

Scrutiny of Einstein's Causality

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Abstract: In the present paper, the so-called Einstein's causality is scrutinized and proven to be an illusion, a sort of mathematical fiction, and the causality as a well-established universal principle would be absolutely valid for subluminal, luminal and superluminal signals under any natural and/or artificial circumstances. It is also shown that any attempt to apply special relativity theory to superluminality of physical phenomena would be a complete waste of time since this theory has the light speed in vacuum as an upper limiting speed in its proper validity domain of applications.

Keywords: Causality, special relativity theory, light speed in vacuum, superluminal signals

1. Introduction

Due to the very old common *misconception* about the causality principle and its possible violation by (hypothetical) superluminal signals, which historically goes back to Einstein's note published in 1907 [1], many textbooks and research articles denied completely the real possibility of signal speed faster than the vacuum speed of light. For example in a paper titled 'Causality and the Speed of Sound' [2], the Authors clearly refused to recognize the reality of superluminal physical phenomena because according to them, causality might be violated if there is really a physical signal faster than c ; and they refused or omitted to refer to a number of important theoretical and experimental works on the topic published in *Nature*; *Science*; *Phys. Lett. Rev.*; *Phys. Lett. A* .etc, and particularly the papers [3-9].

The Causality Principle in the sense of common conventional belief is in fact an assumption according to which the information traveling faster than light speed in vacuum represents a violation of *causality*. Such a postulation remains valid only in the context of special relativity theory (SRT) because of Lorentz transformations (LTs); which are exclusively applicable to the inertial reference frames in relative uniform motion with subluminal velocities.

Therefore, if causality is really a universal principle it would be valid for subluminal, luminal and superluminal velocities because, after all, causality simply means that the cause of an event precedes the effect of the event. For instance, a massive particle is emitted before it is absorbed in a detector. If the particle's velocity was one trillion times faster than c , the cause (emission) would still precede the effect (absorption), and causality would not be violated since, here, LTs should be replaced with superluminal spatio-temporal transformations (STs) for the reason that the particle in question was moving in superluminal space-time not in Minkowski space-time. Consequently, in superluminal space-time, "*the superluminal signals do not violate the Causality Principle but they can shorten the luminal vacuum time span between cause and effect.*"

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Normally, when we speak about the superluminality of physical phenomena, SRT should be naturally overlooked since it is not concerned with superluminality. SRT is a robust and valid theory only in its proper domain of applications, i.e., when the relative velocities are relativistic. Hence, superluminal physical phenomena must be studied in the framework of another physical theory, which will be structurally built on superluminal space-time as a seat of superluminal events and will have the STs as a cornerstone.

It seems certain authors have forgotten that the validity of any physical theory is limited to its proper domain of applications and the perpetual development and vivacity of Science is strongly dependent on these validity limits. For example, the validity limits of classical mechanics led to relativistic mechanics. Since the latter having vacuum light speed as an upper limiting speed thus, as already pointed out, superluminality does not belong to the domain of SRT, and as a result SRT is not related to superluminality of physical phenomena and any attempt to apply SRT to superluminal motions would be waste of time.

Einstein himself was clear on this matter because, in order to separate SRT from superluminality, he had repeatedly stated the following in his papers: *“For velocities greater than that of light our deliberations become meaningless; we shall, however, find in what follows, that the velocity of light in our theory plays the part, physically, of an infinitely great velocity.”* [10]. Note, however, the occurrence of the expression *‘in our theory’* this means that vacuum light speed is, in fact, seen as an upper limiting speed only in SRT-context because of LTs.

The theoretical, observational and experimental evidence of the (apparent) superluminal motions at micro and macroscopic scales allows us to suggest that in Nature there are three kinematical levels (KLs), namely, subluminal-KL, luminal-KL and superluminal-KL in which the physical phenomena may manifest at subluminal, luminal and superluminal velocities, respectively. Also, each KL should be characterized by its own group of spatio-temporal transformations. For example, subluminal-KL is characterized by the Galilean group for subrelativistic speeds ($v \ll c$) and by the Lorentz group for relativistic speeds ($v < c$), luminal-KL and superluminal-KL would be characterized, respectively, by luminal and a superluminal group for luminal ($v = c$) and superluminal speeds ($v > c$).

From all this, we arrive, again, at the following result regarding causality. If causality is really a universal principle, it would be valid in all the KLs. Consequently, in such a case, we can say that there are in fact three kinds of causality, viz., subluminal causality, luminal causality and superluminal causality, and each kind is characterized by its proper circumstances.

The main role of each group of spatio-temporal transformations is the study of the chronology of events defined by the couple (*cause, effect*). This implies that we cannot study, e.g., superluminal causality with the help of the Lorentz group and vice versa, i.e., we cannot apply the group of superluminal transformations to subluminal causality.

2. Einstein's causality is an illusion

Returning to causality as a series of events happening in well-defined chronological order, we shall show that Einstein's application of the addition theorem of velocities (ATV) to superluminal velocities in order to prove the violation of causality is, indeed, incorrect, not only because SRT is clearly inapplicable to superluminal motions, as we have already seen, but also because superluminal velocities as such should be defined in superluminal space-time, not in Minkowski space-time. Thus, physically, we cannot apply ATV to superluminal velocities since ATV itself is only valid for subluminal velocities, without forgetting that ATV is derived from LTs, which are uniquely valid for subluminal velocities, which is why Einstein [1] had, in this case, rightly affirmed that "*A relative motion of reference systems with superluminal velocity is incompatible with our principles.*"

Therefore, from the above considerations, as we shall also see, Einstein's proof of causality violation via ATV applied to superluminal velocities is unphysical.

Einstein's proof [1] is as follows: "*From the addition theorem of velocities results the further interesting consequence, that no action can exist which can be utilized for arbitrary signaling and which has a propagation speed greater than that of light in vacuum. In fact, suppose a material strip extended along the x -axis of S , relative to which a certain action can be propagated with the speed W (as judged from the material strip), and let observers who are at rest relative to S be situated both at the point $x=0$ (point A) and at the point $x=\lambda$ (point B). Let the observer at A send signals to the observer at B by means of the aforementioned action, through the material strip, which is not at rest but moves with the speed v ($v < c$) in the direction of the negative x -axis. The signal is then, according to the first of equations (3), carried from A to B with the speed $(W-v)/[1-(Wv/c^2)]$. The time T required for this is therefore*

$$T = \lambda \left(1 - \frac{Wv}{c^2} \right) (W-v)^{-1} .$$

The speed v can take on any value smaller than c . If therefore, as we have assumed, $W > c$, we can always choose v so that $T < 0$. This result signifies that we must consider as possible a transmission mechanism that allows the intended action to precede the cause. Although from a purely logical point of view this result does not contain, in my opinion, any contradiction, yet it clashes so much with the character of our whole experience, that the impossibility of the assumption $W > c$ appears thereby to be sufficiently proven."

3. Physical view point

Einstein wrote this note in 1907 (see Ref. [1]); that is more than a century ago - with the express purpose of showing the clash between causality and superluminal signals.

It is clear from the above that Einstein violated his own theory in an unphysical manner because he deliberately applied ATV to superluminal speeds to prove the violation of causality by superluminal

signals. However, the way in which this proof was constructed constitutes a major contradiction from the physical view point, particularly, when we take into account the fact that the speed of light in vacuum is an upper limit in SRT.

Furthermore, as has been said, superluminal signals do not propagate in Minkowski space-time but in superluminal space-time as an arena in which superluminal physical phenomena may occur.

4. Mathematical view point

If we put Einstein's treatment under closer scrutiny, especially the assertion "*If therefore, as we have assumed, $W > c$, we can always choose v so that $T < 0$* ", we find that for Einstein, the inequality $T < 0$ is a criterion or sufficient condition to claim that the effect precedes the cause and consequently causality is violated by superluminal velocity.

4.1. First counterexample

However, mathematically, we can always get the same inequality even when $W < c$. To this end, let $\forall k, k' \in (1, +\infty) \subset \mathbf{R} : k > k'$ so that $W = c/k$ and $v = c/k'$. Thus after substitution we get

$$T = \left(1 - \frac{1}{kk'}\right) \left(\frac{1}{k} - \frac{1}{k'}\right)^{-1} \frac{\lambda}{c} < 0. \quad (1)$$

Since there is an infinite set of couples (k, k') satisfying the above conditions, we can affirm that by assuming $W < c$, we can always choose v so that $T < 0$. Therefore, this counterexample shows us that the inequality $T < 0$ cannot hold the status of a criterion or sufficient condition to prove violation of causality.

4.2. Second counterexample

This second counterexample is more important because mathematically, and *only* mathematically, we demonstrate that even when $W > c$, we can always choose v so that $T > 0$. With this aim, let $\forall k, k' \in (1, +\infty) \subset \mathbf{R} : k < k'$ so that $W = kc$ and $v = c/k'$. Hence following substitution, we find

$$T = \left(1 - \frac{k}{k'}\right) \left(k - \frac{1}{k'}\right)^{-1} \frac{\lambda}{c} > 0. \quad (2)$$

In view of the fact that there is an infinite set of couples (k, k') satisfying the above conditions, we can therefore mathematically state that by supposing $W > c$, we can always choose v so that $T > 0$.

Finally, as a pedagogical illustration, we have listed in Tables 1 and 2 – according to the conditions of the first and second counterexamples – some numerical values for the inequalities (1) and (2).

k	k'	T (λ/c)
1.50	1.25	– 03.50
1.75	1.50	– 06.50
2.00	1.75	– 10.00
2.25	2.00	– 14.00
2.50	2.25	– 18.00
2.75	2.50	– 23.50
3.00	2.75	– 29.50
3.25	3.00	– 35.00
3.50	3.25	– 41.51
3.75	3.50	– 48.51

Table 1: Some numerical values for the inequality (1) when the signal is supposed subluminal.

k	k'	T (λ/c)
1.50	2.00	2.500×10^{-1}
2.00	2.50	1.250×10^{-1}
2.50	3.00	7.694×10^{-2}
3.00	3.50	5.263×10^{-2}
3.50	4.00	3.846×10^{-2}
4.00	4.50	2.941×10^{-2}
4.50	5.00	2.325×10^{-2}
5.00	5.50	1.886×10^{-2}
5.50	6.00	1.562×10^{-2}
6.00	6.50	1.315×10^{-2}

Table 2: Some numerical values for the inequality (2) when the signal is supposed superluminal.

5. Conclusion

It has been revealed herein that authors of textbooks and research articles deny the physical reality of superluminality at micro and macroscopic levels and refuse to recognise the real possibility of superluminal signals. The so-called Einstein causality and its supposed violation have been proven to be a pure illusion due to a sort of mathematical fiction. We have also shown that the theoretical, observational and experimental evidence of superluminal motions did not threaten SRT because the superluminality of physical phenomena did not belong to the domain of SRT since SRT has the speed of light in vacuum as an upper limit. Therefore, any attempt to apply SRT to superluminality will be a complete waste of time.

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