchronisations. They can be changed at will. If a convention changes then events that were once considered simultaneous, no longer are.

If one establishes two perfect clocks at separate locations at rest with each other, the indicated time can be randomly set for each clock while they both progress at the same rate. For such "synchronised" clocks nothing can be said about simultaneity of events recorded at equal times.

For example, more rational synchronisation principle would be to set the clocks to twelve o'clock when the sun reaches highest point above the horizon. That has been proven quite useful for every day purposes. But to say that people start lunch break simultaneously all over the world, just because they usually do it at twelve o'clock midday, is not correct. From this example it is clear that conventional simultaneity in general may allow certain classes of successive events to be called simultaneous just because two clocks show equal time. But is there any convention that would rule this out? Can we say what is successive beyond a doubt?

Simultaneity that is to be described in terms of time indication requires prior synchronisation of clocks. For two identical arbitrary selected clocks separated by a fixed distance at some points ***A*** and ***B*** one may chose from the three methods of synchronisation:

a) Generating two simultaneous events E_A at point **A** and an event E_B at point **B,**
b) Generating two successive events: E_A at point **A** then event E_B at point **B** by sending a signal.
c) Infinitesimally slow clock transportation.

First two methods present challenges because a) requires precise definition and execution of simultaneous distant events while b) requires assumption about signal propagation law and knowledge of the distance between the points. Method c) requires assumptions about clock being affected by motion and it can only be accomplished approximately.

Using method a), when clock **A** is synchronised to a value of *0* by an event $\boldsymbol{E_A}$ at point ***A***, the clock at **B** has to be synchronised to *0* by its local synchronisation event $\boldsymbol{E_B}$**,** given $\boldsymbol{E_A}$ and $\boldsymbol{E_B}$ are simultaneous.

For method b) clock at ***A*** is set to *0*, then using a delayed event after sending a signal setting clock at ***B*** to a value of l_{AB}/c given that distance l_{AB} and signal propagation speed c are precisely known before synchronisation.

Einstein (1) uses method b) for synchronising clocks. This seems to be the most popular one in relativity literature. This study will attempt to explore the method a) which requires minimum assumptions.

Only after full understanding of simultaneity within an inertial system, one can attempt to investigate its relativistic aspect.

Disregarding all technicalities, the problem of synchronising clocks by method a) reduces to determination of physical criteria when spatially separated events $\boldsymbol{E_A}$ and $\boldsymbol{E_B}$ can be confirmed being temporally coincident as opposed to successive.

3.2 Ontological Approach to Temporal Coincidence

I shall first approach Temporal Coincidence from a primitive ontological perspective. It is primitive because it does not dwell on the nature of existence of space and objects, but takes it for granted as an axiom consistent with common understanding and macroscopic perception of the reality available to common sense.

Whether one agrees with this "ontology" or not, it does not change the fact it is only used as a starting point to a stepwise refinement process in order to discover a satisfactory meaning of Temporal Coincidence. In this potentially iterative approach, each next phase gives an opportunity to uncover a contradiction in the former. In that view, the ontological approach presented below can be treated as an educated guess to get iteration started.

Definition 1 Physical Object

Physical Object is anything physically discernible that can be located in physical space. In the context of theoretical physics in a coordinate system, it can be reduced to an abstraction of a material point or that of a rigid body.

Note 1: Physical space, material point, and rigid body, are primitive concepts generally understood in elementary physics.

Note 2: Arguably the front of the light beam, spherical wave front, or light pulse or photon often quoted in relativity literature as examples for motion at the speed of light can be included into the category of physical objects. Alternatively one can conceptualise a neutrino that propagates at the speed of light. At the end, all considerations are transposed to a coordinate system with an abstract material point which has no size but only position, velocity and mass if one wishes to take this into account.

The following statements have been taken as axioms:

Axiom 1:

Multiple Physical Objects exist in physical space by occupying a position relative to each other, where position is measured by using rigid rod standards.

Axiom 2:

Physical Objects are capable of moving through physical space where "moving" means changing position relative to another Physical Object.

For the purpose of extension of ontological arguments to theoretical physics domain, an additional axiom is needed.

Axiom 3:

Physical space and the motion of physical objects can be sufficiently represented by coordinate systems and other mathematical abstractions used in Special Theory of Relativity (1).

Definition 2 – Temporal Coincidence - Object

Two or more Physical Objects A, B, C.... are in Temporal Coincidence relation with each other if they all exist (coexist)

Symbolically Temporal Coincidence relation can be expressed by = like symbol so we have

$$A \stackrel{t}{=} B \iff \exists A \land \exists B$$

$$A \stackrel{t}{=} C \iff \exists A \land \exists C$$

$$B \stackrel{t}{=} C \iff \exists B \land \exists C$$

...

Note 3: Temporal Coincidence is first noted as a relation applicable to objects, in a similar way as spatial coincidence is applicable to those objects. They can spatially coincide if they share at least one point. Additionally objects that spatially coincide also coincide temporally because to be able to coincide they have to exist first. Definition 2 is consistent with Kant's perception of simultaneity. In his *Critique of Pure Reason* (5) he acknowledges that: "different times are not coexistent but successive" or refers to simultaneity as the "complex of all existence". The existence of an object is an axiomatic attribute. For two or more objects individual existences may not be causally connected, however they can be related in some other ways and for instance the two objects may successively exist but may never coexist. When they coexist they are Temporally Coincident.

Note 4: The existence can also be narrowed to a weaker form as relative to a bounded region of space for which case it can be better named as "presence". The Physical object is present in a bounded region of space if and only if it exists and is wholly or partially enclosed in the bounded region. Temporal Coincidence can then be defined in terms of "presence".

Note 5: The practical difficulties of determining coexistence in certain cases are disregarded to separate concerns. Suffice to say that it is possible to determine coexistence of physical objects at least in some cases. The example of that can be sending of two unique physical objects into remote locations and bringing them back. Between sending and returning events the objects no doubt existed together (coexisted). It is satisfactory to analyse coexistence retrospectively as all our thoughts and judgements are retrospective.

Note 6: The concept of coexistence carries an inherent risk of something ceasing to exist, but this is a separate concern and can be put to test and evaluated retrospectively if relevant to specific situation.

Note 7: It does not matter whether Physical Objects are moving relatively with respect each other or not, but while in motion they can be useful to define a class of Temporally Coincident events.

Definition 3 - Event.

An event is said to happen when some change of state occurs in physical space. In particular, an event can be an arrival of a Physical Object at a position relative to a reference object.

Note 8: No time reference is included in the definition of event. As much as it can be of vital interest, it is not necessary to know clock time to determine that some events have happened. This effectively decouples definition of an event from temporal aspect, which can always be added when needed.

Note 9: I do not consider a point in space-time as an event for an event cannot happen by itself without physical object or field existing at some location and also space-time continuum is not included as an entity in this ontology for it is not necessary to explain the matter of interest. That is consistent with Newton's rules of reasoning.

Definition 4 - Observer

An observer is a Physical Objet capable of perception of states of coexisting Physical Objects and events and memorising them.

Definition 5 – Temporal Coincidence **–** Events

Any pair of events happening at Temporally Coincident rectilinearly moving objects A and B due to their arrival at coexisting positions relative to an observer, is Temporally Coincident.

Note 10: The scope of this definition is very narrow. It is only sufficient to satisfy the immediate purpose of this study. If it is found free from contradiction and useful, it can be generalised further.

Note 11: Objects by themselves may or may not generate events which may or may not be temporally coincident. When two objects are set in motion they successively change positions relative to an observer and possibly to each other. If the objects spatially coincide, the change of position to/from this point is trivially temporally coincident, however when they separate it may not be immediately clear.

Note 12: The definition of Temporal Coincidence of events uses the notion of "coexisting positions" which per se has no explicit temporal connotation. "Coexisting positions" differ from "Temporal Coincidence" in that the former determines **where** one object is located in relation to the other at all times of their existence, while the later defines **a temporal relation** between events. The definition allows geometry relations to be used for generation of Temporally Coincident events. If we have two material points departing together in different direction from the same location, then for every position of one point on its trajectory there is one and only coexisting position of the other on its trajectory.

Definition 6 - Earlier and Later

If a Physical Object A exists, and a Physical Object B does not exist, then both A and B coexist, than A came to existence and has existed earlier than B, and B came to existence later than A.

Definition 7 - Now

For any observer, "Now" is an instant of existence of this observer with all Temporally Coincident relations to any other existing observer or a Physical Object.

Note 13: "Now" is defined as relative to the observer because it has meaning only to a human intelligence which an observer may possess. The question whether "Now" has a universally meaningful status of being common, is to be inferred from the axioms and definitions above.

Conjecture 1

Temporal Coincidence is invariant for all observers.

Note 14: This conjecture is intuitively acceptable if one assumes (consistently with Definitions 1-7 and axioms) that two moving physical objects, if exist for one observer, they exists equally for all other observers. The problem of who and when detects existing objects, is a separate concern.

Physical space as a container of objects is shared and common to all observers. This space only differs for each observer by their respective metrics. Since both objects of the collection exist for all observes they are in Temporally Coincident relation with each other and with all the existing observers.

When objects move relatively, arrival events generated at current objects positions may have different coordinates for every observer but they are Temporally Coincident with the corresponding events at the other object's coexisting position (by definition 5). Technical difficulties in determining coexisting positions are a separate concern.

The conjecture poses an immediate problem as it contradicts relativity of simultaneity.

Note 15: This conjecture should be reformulated in the context of inertial frames as understood by STR because the presented reasoning is lacking sufficient precision operating on vague understanding of position space and motion.

Note 16: Every inertial frame can map each of its space points to exactly one space point in the other by linear transformations, so verification of the conjecture is possible. Once an object comes to existence in its own one and only rest frame, it overlaps a subset of its space points which are and always have been instantaneously present in an arbitrary pre-existing inertial frame. Then the overlapped points present themselves as successive trajectory points in that arbitrary inertial frame. It means the object has to exist in any arbitrary frame because there is nowhere to hide.

Note 17: A position in physical space cannot be occupied in one inertial frame and be vacant in another at the same instance of existence after a linear transformation unless we deliberately request retrospective or predictive mapping. It does not matter whether an observer is unable to detect the existing thing instantaneously. Physical space is a persistent and common container no matter how measured, and if it is occupied it is not free in all frames. If I accept the reality of existence I do not consider any mathematical transformation that shows something does not exist in one frame while it does in another "at the same time", to be properly understood and interpreted in terms of true Temporal Coincidence.

It seems fair not trust this commonsense reasoning because errors may be hiding behind seemingly logical statements as lessons can be learnt from Zeno's paradoxes.

3.3 Temporal Coincidence within the Same Inertial Frame

This section presents a scenario which can demonstrate that definition 5 of Temporal Coincidence can be validly applied in a plausible thought experiment synchronising two clocks in the coordinate system framework that is identical to that first used by Einstein in the 1905 publication(1). In this scenario the

Temporally Coincident objects and events are demonstrated. This is the second step in the stepwise refinement approach to make the concept of Temporal Coincidence better understood.

By the virtue of assumptions laid out in section 2, definitions and axioms in section 3.2, the following reasoning operates within the representation of the physical world that is compatible with STR framework.

Before going further, one question has to be answered. How does the definition 2 relate to Temporal Coincidence of arbitrary events?

This may be a non trivial question when it is to be answered in the most general terms, however if we limit our considerations to some selected classes of events given by Definition 5, it becomes much easier.

As per rule of separate concerns I shall postpone the practicality aspect of discussed scenarios.

Proposition 1

It is possible to generate Temporally Coincident events at arbitrary locations within an inertial system.

Proof:

To prove the proposition 1 it is enough to give just one example.

The basis for the proof is Einstein's original publication, as translated and reproduced in *The Principle of Relativity* (1). In the following paragraphs, I intentionally quote and/or paraphrase some of the Einstein's statements with necessary additions and alterations where appropriate, in order to prove the proposition. This is a way of showing compatibility of this derivation with the STR framework.

1. Let us take a system of coordinates *(x,y,z)* in which the non-accelerated inertial motions as defined by Newtonian mechanics can be considered valid. In order to render my presentation more precise and to distinguish this system of coordinates verbally from others which will be introduced hereafter, I call it the "stationary system." If a material point representing a physical object is at rest relatively to this system of coordinates, its position can be defined relatively thereto by the employment of rigid standards of measurement and the methods of Euclidean geometry, and can be expressed in Cartesian coordinates.
2. If I wish to describe the motion of a material point representing a physical object, I give the values of its coordinates as functions of time (which precise meaning is in accordance with definition in section 2.3 paragraph 1).
3. Now I must bear carefully in mind that a mathematical description of this kind has no physical meaning unless I am quite clear as to what I understand by "time." I have to take into account that all my judgments in which time plays a part are always judgments of Temporally Coincident events.
4. Let us assume two Physical Objects represented by material points $\boldsymbol{D_0}$ and $\boldsymbol{D_1}$ exist and move relatively to themselves and to an observer at point $\boldsymbol{A}$ in an inertial frame. The observer coexists with them at all times. (Figure 1)
5. Definition 2 implies that wherever the two material points are positioned, and irrespective of their motion characteristics they are in Temporally Coincident relation with each other and with the observer.
6. Let the "stationary" system $\boldsymbol{K}$ configured as three rigid material lines, perpendicular to one another, and originating from an arbitrary point.
7. Let the axes be $\boldsymbol{X}$, $\boldsymbol{Y}$, $\boldsymbol{Z}$ with coordinates of an arbitrary point described accordingly as *(x,y,z).*

8. Let point ***A*** coincide with the origin of ***K*** *(0,0,0)* and point ***B*** somewhere on the positive side of ***X*** at a distance *l* ***B*** *=(l,0,0)* as in Figure 1.
9. Let a point ***C*** be chosen as equidistant from ***A*** and ***B*** but shifted by an arbitrary offset *h* in a lateral direction e.g. along ***Y*** axis on ***XY*** plane: ***B*** *=(l/2,-h, 0).(*Figure 1*)*
10. Moving points D_0 and D_1 have coexisting positions and in accordance with Definition 5 they generate pairs of Temporally Coincident events at each instance of existence.

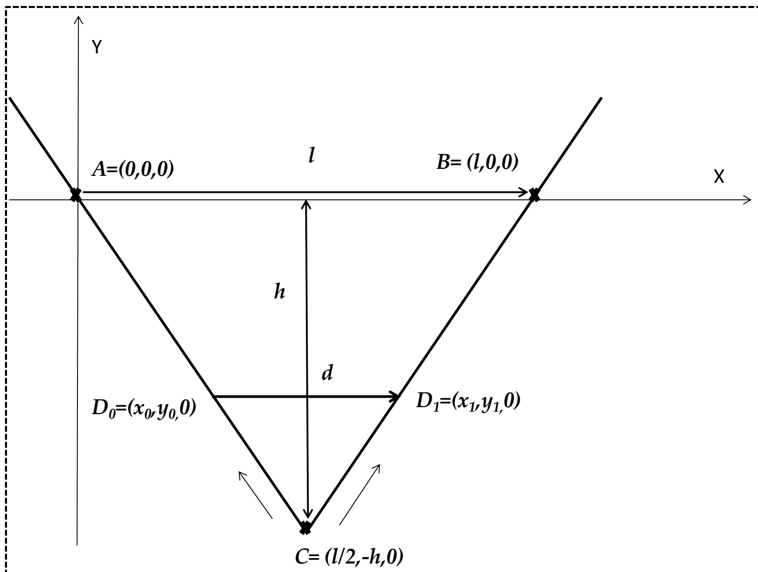

Figure 1Temporal Coincidence synchronisation in a V scenario

11. The two events defined above, in two distinct points in space designate a unique straight line and the vector $\overrightarrow{D_0D_1}$ lies on this line. (Figure 1)
12. Let us assume two identical material points initially exist and coincide in ***C***. Then under the same physical law depart together along the straight lines towards ***A*** and ***B*** respectively. Their motion differs only in direction but otherwise identical[4].
13. Let us assume that Nature does not conspire against the experiment, and material points exist continuously between ***C*** and ***A***, ***B***.
14. After coming to existence at point ***C*** together, the two material points are in Temporal Coincidence relation by the virtue of Definition 2, and they remain so until any one of them ceases to exist, hence Temporal Coincidence relation of events in line with Definition 5 holds for some arbitrary intermediate positions of D_0 and D_1 at any stage of their motion towards ***A*** and **B** prior to reaching them.
15. Because motions of D_0 and D_1 are identical and because of isotropy of space the distances CD_0 and CD_1 are equal at any instance of existence after leaving ***C***.
16. Due to symmetry configuration the distances of both points from the X axis are equal i.e. $D_0X = D_1X$. This implies line segments D_0D_1 and ***AB*** are always parallel to each other.
17. When D_0 approaches ***A*** so does D_1 with respect to ***B***.

[4] Cf. Note 1 at the end of this section for example of plausible realisations of such underspecified motion.

18. At some instance of existence $\boldsymbol{D_0}$ and $\boldsymbol{D_1}$ arrive on ***X*** axis and coincide with ***A*** and ***B*** respectively such that the following relations become both true:

$$\begin{cases} D_0 = (0,0,0) \equiv A \\ D_1 = (l,0,0) \equiv B \end{cases} \qquad (1)$$

19. Because ***A*** and ***B*** are arbitrary points and because of the identity above and definition 5 applicable to $\boldsymbol{D_0}$ and $\boldsymbol{D_1}$ at all instances of existence between ***C*** and ***AB***, the events of $\boldsymbol{D_0}$ and $\boldsymbol{D_1}$ arriving at point ***A*** and ***B*** are Temporally Coincident.
Q.E.D.
20. Since nothing can be said about the clocks prior to synchronisation they now should be set to the same value, preferably *0* in order to materialise the one unique instance of the space-time coordinate system origin of (0,0,0,0). Thereby the clocks are synchronised by two temporally coincident events so time has been defined as per definition adopted in section 2.3 paragraph 1.

The following conclusions can be derived from such defined synchronisation process:

a) Indicated time in ***A*** can be taken as representative time for the entire system ***K*** therefore it can be seen as common for every position. This is because the same value was imposed on clocks in arbitrary selected locations.
b) "Now" is an instance of existence uniquely identified by the clock of the observer in the origin.
c) This synchronisation is equivalent to having the ability of synchronising clocks instantaneously.
d) The claim that "Now" has no meaning because it cannot be instantaneously verified is unfounded. Geometry relations in established symmetrical concurrent motion scenarios replace the need for instantaneous communication for synchronisation purposes - at least in thought experiments.
e) The very concept and structure of coordinate system used together with the concept of time coordinate to produce equations of motion has the concept of "Now" built in implicitly. Denying "Now" is a posture inconsistent with mathematical framework of the STR. Any time coordinate can intersect with all spatial points whether or not the points can be reached instantaneously.
f) Since by convention, the measure of time is monotonically increasing then for any $t_1 < t$, t_1 indicates realised past with respect to "Now"(t) and $t_2 > t$ refers to unrealised future.
g) Contrary to the claim presented by Reichenbach (6 p. 144), distant events within an inertial system can be ordered by earlier, later and simultaneous relations, because the establishment of common indicated time after synchronisation allows such ordering.
h) Contrary to the claim presented by Reichenbach (6 p. 132), there is a mechanism to determine absolute simultaneity, if that is understood as Temporal Coincidence defined here.
i) Contrary to popular claims, distant point can be simultaneously influenced together with an arbitrary local point at any instance of existence by means of signals sent earlier than the given instance. This requires having the concept of future and precise planning capability which are available to human intelligence, and which are not fully definable within the domain of physics.
j) There is no particular speed or motion characteristic along ***CA*** or ***CB*** required to be known for synchronisation purposes as long as it is rectilinear and the same for both material points. This removes circularity problem notorious in various approaches to simultaneity.
k) No assumption is made regarding propagation of light.

Note 1: Consistently with Einstein's assumptions Euclidean geometry is valid within an inertial frame and analytic geometry can be applied within coordinate systems. For the readers concerned with the practical aspect of described synchronisation it can be said that for example firing two identical rifles at an angle or using electric or sound signals applied to the joint of two metal rigid rods arranged in V shape and resting on ***X*** axis are plausible arrangements to deliver simultaneous events at distant points ***A*** and ***B***. This is to show some physical reality, not necessarily an experimentally optimal arrangement. Once the principle of synchronisation is clear, the experimental physicists can design adequate experiments. For future reference, the arrangement described above is named as V scenario or V synchronisation.

3.4 Invariance of Temporal Coincidence

In this section I demonstrate that Temporal Coincidence as established in the stationary system is invariant in an arbitrary inertial frame. The nature of this invariance is based on analytic geometry and axioms of existence. This is a refinement of the conjecture 1 within the proper framework defined for STR. Similarly to previous sections, some of the statements from Einstein's work (1) is used or paraphrased to emphasise compatibility with the STR framework.[5]

Proposition 2

Temporally Coincident events in a stationary system as per Definition 5 are also Temporally Coincident in an arbitrary chosen moving inertial system, where "moving" means at constant velocity less than the speed of light.

1. Let a system ***K'*** be configured as three rigid material lines identical to **K** defined in section 3.3.
2. Let the axes be ***X', Y', Z'*** and parallel ***to X, Y, Z*** before ***K'*** moves. The coordinates of an arbitrary point are then described as (x',y',z')
3. Let an unspecified greater than zero constant velocity which is less than the speed of light, be imparted to the origin of ***K'*** in the direction of the increasing x of the stationary system(***K***),
4. Let this velocity be communicated to the axes of the co-ordinates, to the relevant measuring-rod, and to the clocks**.**
5. There then will correspond a definite position of the axes of the moving system, and from reasons of symmetry I am entitled to assume that the motion of **K'** may be such that the axes of the moving system are at given indicated time t (this *"t"* always denotes a time of the stationary system) <u>parallel to the axes of the stationary system</u>.
6. I can imagine space to be measured from the stationary system ***K*** by means of the stationary measuring-rod, and also from the moving system ***K'*** by means of the measuring-rod moving with it; and that I thus obtain the co-ordinates $x, y, z,$ and x',y',z' respectively.
7. Let the indicated time t of the stationary system ***K*** be determined for points of interest at which there are clocks to be synchronised by the procedure described paragraphs 4 to 20 in section 3.3
8. Let the indicated time $t'=0$ of the moving system be determined during the same synchronisation run such that point ***A*** at $t=0$ coincide with point ***A'*** = $(0,0,0)$ at $t'=0$ then we have point ***B'***$=(l',0,0)$ coinciding with ***B***, where value l' depends on transformation equations between the two coordinate systems.
9. Because the axes ***X*** and ***X'*** coincide (slide along each other) so they are parallel as already exposed in paragraph 5.
10. Then, because ***D_0=A*** and ***D_1=B*** are coexisting positions on ***X*** axis when $t=0$, the same occurs on ***X'*** axis, as the two axes always coincide:

[5] At some point this may look like a departure from the rule of separate concerns, however this way was chosen by Einstein and this is a way to show binding between physical system and its coordinate system based description.

$$\begin{cases} D'_0 = (0,0,0) \equiv A' \\ D'_1 = (l', 0,0) \equiv B' \end{cases} \qquad (2)$$

at the same instance of existence.

11. Line segment $D'_0D'_1$ that has a common point with X' axis is coincident with X' axis and it is the same as the segment $A'\ B'$ and AB at the same instance of existence. Events at A' and B' are both Temporally Coincident events by the virtue of definition 5, because they are the same events that happen in A and B which are coexisting positions of the material points at $t=0$.
12. Coordinates of the material points and therefore coordinates of the events need to be expressed in terms of each coordinate system in their own right, and they obviously differ.
13. Since K' is an arbitrary moving inertial system, the conclusion in paragraph 11 above implies that Temporal Coincidence of events is invariant for an arbitrary moving inertial system.
    Q.E.D.
14. Nothing in this derivation is assumed about rates of clocks in K and K' or distances AB vs $A'B'$. No explicit knowledge of time or velocity is required. Enough to wait for the two events to happen and restart clocks from 0.

Proposition 2 is in essential disagreement with the thesis about relativity of simultaneity. Additional checks are needed since there is no reference to the STR other than using its framework that is equally applicable to classic Galilean systems.

3.5 Temporal Coincidence Verification in STR Framework.

This section demonstrates that the synchronisation experiment in K described in section 3.4 when transformed to K' using Lorentz transformation, has conflicting interpretations depending on how one looks at results of the transformation. From one point of view Temporal Coincidence appears to be invariant, from another we still get relativistic non-simultaneity of simultaneous events. The clarification follows and Temporal Coincidence is confirmed invariant while Einstein's simultaneity remains relative.

The STR is by consensus a valid theory that has been challenged multiple times, and none of the challenges have been accepted by the majority of domain experts. It then makes sense to use the STR to verify the claim made in section 3.4 in the proposition 2.

To put the Temporal Coincidence to test I present the previously discussed V synchronisation model in the stationary system K in terms of coordinates, equation of motion and transformations using the framework of the STR.

From the logical point of view the ontological definition of Temporal Coincidence mapped to a physical scenario has so far been proven useful and free from contradictions, and the conjecture 1 seems to have been confirmed by the proof of the proposition 2 - at least within the presented scenario. At this stage of stepwise refinement process, there is no reason to object to definitions of Temporal Coincidence.

Let us examine in detail the effects of V synchronisation scenario (Figure 1) used to prove proposition 2 within the STR framework.

1. Let us assume the STR is valid and K is stationary system as before.
2. Let point A coincide with the origin of K: $A = (0,0,0)$ and point B somewhere on the positive side of X at a distance l, $B = (l,0,0)$.
3. Let point C be located on the XY plane: $\mathbf{C} = (l/2, -h, 0)$.

4. Let us assume two identical physical objects ejected coincidently from $\boldsymbol{C}$ and propagating together towards $\boldsymbol{A}$ and $\boldsymbol{B}$ respectively. Their motion is given by the following four dimensional vectors in $\boldsymbol{K}$:

$$\overrightarrow{\boldsymbol{D_0}} = \begin{vmatrix} ct \\ -v_x \cdot t \\ v_y \cdot t \\ 0 \end{vmatrix} \quad \overrightarrow{\boldsymbol{D_1}} = \begin{vmatrix} ct \\ l + v_x \cdot t \\ v_y \cdot t \\ 0 \end{vmatrix} \tag{3}$$

Velocities v_x, v_y are symbols which will have defined values only after synchronisation at *t=0* and *c* is the universal constant expressed in selected units of measure. The first coordinate in each four dimensional vector represents the value of the coordinate time multiplied by the speed of light *c*, at locations described by the values of the three remaining coordinates.

5. Components *(x,y,z)* of $\overrightarrow{\boldsymbol{D_0}}$ and $\overrightarrow{\boldsymbol{D_1}}$ have *z=0* and the same $\boldsymbol{Y}$ coordinates for $t \in < -\frac{l}{2v_x}, 0 >$, therefore the vector $\overrightarrow{\boldsymbol{D_0 D_1}} \stackrel{\text{def}}{=} \overrightarrow{\boldsymbol{D_1}} - \overrightarrow{\boldsymbol{D_0}} = [l + 2v_x\, t, 0,0]^T$ stays on $\boldsymbol{X}$ axis at all times as expected.
Note that these equations are somewhat retrospective because they can only be meaningful after the synchronisation is completed at *t=0*.
6. When points $\boldsymbol{D_0}$ and $\boldsymbol{D_1}$ coincide with $\boldsymbol{X}$ at *t=0,* two Temporally Coincident events are generated at *x=0* and *x=l* respectively as previously demonstrated.
7. Let the indicated time *t′=0* in the $\boldsymbol{K'}$ system moving along $\boldsymbol{X}$ with velocity *v* be set during the same synchronisation run such that point $\boldsymbol{A}$*=(0,0,0)* at *t=0* coincides with point **A′** = *(0,0,0)* at *t′=0.*
8. The system $\boldsymbol{K'}$ meets all necessary conditions for which the STR equations apply once origins of $\boldsymbol{K}$ and $\boldsymbol{K'}$ are aligned and times are set to *0* at the origins.
9. The V synchronisation of clocks used to represent time in $\boldsymbol{K}$ has already been demonstrated. Lorentz transformations can now be used to convert vectors from $\boldsymbol{K}$ to $\boldsymbol{K'}$ to demonstrate the effect of this synchronisation in K′.
10. Motions represented by vectors $\overrightarrow{\boldsymbol{D_0}}$ and $\overrightarrow{\boldsymbol{D_1}}$ can be transformed as:

$$\overrightarrow{\boldsymbol{D'_0}} = \boldsymbol{L} \begin{bmatrix} ct \\ -v_x \cdot t \\ v_y \cdot t \\ 0 \end{bmatrix} = \begin{bmatrix} \gamma t(c + v v_x/c) \\ -\gamma t(v + v_x) \\ v_y t \\ 0 \end{bmatrix}, \qquad \overrightarrow{\boldsymbol{D'_1}} = \boldsymbol{L} \begin{bmatrix} ct \\ l + v_x \cdot t \\ v_y \cdot t \\ 0 \end{bmatrix} = \begin{bmatrix} \gamma t(c - v_x v/c) - \gamma l v/c \\ -\gamma t(v - v_x) + \gamma l \\ v_y t \\ 0 \end{bmatrix}, \tag{4}$$

where $\boldsymbol{L}$ is the Lorentz Transformation Matrix :

$$\mathbf{L} = \begin{bmatrix} \gamma & \frac{-v}{c}\gamma & 0 & 0 \\ \frac{-v}{c}\gamma & \gamma & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}, \tag{5}$$

and $\gamma = \sqrt{\frac{1}{1-\frac{v^2}{c^2}}}$.

11. The first coordinate can be expressed by *ct* in $\boldsymbol{K}$ or ct′ in $\boldsymbol{K'}$ where *t* or *t′* are coordinate time variables in the respective systems.
12. The four dimensional vector joining the temporally coincident points is the difference of the respective vectors is:

$$\overrightarrow{\boldsymbol{D'_1}} - \overrightarrow{\boldsymbol{D'_0}} = \begin{bmatrix} -\gamma v(2v_x t + l)/c \\ 2\gamma v_x t + \gamma l \\ 0 \\ 0 \end{bmatrix}, \tag{6}$$

where three dimensional spatial component is defined as:

$$\overrightarrow{\boldsymbol{D'_0 D'_1}} \stackrel{\text{def}}{=} \begin{bmatrix} 2\gamma v_x t + \gamma l \\ 0 \\ 0 \end{bmatrix} \tag{7}$$

13. After transformations presented in the matrix form, the vector components x',y' and $z'=0$ are expressed in terms of variable t. In that form, if the variable t representing any clock in $\boldsymbol{K}$ changes monotonically in the range $t < -l/(2v_x, 0>$, the components x' and y' of the two vectors $\overrightarrow{\boldsymbol{D'_0}}$ and $\overrightarrow{\boldsymbol{D'_1}}$ follow that change such that that the vector $\overrightarrow{\boldsymbol{D'_0 D'_1}}$ constructed as spatial component of $\overrightarrow{\boldsymbol{D'_1}} - \overrightarrow{\boldsymbol{D'_0}}$ stays on $\boldsymbol{X'}$ axis at all times.
14. Both points $\boldsymbol{D'_0}$ and $\boldsymbol{D'_1}$ appear to coincide with $\boldsymbol{X'}$ at $t=0$ as expected. Point $\boldsymbol{D'_1}$ coincides together with $\boldsymbol{D'_0}$ on $\boldsymbol{X'}$ axis because of common value of coordinates $y'$and z'.
15. Time coordinates however differ in the two vectors. While t' for $\overrightarrow{\boldsymbol{D'_0}}$ at $t=0$ is equal to 0, the t' for $\boldsymbol{D'_1}$ reads $-v\gamma l/c^2$ as it can be calculated from the equality: $ct' = \gamma t(c - v_x v/c) - \gamma l v/c$ at $t=0$.
16. If one is prepared to assume $t'(0,0,0)=0$ as the common system time in K' at the moment of synchronisation, then for $t=0$, $v>0$ the value $t'(\gamma l,0,0) = -v\gamma l/c^2$ is in its past. This would imply $\boldsymbol{D'_1}$ had already been synchronised before synchronisation has started in $\boldsymbol{K'}$, which makes an interesting case of the conflict between Einstein's simultaneity and Temporal Coincidence. Furthermore it will be shown that $\boldsymbol{D'_1}$ no longer coincides with $\boldsymbol{X'}$ axis for $t'=0$ which it should according to $\boldsymbol{K}$.
17. The fact that indicated times are not equal in $\boldsymbol{K'}$ for the positions $x'=\gamma l$, $y'=0$, $z'=0$ and that at $x'=0$, $y'=0$, $z'=0$, is the universally acclaimed evidence of relativity of simultaneity.
18. The fact of persistent parallel orientation of 3 dimensional spatial component of vector $\overrightarrow{D'_0 D'_1}$ is the evidence of invariance of Temporal Coincidence as understood in this study.
19. When variable t is consistently eliminated for each vector separately and they are expressed in terms of t' only, we get:

$$\overrightarrow{\boldsymbol{D'_0}} = \begin{bmatrix} ct' \\ -c^2 t'(v + v_x)/(c^2 + vv_x) \\ v_y c^2 t'/(\gamma(c^2 + vv_x)) \\ 0 \end{bmatrix} \tag{8}$$

$$`\overrightarrow{\boldsymbol{D'_1}} = \begin{bmatrix} ct' \\ \gamma l(c^2 - v^2)/(c^2 - vv_x) - c^2 t'(v - v_x)/(c^2 - vv_x) \\ lvv_y/(c^2 - vv_x) + v_y c^2 t'/(\gamma(c^2 - vv_x)) \\ 0 \end{bmatrix} \tag{9}$$

20. Vector $\overrightarrow{\boldsymbol{D'_0 D'_1}}$ is no longer parallel to $\boldsymbol{X'}$ axis at any instant of t' and for $t'=0$ it has the form:

$$\overrightarrow{\boldsymbol{D'_0 D'_1}}(t' = 0) = \begin{bmatrix} \gamma l(c^2 - v^2)/(c^2 - vv_x) \\ lvv_y/(c^2 - vv_x) \\ 0 \end{bmatrix} \tag{10}$$

21. The conclusion is: For equal indicated times t, two points in $\boldsymbol{K}$ designate a line parallel to $\boldsymbol{X}$ axis at all times t. When transformed to $\boldsymbol{K'}$ and expressed in terms of t', they designate a line that is <u>not</u> parallel to $\boldsymbol{X'}$ at all t', which is the manifestation of apparent non-simultaneity in $\boldsymbol{K'}$ claimed by the STR.
22. While there is a conflict of the two points of view, there is no mathematical contradiction since two different parameters: either t or t' in their own rights determine sequencing of the x' coordinates of the material point in $\boldsymbol{K'}$. The essence of the conflict lies in the interpretation of the above facts.

23. I consider the coexistence of locations of the material points to be the determinant of common temporal reality rather than the same value of indicated times at respective positions, because the time value depends on synchronisation method.
24. The possible explanation of the conflicting views is that equal times t' after Lorentz transformation do not connect simultaneous events and therefore cannot be used to judge Temporal Coincidence. The divergence of Temporal Coincidence and Einstein's simultaneity is discussed below.

3.6 Temporal Coincidence vs Einstein's Simultaneity

This section interprets discovered apparent contradiction between Einstein's simultaneity and Temporal Coincidence. The contradiction is due to difference of opinions on what constitutes the instance of coexistence of physical objects and events resulting from objects in motion.

With the V scenario of concurrent motions I have demonstrated that two material points moving together in that manner can uniquely form a line parallel to the **X** axis.

The **X** axis is parallel and coincident with the **X'** axis by the definition of the coordinate systems of **K** and **K'**.

To emphasise the importance of notion of parallel axes I quote verbatim from Einstein as in (1 p. 43):

> To any time of the stationary system ***K*** there then will correspond a definite position of the axes of the moving system, and from reasons of symmetry we are entitled to assume that the motion of ***k***[6] may be such that the axes of the moving system are at the time t (this "t" always denotes a time of the stationary system) parallel to the axes of the stationary system.

This implies:

a) Any line parallel to ***X*** is automatically parallel to ***X'*** in terms of ***K'*** coordinates (x',y',z').
b) Since travelling material points in the V scenario always designate a line parallel to ***X***, they are automatically on a line parallel to ***X'*** in terms of (x',y',z') including the synchronisation moment at $y=0$ and $y'=0$.
c) This is not only a logical conclusion but it can be shown algebraically that any static line[7] parallel to ***X*** in ***K***, after Lorentz transformations remains parallel to ***X'***. It is clear that any line segment coinciding with such static line in ***K***, automatically coincides with the line that is parallel to ***X'*** in ***K'*** in terms of (x',y',z').
d) Material points in the V scenario are unique. D_0,D_1 and D'_0,D'_1 are the same pair of material points only expressed by two different sets of coordinates, hence the line segment $D'_0D'_1$ can only be non-parallel to ***X'*** if the positions of D'_0 and D'_1 belong to different instances of existence (non-coexisting positions). In other words, two positions of the two material points belong to different moments in history.

Equal coordinate time t' after Lorentz transformation associates events in space and time which do not belong to the same instance of existence. In other words after Lorentz transformation, coordinate time is not the one we know in the "stationary system", therefore there cannot be a real experience associated with that kind of time.

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[6] Symbol ***K'*** used in this study

[7] Static line is represented by two fixed points (x_1,y_1,z_1) and (x_2,y_2,z_2) and coordinate $t \in (-\infty,+\infty)$

The following consideration may be helpful in reassuring this point of view.

It is possible to make a thought experiment in the stationary system by which two light signals are emitted in the opposite directions from the origin of its coordinate system. In any case according to the STR, light propagates simultaneously in both directions and consequently at any instance of t or t' the signals are equidistant to the origin.

1. Let us assume system ***K*** is stationary as before.
2. Let point ***O*** coincide with the origin of ***K***: ***O*** = *(0,0,0).*
3. Let point ***F*** be located somewhere on the positive side of ***X*** at a distance *l*, ***F***= *(l,0,0).*
4. Let point ***B*** be on the negative side of ***X*** symmetrically at a distance *l*, ***B***= *(-l,0,0).*
5. Let the two light signals be emitted simultaneously from ***O*** towards ***B*** and ***F*** with the respective equation of motion $x(t)=ct$, and $x(t)=-ct$.
6. It is then the expectation of the stationary system that point ***B*** and ***F*** are reached simultaneously at $t_1=l/c$.
7. Let the same experiment be conducted in the moving system ***K′*** using exactly the same two common light signals, where two points ***F′*** and ***B′*** initially coincide with ***F*** and ***B*** at the moment when $t'=t=0$ at ***O***=*(0,0,0)* and ***O′***=*(0,0,0)* while **K′** has already be set in motion (i.e. it has already contracted due to velocity).
8. The two systems make separate judgements about arrival at ***F*** and ***B*** and ***F′*** and ***B′*** respectively.
9. ***B*** and ***F*** stay with the system ***K*** while ***F′*** and ***B′*** travel relatively together with the origin of ***K′*** moving in positive direction of ***X.***
10. The judgement of ***K*** with respect to ***F*** and ***B*** is already given in paragraph 6.
11. The expectation of the moving system ***K′*** after Lorentz transformation are that point **B′**=($-\gamma l,0,0$) and ***F′***=($\gamma l,0,0$) are reached simultaneously at $t'_1=\gamma\ l/c$ which is consistent with the STR.
12. Let the experiment of ***K′*** be judged by ***K*** in its own coordinates.
13. The light signal reaches ***B′*** first. Later on, the other signal arrives at ***F′*** after a delay that would grow towards infinity as velocity of the moving system v approaches the speed of light c in ***K***. This delay according to the STR is always 0 in ***K′***.
14. From the perspective of ***K***, due to the motion of ***K′*** competing with light signals, the signal positions are <u>never</u> equidistant to ***O′*** except when at the origin.
15. The light propagation law in ***K′*** however says that both light signals are always equidistant and due to arrive simultaneously at symmetric locations $-\gamma l$ and γl respectively.
16. It can be then said consistently with the STR that significantly successive events in ***K*** can be simultaneous in ***K′***.
17. The non-equidistant propagation of signals is an obvious potentially observable fact in **K.** It could be arranged that positions of signals at any stage are physically marked on ***X′*** axis as they continue to move. At the moment of coincidence with point ***B′***, the system ***K′*** could be brought into an abrupt halt by actions in ***K***, only to discover by analysis of the markings post-mortem, that there was no simultaneous event at ***F′*** because the forward signal failed to reach F at the moment K′ was halted. If the velocity v was sufficiently high it would be miles long discrepancy.
18. To maintain equidistant position of the light signal at time indicated by the origin, the "current" positions of the light signals have to belong to different moments in history.

There exist an infinite number of geometric points in a space, but a material point can be chosen and made unique as it has only one set of coordinates at each instance of existence, to the exclusion of others. It coincides with one and only point of space "at a time".

What is the meaning of Galilean transformation of an instance of existence represented by a position four dimensional vector in a classical interpretation? It is that the view of an instant of existence in one system ***K*** transforms into a view of the same instance of existence in ***K′***. Position of material point ***P*** in ***K*** translates to a position of the same material point designated as ***P′*** in ***K`***. At every instance of existence there is only one and the same material point that can be at different relative positions in different inertial frames, but still the same one and only. What is the reason to claim that Lorentz transformation has a different meaning than the Galilean one?

The fact that the two coexisting material points at coexisting positions P_1 and P_2 at a common time t in ***K*** can have two different times in ***K′*** can only be seen a result of clocks in ***K′*** being synchronised such that they are phase shifted. In case of Lorentz transformation they are shifted along ***X′*** axis in ***K′*** while running at the same rate within that system. This is the simplest explanation of relativity of simultaneity.

Newton's rules of reasoning demand a simple rather than an exotic explanation first. Postulating multiple different time realities appears superfluous as I believe we had enough problems resulting from postulating the existence of just one absolute, true and mathematical time of itself as presented by Newton(4).

Each moving material point after Lorentz transformation gets its own time coordinate that is different from any other moving point. This is not the case in the stationary system in which it is traditionally assumed that time is common everywhere at once. This coordinate time difference is due to synchronisation method chosen by Einstein and the convention of light speed being the same in all directions.

Times of different material points as seen in the four dimensional vectors after Lorentz transformation, cannot be compared or grouped the same way as after Galilean transformation and for the same reason the identity of indicated time does not mean Temporal Coincidence. It can still be named "simultaneity" since this is the current convention.

Subsequently I believe there is nothing strange about time, but only the complexity of the problem of synchronising distant clocks which can also slow down in motion makes it a bit obscure and difficult to manage.

The STR discovered time dilation, mass variation with speed and allows unification of Maxwell equations in all inertial systems, however coordinate time after Lorentz transformation is not time as we know it, however it changes nothing in Temporal Coincidence as demonstrated in this study.

I have to conclude that the demand to keep the speed of light c constant across all inertial systems require clocks to be phase shifted with respect to each other in order to comply with this basic special relativity postulate. Although all clocks within an inertial system have the same rate, the phase shift increases in the direction of moving system velocity by the factor of $-v/c^2$ per length unit.

The effects are similar to those between time zones on Earth. Time comparison after transformation to t' does not mean that equal time designates Temporal Coincidence, as it does not mean that between time zones on Earth.

It would be hard to believe that this simple observation has not been brought in to light earlier. The answer is: it has already been published, but ignored altogether.

In the article titled:"Invariant Simultaneity" written by W.Kantor (7) this problem is discussed at length with the following summary:

> The concept of the "relativity of simultaneity", as a consequence of the Lorentz transformations, is shown to be an unproven inference based on the implicit idea that simultaneity can be determined only on the basis of synchroneity. The Lorentz transformations do imply, by interpretive inference, a relativity of synchroneity whereby a "moving" system of synchronized clocks appears to be nonsynchronous, with constant nonzero time invariant phases among the clocks that depend only on their relative fixed distances from each other. It does not seem to have been recognized that such an array of uniformly running nonsynchronous clocks, described as isochronous, can also lead to the unambiguous determination of simultaneity. The important significance of the relative temporal phases, namely the relativity of synchroneity, entailed by the Lorentz transformations is that certain alleged logical inconsistencies, asserted by both proponents and opponents of the special theory of relativity, can be readily resolved. The relativity of synchroneity does, however, raise certain other consequences that merit attention and careful consideration.

This article was not known to me until after the ontological approach to the Temporal Coincidence has materialised as an early draft of this publication, so it was quite reassuring to find another source that arrives at similar conclusions from different premises. Kantor's publication is an interesting read. Although providing detailed derivations of his claims, Kantor did not focus enough to expose them with sufficient clarity to attract attention. Additionally he voiced dissatisfaction with Einstein's theory which would largely limit the circle of readers. Also the fact that it has been published during the cold war in a country that was then behind the iron curtain, would limit that circle even more. There is hardly any reference to this article. Jammer (2) has commented on many interesting and controversial publications on simultaneity, but he has not mentioned Kantor's work at all.

F. Jackson and R. Pargetter (8) from La Trobe University in Australia presented a synchronisation method by a rigid rod moving parallel towards a line with clocks which is in principle (in its end result) somewhat equivalent to V synchronisation proposed in this study. Their method is shortly and clearly described as follows:

> Let U_A, U_B be clocks at ***A,B***, respectively. Let ***XY*** be an axis perpendicular to ***AB***, passing through ***C***, the midpoint of ***AB***. Take a rigid straight rod ***A′ B′*** with midpoint ***C′*** and length equal to the length ***AB***. Move ***A′ B′*** with uniform velocity such that ***C′*** travels along ***XY*** towards ***C***, and ***A′ B′*** is perpendicular to ***XY*** (i.e. parallel to ***AB***); then if the reading (as noted by an observer at ***A***) U_A just when ***A′*** coincides with ***A*** is the same as the reading (as noted by an observer at ***B***) on U_B just when *B′* coincides with *B*, clocks U_A and U_B will be synchronous.(Alternatively, U_A, U_B could be set at zero, and triggered by the arrival of ***A′*** at ***A***, and ***B′*** at ***B***, respectively.) (8 p. 468)

F. Jackson and R. Pargetter, were criticised by multiple experts e.g. Giannoni (9), Torretti (10), Øhrstrøm (11), and none of them seems to have appreciated the concept. All critics have failed to see the merit. Moving rigid rod set in motion with no rotation must coincide with any line that it is crossing and which is parallel to it. This includes the line instrumented with an array of clocks. The ends of the rod as well as any intermediate part of it can physically trigger the array of clocks at once, with all the consequences as presented in this study.

To dismiss the validity of such scenario other than due to experimental accuracy issues, one has to deny the possibility of modelling a non rotating rigid rod of macroscopic length which has a velocity component perpendicular to its maximum length vector. If putting the rod in such motion is a problem then one may chose to leave the rod in its place and move the observer instead. According to the relativity principles, it does not matter which one has moved.

In my opinion, the lack of positive feedback to Jackson-Pargetter's proposal was because of problems with their presentation of proofs in which they concurrently address abstract mathematical concepts with experimental verification. To separate those concerns would do the justice.

The essence of parallel motion as a means of synchronisation can be further visualised with the help of Einstein's train (12 p. 30) so frequently referred to in literature.

While the station master in the middle of the embankment and the midpoint observer in the train are busy waiting for the lightning flash to determine simultaneity, the clocks attached to the rails in the middle of the embankment and those attached to the wheels of the middle axle of the train are synchronized upon direct contact. Both systems clock pairs become synchronized at a distance at once, such that they are temporally coincident.

It is hard to imagine that the axles would not be progressing as a parallel translation in the tracks or that they would not be perpendicular to the rails.

Since this is an imaginary train, then not only it can be arbitrary long and fast, but also arbitrary wide. We do not care much about the direction of the train motion since we are only interested in distant synchronisation within each inertial system for two arbitrary points, and we have just made an arbitrary decision on clocks on rails and axles. Additionally, parallel train tracks can go in an arbitrary direction as well. And who said there has to be only two rails?

As it comes to real experiments, custom built rigid objects are limited in length so accuracy of such synchronisation may never be adequate to account for possible relativistic effects of simultaneity. Doing V synchronisation with a light pulse at large distances is far more plausible. As the STR is the widely acclaimed theory in accordance with assumption in section 2.2 paragraph 3, there is no objection of light speed being exactly the same in any direction within an inertial system. All considerations in section 3 are then applicable to light signals to be used for V synchronisation.

4 CONCLUSIONS

In the view of the presented material I conclude that in the framework of the STR, after Lorentz transformation, the distant events happening at equal time indicated by clocks in distant locations within an inertial system belong to different instances of existence. This is because they are grouped that way to enforce the light speed constancy in all directions. The resulting simultaneity is then conventional and has little in common with Temporal Coincidence.

Temporal Coincidence is a relation pertinent to existence of physical objects that can be used to uniquely synchronise clocks in inertial frames. It is unclear at this stage what would be the best experimental set-up to establish high accuracy of synchronisation.

The multiplicity of time realities for different inertial systems has no grounds in the STR although the relative clock rates might be different in each system.

The definitions of Temporal Coincidence as a necessary relation amongst all coexisting objects and certain classes of events generated by moving objects has been found useful and has not been contradicted by the STR.

The denial of meaning of "Now" is the posture inconsistent with the STR, which includes the concept of "common time" within an inertial system which was explicitly called for by Einstein (1 p. 40).

It does no matter whether clocks run different rates or not. With demonstrated invariance of Temporal Coincidence, moving inertial systems belong to common temporal reality. "Now" has a universal significance since any object's own inertial frame contains all the remaining coexisting objects.

Nothing in this study denies time dilation, which simply can be seen as clock getting out of synchronisation while in motion. This is no more or less strange than slowing metabolism rates in refrigerators. The slow and fast metabolising microorganisms still live in temporal coincidence with each other albeit aging and multiplying at different rates.

Overall, the innate temporal logic we have is not erroneous and does not need to be replaced contrary to the claims of relativity educators[8]. So it seems that science despite its universal success sometimes chooses to ignore the obvious for the benefit of the strange, perhaps in need of keeping some mystery alive.

5 BIBLIOGRAPHY

1. **Einstein, A.** On the Electrodynamics of Moving Bodies. [book auth.] Einstein A. et.al. *The Principle of Relativity, A Collection of Original Papers...* New York : Dover Publications, Inc., 1952.

2. **Jammer, M.** *Concepts of Simultaneity: From Antiquity to Einstein and Beyond* . Baltimore : Johns Hopkins University Press, 2006.

3. **Einstein, A.** *The Meaning of Relativity.* Princeton : Princeton University Press, 1988.

4. **Newton, I.** *The Principia.* [trans.] A Motte. New York : Prometheus Books, 1995.

5. **Kant, I.** *The Critique of Pure Reason.* [E-book Kindle Edition] [trans.] J. M. D. Meiklejohn. Adelaide : The University of Adelaide, 2013.

6. **Reichenbach, H.** *The Philosophy of Space & Time.* [trans.] .M Reichenbach. New York : Dover Publications, Inc., 1958.

7. **Kantor, W.** Invariant Simultaneity. *Chech. J. Phys. B.* 1972, Vol. 22, 11.

8. **Jackson, F. and Pargetter, R.** Relative Simultaneity in Special Relativity. *Phil. Sci.* 1977, Vol. 44, 3.

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[8]For example Mermin (14 p. 146) finds it a joyful experience to treat wrong innate temporal misconceptions:
"This process of discovering that one's former beliefs are wrong, and the painstaking search to identify the old errors, enabling one to construct better founded beliefs to replace them, is what makes the pursuit of science so engrossing. The world would be a far better place for all of us if this joy in exposing one's own misconceptions were more common in other areas of human endeavor".

9. **Giannoni, C.** Comment on "Relative Simultaneity in the Special Theory of Relativity". *Phil. Sci.* 1979, Vol. 46, 2.

10. **Torretti, R.** Jackson and Pargetter's Criterion of Distant Simultaneity. *Phil. Sci.* 1979, Vol. 46, 2.

11. **Øhrstrøm, P.** Conventionality of Distant Simultaneity. *Found. Phys.* 1980, Vol. 10, 3/4.

12. **Einstein, A.** *Relativity: The Special and General Theory.* [trans.] R. Lawson. New York : Henry Holt And Company, 1921.

13. **Merriam-Webster.** Indicated Airspeed. [Online] [Cited: 7 03 2014.] www.merriam-webster.com/dictionary/indicated%20airspeed.

14. **Mermin, N.,D.** *It's About Time : Understanding Einstein's Relativity.* Princeton : Princeton University Press, 2009.