Einstein's Famous Thought Experiment on Simultaneity Put to Test

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Abstract

Experiments to directly test relativity of simultaneity and relativity of spatial concurrence have already been proposed. In this eighth paper in the series of "Rudiments of relativity revisited", the famous train embankment thought experiment for simultaneity is analyzed under the new formulation of relativity, and the experiments on the same are proposed to differentiate between the two theories. Current relativity assumes a photon to be classically localized at an overlapped position in different frames leading to the relativity of simultaneity, while the new relativity asserts their relativistic non-localized existence at different positions in different frames, leading to the relativity of spatial concurrence. New theory reproduces the so far proven results of relativity besides predicting new experimentally verifiable phenomena unexplored so far.

1. Introduction

The current relativity (CR) [1-5] and the new relativity (NR) [6,7] both preserve the lightspeed. However, NR asserts relativistic non-localization (RNL) and complies with the second axiom that recommends odd-order warping of space over time. The new transforms (NT) are produced below along with the Lorentz transforms (LT) [6].

NT: $x' = em(x - vt)\ ,\ y' = em_{\perp}\, y\ ,\ z' = e\, m_{\perp} z$ (1)

$t' = e\, t\ ,$ (2)

where,

$e = \sqrt{1 - v^2/c^2}\ ,\ m = \frac{1}{1-(v/c^2)(x/t)}\ ,\ m_{\perp} = \frac{\sqrt{1-v^2/c^2}}{1-(v/c^2)(x/t)}$ (3)

LT: $x' = (x - vt)\ ,\ y' = y\ ,\ z' = z$ (4)

$t' = (\, t - vx/c^2)$ (5)

where $\gamma=1/e$, v is the relative velocity between the two frames whose spacetime coordinates are (x,y,z,t) and (x',y',z',t'). NT and LT are shown to be equivalent except that they operate in real and Minkowski domains, each one having its own advantage over the other [6-8]. CR however interprets LT based on the relativity of simultaneity (RoS) which is shown to be the result of CR's assumption of localized existence of a moving particle at an overlapped position in different frames (OPDF) [9]. CR and NR follow different schemes to map the events of one frame to the other, CR assumes the photons to be classically and relativistically localized, while NR asserts their relativistic non-localized existence at different positions in different frames (DPDF). Thus, NR successfully maps a set of simultaneous events in one frame to a set of simultaneous events in the other frame, discarding the relativity of simultaneity (RoS) and synchronization. However, NT brings to light many new relativistic phenomena that had remained hidden under the mathematical elegance of LT and their literal interpretation by CR. The new phenomena include anisotropic spatial warping (ASW) that explains the Sagnac effect, relativity of spatial concurrence (RSC) that replaces RoS, and the relativistic non localization (RNL) which brings relativity and quantum mechanics closer [7]. However, the neutral math of LT devoid of CR's interpretation and assumption does not contradict the newly proposed phenomena.

Einstein proposed the famous train embankment thought experiment [1,2] where simultaneous blasts occur in the rest frame of embankment across the two ends of a moving train and it is deduced that the blasts are not simultaneous for the moving frame observer (MFO) while they are simultaneous for the rest frame observer (RFO) [2]. In this thought experiment, the observers are stationed at the origins of their respective frames away from the blast locations. The experiments have been proposed to test RoS and RSC directly in our previous papers [9-11] besides the other experiments that can verify the new tenets of NR [12-14]. Here, we consider the train embankment thought experiment in its original form that uses a single observer at the origin of each frame, to see if its outcomes as described in [1,2] are valid under NR for the moving frame (MF). Experimental setups are detailed to test the outcomes of the originally proposed form without employing separate synched detectors at the very sites of the blasts.

2. Train Embankment thought experiment

According to NR, RoS is a fallacy of CR, (not of LT) that results from three others: 1. Allowing undesirable effects of finite signal speed (UEFSS) to creep into the framework of CR's relativistic physics, which results in confusing the linear warping of space as that of time 2. Its belief in relativistically localized photons or ignorance of new phenomena like RSC, ASW, and RNL in the cross frame detections. 3. Tendency to proportionally estimate the distances traveled by the flashes in the moving frame from the directly mapped positions in the rest frame (RF) based on OPDF. Same is witnessed in CR's analysis of the train embankment experiment.

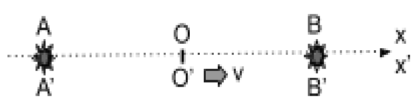

Fig 1a. Points A, B equidistant from origin O in the RF flash when points A', O', B' of the MF overlap with points A,O,B respectively.

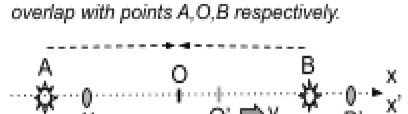

Fig 1b. At a time T = X/c. Flashes meet at O in the RF. Where do they meet in the MF?

First, Lali explains to Kishori one of the versions of the famous train (as a primed moving frame) and embankment (as an unprimed rest frame) thought experiment often used for establishing RoS [1,2], as shown in Fig 2. At time *t*=*t'*=0, the origins *O* and *O'* coincide, blasts occur simultaneously at points *A* and *B* of the embankment, which also happens to be the endpoints of a moving train *A'B'* whose midpoint *O'* coincides with the midpoint *O* of *AB*, i.e. *OA*=*OB*=*AB*/2=*X*, similarly *O'A'*=*O'B'*=*A'B'*/2=*X'*. At time *T*=*X*/*c*, the rest frame observer (RFO) at *O* sees the flashes from *A* and *B* boh, confirming to him the simultaneity of the blasts in the rest frame (RF). Meanwhile, as *O'* has moved away from *A* towards *B* therefore it will see the flash coming from *B* earlier to the flash coming from *A*, confirming non-simultaneity of the blasts for the MF, and hence the RoS is established for a conventional relativist (CRist). With few variations, above is often the standard sequence of a CRist's arguments for RoS [2].

In the above analysis, CR inherently assumes that if flashes meet at *O* in the rest frame they also meet at an MF point overlapping with *O* at the time of the meeting of the flashes. As *O* has moved to the left for the MFO, it coincides with the point -*vT'* of the MF at *T'*, where *T'* is MF time when the two flashes meet. Thus, flashes travel unequal distances in the MF to meet at a point -*vT'* that overlaps with *O*. Unequal distances traversed in the MF are translated as unequal times of origin of the two flashes in the MF. Kishori argues this indirect test of simultaneity where each frame uses a distantly placed observer or detector to detect the events of blasts is not suitable for thought experiments as it is prone to UEFSS. For a thought experiment, it is better to use a direct method where both frames use a pair of detectors placed at the very sight of the blasts in their respective frames. The moment moving frame observer (MFO) uses two synched detectors in line with the first axiom of NR at the very location of the blasts *A'* and *B'*, the RoS disappears as shown below under the first axiom.

2.1 Direct detection thought experiment: A real experiment on direct detection has already been proposed in [9], here we analyze it heuristically.

Consider both RFO and MFO place their detectors at the very sites of the blasts given by *A*, *B* in RF and *A'*, *B'* in the MF. Further, the instant of the two blasts given by *t*=0 in the RF is shown in fig 1a. For CRist, in the MF the blast at *A/A'* will happen $2vX/c^2$ before the blast at *B/B'*. From symmetry, the MF detector must detect the blast at A, vX/c^2 time after the RF detector detects it, and vX/c^2 time before the RF detects this second blast so that the time gap for the two blasts in the MF comes out to be $2vX/c^2$. Now focus on a single site say *A/A'*, and imagine the blast is strong enough to blow the detectors put at this site. For CR, the RF-detector will be blown earlier than MF-detector. MF-detector will remain intact when the detector of RF will be torn into pieces, and after vX/c^2 time, the MF detector will be blown, though both the RF and MF detectors occupied the same location of the blast. Similarly, at the other blast-site B/B', the RF-detector is lucky to live longer than the MF-detector, if one believes the arguments of CR. This exposes both the CR and the RoS, showing how CR's analysis in the case of the indirect detection method is misleading and prone to UEFSS.

2.2 Indirect method analyzed under NR

Where does the analysis of CR go wrong? From the very beginning, when CRist assumes if flashes meet at *O* in the RF they will also meet there at an overlapped point in the MF based on localized existence of photons or say OPDF. NR on the other hand asserts the moving particles exhibit RNL and exist at DPDF. And therefore while the flashes from the blasts meet at *O* in the RF they meet at *O'* in the MF, and by meeting at *O'* they traverse equal distances in MF too establishing simultaneity. This phenomenon is also a beautiful demonstration of RNL, that in the rest frame the flashes meet at *O* but in the MF they meet at O'. Let's apply the NT below.

1. Distances traversed: From (2), when flashes meet at point *O* of RF at *T*, the corresponding moving frame time for both flashes is *T'=eT*. Thus using (1), NT generates equal distances, *X'=cT'*, traveled by both the flashes in the MF.

2. Meeting Points: Instead of origin, if particle starts its journey from *X* in the rest frame at time *t=0*, then its final positions in the rest frame is, $x_f = X + x$, and in the moving frame both *X* and *x* are separately transformed as in eq (24) of [6],

$$x_f' = e\{X + m(x - vt)\} \qquad (6)$$

Using *x=-cT* for flash from blast B, *x=cT* for flash from blast *A* in (6), the positions of flashes in the MF at a time *T'* comes out to be zero. Thus, while flashes meet at *O* in the RF, they meet at *O'* in the MF and it is a beautiful demonstration of DPDF for photons. We derived the above equations using NT, but LT can also lead to the same, provided CR's assumption and interpretation of LT based on OPDF and RoS are discarded.

The mechanism behind this DPDF or RSC is RNL i.e the state of motion of the detector affects the position of detection of a moving particle or the flash in this case. Therefore this experiment not only tests RoS but also demonstrates RNL beautifully. The detectors in MF and RF have a relative velocity *v* between them and hence as has been shown [6,7,9,10] the position shift for a photon that has traversed *x* distance in RF is given by *vx/c*.

3. The setups to test the meeting point

As shown above in the indirect method the test of simultaneity boils down to the meeting point of the flashes and distances traversed them in the moving frame.

3.1 Setup A

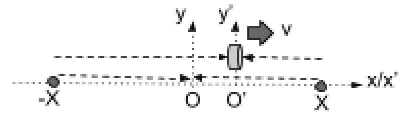

Fig 2. While pulses meet at O in the RF, they meet at O' on which placed a moving detector in the MF. O and O' aligned at the time of pulse emissions at X and -X.

Two sharp pulse emitting sources at *+X* and *-X* in the RF separated by a considerably large distance *2X* fitted with synchronized clocks that enable them to emit sharp but intense light bursts simultaneously at a time *t=t'=0* when *y* and *y'* are aligned, fig 6. As both

NR and CR agree on pulses meeting at *O* in the RF at a time *t=T=X/c*, let us harness the origin *O'* (along y'-axis) of the MF with synchronized pulse detectors that can record the time of receipts of the oppositely directed pulses in the MF from their sources in the RF. We can also use two detectors placed back to back at *O'* both either controlled by a single clock or their respective clocks synchronized with each other.

Thus, MF consists of this doubly faced moving detector system (MDS placed at *O'*) that passes through point *O* at the time of emission of the pulses at time *t=t'=0*, which is not difficult to ensure. Suppose after taking the experimental errors into account the MDS records the receipt times for both the pulses as t_a' and t_b'. CR predicts a path difference of $c(t_a' - t_b') = 2vX/c$ for two pulses to reach at *O'* to a first-order approximation. By increasing *v* and *X*, we can ensure that the cumulative experimental errors are much smaller than $2vX/c$. With such a setup, the RoS is refuted if

$$c(t_a' - t_b') << 2vX/c \qquad (7)$$

thus, invalidating OPDF as well.

Thus, within the experimental error limits $\varepsilon < 2vX/c$, if this measured path difference is found to be zero,

$$c(t_a' - t_b') = 0 \pm \varepsilon \qquad (8)$$

then the tenets of strict NR like RNL, RSC, and DPDF are validated once and forever, and CR's interpretation of LT based on OPDF and RoS is unequivocally refuted.

3.2 Setup B

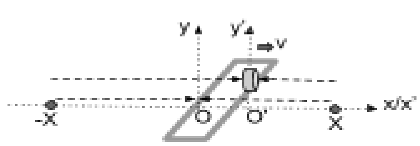

Fig 3. Setup two with a strip painted gray such that MDS is triggered twice when it passes over the gray strip once at O and next at O'. The moving system detects both pulses when it aligns with O' i.e. vX/c distance right to O, confirming that in MF the pulses meet at O' whereas in the rest frame they meet at O.

Even more effective way that frees us from stringent temporal measurement is based on spatially localized sensing of the pulse using spatially limited electric path shown as gray strips in fig 3. Devise a rectangular gray strip such that the left side of it passes through fixed origin *O* and the right side lies at *x=vX/c* which is the position of *O'* when the flashes meet at *O*. Think of gray strips as some engraved metal path at a high voltage which enables the detection window of the moving frame detector (MFD) as it passes through it. MFD passes the right branch of the gray-strip at time *t=T=X/c* when *O* receives the two flashes simultaneously. CR predicts that the two pulses will reach at *O'* with a path difference of *2vX/c* while the NR predicts they reach with a path difference of zero. This gray strip can be a spatially limited EM field or simply a metal strip held at a high voltage, which triggers the MFD for a spatial window equal to its width *w*. For *w < vX/2c* will ensure that at *T* MFD will miss both the pulses according to the CR but will receive both the pulses according to the NR. So, this right-side branch of the strip suffices to prove the NR and refute the CR. However, we can run another MFD just *vX/c* distance behind the primary MFD at *O'*, so that this second MFD crosses over the left branch of the gray-strip passing through *O* at time *T* to exclusively conclude that at instant *T*, when *O* receives the two pulses, this second MFD though crossing *O* at time *T* does not receive the two pulses, thereby categorically negating the OPDF of the CR. Through repeated experimentation, one can confirm that the primary MDS while at *O'* as shown fig 3, receives the two pulses as and when the stationary detector at *O* receives them, but the second MFD passing the left strip at *O* fails to do so.

The importance of this setup B over setup A is that here stringent temporal sensing window requirements are converted to spatially limited sensing windows. Obviously, the pulse width response window and cumulative path errors need to be << *vX/2c*.

5. Conclusion

Train embankment thought experiment which is most often used to establish RoS has been analyzed under NR. Both CR and NR disagree on the distances traveled and the meeting points in the MF of the two simultaneous emitted flashes in the RF. Therefore, two experimental setups are designed and proposed on the lines of this thought experiment that can discriminate between NR and CR. Papers [7-14] are our attempts to explore various aspects of the NR further. Moreover, If CR's interpretation of LT based on OPDF and RoS is dropped then neutral math LT does not contradict the tenets of NR like DPDF, RNL, and RSC. Paper [15] extends the NT to static energy fields.

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