Interpretational Scenarios of Special Relativity

A MONOGRAPH

ON

SPECIAL RELATIVITY THEORY

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This monograph is an evolving document and is updated regularly.

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INTRODUCTION

This monograph was motivated by the following question posted by the author at the ResearchGate (RG) Website:

In the context of Special Relativity (SR): is it time dilation, clock frequency increase, both of the above or none of the above?

This question may seem overbeaten, but the evidence is that in spite of hundreds, perhaps thousands, of answers in RG posts related to this question, the controversy seems endless.

This question is not about the veracity, verifiability or validity of SR formulation; because I believe there is enough empirical evidence to attest to the formulation. This post is about its possible interpretational scenarios with respect to time; therefore none of the above is here for completeness, but not as part of the question. If you are convinced that SR formulation is totally invalid, unverifiable or not falsifiable, this may not be the proper question for you to answer. Consequently, this leaves us with:

***Time dilation**. By this I mean the local or nonlocal dilation of time (of the dimension) itself, where the concept of time is not invariant to motion.*

***Clock frequency increase**. In the case of natural clocks such as atomic clocks, in contrast to mechanical clocks, the frequency of clocks (number of clicks/time-cycle) varies with local motion. In this case, the concept of time is absolute (nonlocal) and invariant to local speed.*

***Both of the above**. I hope this is not your answer because if it is, I believe we are up the creek without a paddle, but please explain.*

At the writing of this document there were over 520 RG postings related to the above question by many different scholars/researchers, both proponents and dissenters of Special Relativity. The discourse of the answers clearly shows in my opinion that most of the apparent incongruencies mentioned in the posts about Special Relativity were not necessarily because of its formulation, but because of the different interpretations that arise from the physical effects that the Lorentz Transformation (LT) predicts. This is not to say that SR has or has not problems as a theory but that its general acceptability is hampered by the many interpretational paradoxes that can be formulated because of its notoriously ambiguous concepts regarding time dilation and length contraction. Not surprisingly, the concepts of relativistic momentum and energy were not subject to scrutiny, I suspect because of their already accepted relative nature and their established relativistic relation to motion as empirically demonstrated in particle accelerators and the like.

Needless to say, most of the so called incongruencies that were posted dealt with time dilatation, as to its meaning or as to whether it is real or apparent. As usual on RG posts, many of the answers were diametrically opposed.

In this monograph, I propose a comparative scenario of SR that is shown to be free of incongruencies or paradoxes.

INTERPRETATIONS OF SPECIAL RELATIVITY

Because of SR's first postulate (the invariance of physical laws, etc.) SR relations must be reciprocal between two inertial reference frames (IRFs). In other words in a single or double IRF scenario, it is totally oblivious to the observer as to the absolute direction or the magnitude of motion, due to the absence of an established absolute IRF.

Reciprocal Special Relativity

Additionally, in the case where two IRFs are involved, either IRF can be chosen as the proper frame, thus leaving us without any possible way of determining an absolute statement of motion, therefore the LT results in reciprocal relations between both IRFs. This is what I mean by Reciprocal SR (RSR). As a side note, there is nothing new being stated here, we are just establishing names for different scenarios of SR.

As stated by Albert Einstein, SR deals only with the kinematics of particles and with the exception of his second postulate (the isotropy of the speed of light) he addresses only one of the wave properties of matter in general, but does not address its wavicle[1] (Compton and de Broglie) properties.

This monograph limits the discussion to the particle properties of matter and their relation to SR so as not to confuse the issues. Consequently, the kinematic behavior of wavicles in relation to SR, although a very insightful subject, is left to be treated in another future monograph by the author.

PARTICLE SCENARIOS OF SPECIAL RELATIVITY

Particle scenarios are the standard way of interpreting SR, because they are understood by most scholars and because they are the subject of most textbooks on SR. I will examine these here because they are the most often mentioned and therefore also mostly criticized.

RECIPROCAL SPECIAL RELATIVITY

There are two principle ways of interpreting time dilation, does the time dimension dilate or do clock frequencies decrease? Let's look at the two possibilities:

The time dimension dilates

The following are implications of a dilated time dimension.

If the time dimension dilates with relative motion:

[1] A reference to absolute time is undefined in SR, nonetheless time dilates locally at each remote IRF while observed from the proper frame. This is acceptable if the time dimension has some kind of "fabric" (substance), but it is not very useful without an absolute time reference.

[1] The term *wavicle* in this context refers to the wave properties of objects, as in de Broglie matter-waves. The term *wavicle* was coined by Arthur Eddington in 1928.

[2] Because of reciprocity (symmetrical relations), each observer sees the other's time dimension dilated. This is not rationally acceptable as a physical effect because it implies that the motion of a remote particle somehow affects its local time dimension (more than one time dimension?!!). Additionally, the accepted concept of simultaneity requires modification in order to explain the reciprocal behavior, thus leading to, what I believe, are meaningless statements due to the absence of an absolute time reference. In other words, the concept of simultaneity cannot be redefined unambiguously without an absolute time reference.

[3] Therefore, reciprocal time dilation is an apparent (not a real) physical effect.

Clock frequencies decrease

If clock frequencies decrease with relative motion:

[4] Time dilation is interpreted to mean that a clock's period increases (dilates) with motion, therefore decreasing its frequency.

[5] In this scenario, the time dimension is invariant to motion, which is a very reasonable physical interpretation.

[6] Nevertheless, reciprocal frequency decrease suffers from the same ailments as reciprocal time dilation (see Implication [2] above).

[7] Reciprocal frequency decrease, although a rationally acceptable physical effect is also apparent.

By the same reasoning:

[8] It can be shown that all of the effects implied by RSR are apparent physical effects.

[9] The physical effects implied by the formulation of RSR are all apparent because of its dismissal of an external motional reference.

[10] Without an external motional reference, RSR's formulation is correct but not useful in determining its real physical effects.

Observations on Reciprocal Special Relativity

- ✓ Special Relativity, as its name implies, does not postulate or consider, in any shape of form, the possibility of an absolute IRF (AIRF).
- ✓ Nevertheless, setting the proper's frame velocity to zero implies its assignment as the stationary IRF (SIRF); therefore, it is illogical to assign stationary qualities to both IRFs. This is a common interpretational scenario which leads to contradictions.
- ✓ In order for RSR to make any sense, only one of the IRF's must be exclusively chosen to be the SIRF for the obvious reason that there is no way of determining the "real" stationary one. In other words, both IRF's cannot be real SIFRs unless their relative velocity is zero, in which case SR becomes irrelevant.
- ✓ Choosing one IRF exclusively as the SIRF, resolves contradictions in the calculated relativistic effects, but without another motional reference they are still not completely real (they are inaccurate).

So far we have established that RSR is valid but not fully useful to determine physical effects. Does that mean that we need to throw SR away? No such thing! Let' not throw away the baby with the bath water!

SR's concept of relative velocities is very similar to the concept of reciprocal (relative) distances between two points and yet nobody wants to throw that concept away. I don't hear any complaints about not being to determine the "real" distance between two points in the absence of an absolute spatial reference. Why? Because all we need is a third point and because it doesn't make any difference if the third point is not at the origin and because any point can be set as a new origin. Consequently, let's see what happens if we introduce a third IRF into the SR formulation to act as an external motional reference. We will call this scenario Comparative SR (CSR).

COMPARATIVE SPECIAL RELATIVITY

Without having to assign any particular motional geometry to SR let's introduce a motional reference ISR which is collinear (on the same geodesic) with the other two IRF's of RSR. To be practical (useful), we will call this IRF the stationary reference frame (F_s) and the other two relative IRFs the terrestrial frame (F_t) and the rocket frame (F_r) respectively, F_t at the center of the earth and F_r at a rocket travelling in either direction from the earth. Because F_s can be motionally placed on either side or in the middle of the reciprocal frames, we can choose, for a forward trip, to place F_s next to F_t. The motional configuration looks as follows:

Forward trip: $\boxed{F_s} \longrightarrow \boxed{F_t} \longrightarrow \boxed{F_r}$

Return trip: $\boxed{F_s} \longleftarrow \boxed{F_r} \longrightarrow \boxed{F_t}$

COMPARATIVE MOTIONAL CONFIGURATION

Comparative length contraction

Now, let's apply the Reciprocal SR length contraction relation to each of the relative frames (F_t and F_r) from the newly established proper frame F_s, to see how that particular aspect of the formulation behaves as to its physical implications,

(1) $L_t = \frac{L_s}{\gamma_{ts}} = \frac{L_s}{\gamma_t} = \frac{L_0}{\gamma_t} = L_0\sqrt{1 - \left(\frac{v_t}{c_0}\right)^2}$, where,
L_t is the contracted length of a particle (as observed from F_s) moving with the center of the earth at a velocity v_t relative to F_s, with $v_s = 0$, so that F_s is set at the motional origin of the configuration,
$L_s = L_0$ is the real/absolute length of the particle as observed at F_s and
$\gamma_{ts} = \gamma_t$ is the Lorentz factor observed at F_s due to velocity v_t, relative to F_s.

Also,

(2) $L_r = \frac{L_s}{\gamma_{rs}} = \frac{L_s}{\gamma_r} = \frac{L_0}{\gamma_{t+rt}} = L_0\sqrt{1 - \left(\frac{v_t+v_{rt}}{c_0}\right)^2}$, where,
L_r is the contracted length of a particle (as observed from F_s) moving with the rocket at a velocity $v_r = v_{rs} = v_t + v_{rt}$ relative to F_s,
v_{rt} is the velocity at F_r relative to F_t and
$\gamma_{rs} = \gamma_r = \gamma_{t+rt}$ is the Lorentz factor at F_s due to velocity v_r relative to F_s.

Finding the limits of *Eq. (2)*,

(3) $\lim_{v_t \to 0} L_r = L_0\sqrt{1 - \left(\frac{v_{rt}}{c_0}\right)^2}$ and
(4) $\lim_{v_{rt} \to (c_0 - v_t)} L_r = 0$, as expected.

Observations on *Eq. (1)* to *Eq. (4)*

- ✓ *Equations (1)* and *(2)* represent the length relations of Comparative SR (CSR).
- ✓ Particles at each IRF are theoretically identical particles.
- ✓ The same set of two equations will result independently of where F_s is motionally placed, in the middle or on either side of the other two reciprocal IRFs.
- ✓ The proper length value L_s of a particle at F_s can be substituted in both equations by the absolute (real) length of a particle at absolute zero motion L_0, because L_s is measured with a contracted length ruler (it is a proper length), which makes both length values identical.
- ✓ The absolute accuracy of the calculations of all relativistic effects do not depend on the magnitude or sign of the absolute velocity at F_s, because all measured properties at F_s are proper effects.
- ✓ The relative calculated effect values behave differently depending on the signs and magnitudes of the velocities involved, and will remain real relative effects with different real behavior depending on the magnitudes and signs of v_t andv_{rt}.
- ✓ As can be easily shown, similar comparative relations can be obtained for all relativistic effects, including clock frequency decrease, momentum increase, energy increase, etc.
- ✓ Both equations represent real (physical) lengths because they are both in terms of the real length L_0 of the particle.
- ✓ Because both relations result in real physical lengths, any contradictions or paradoxes implied by them can/will invalidate SR as a theory.
- ✓ *Eq. (3)* represents one limit of CSR, which reduces to RSR, when F_t is assumed equivalent to the stationary frame ($v_t = 0$).
- ✓ *Eq. (4)* represents another limit of CSR, which also reduces similarly to RSR, when the speed of the rocket approaches $c_0 - v_t$, where the limit is reached sooner or later depending on v_t.
- ✓ As *Equations (3) and (4)* show, both limits of CSR reduce to RSR, which means that for a small v_t relative to c_0 RSR is accurate enough, thus making it a practical scenario as long as F_t is exclusively chosen as the stationary IRF.

Let's see if the Ladder paradox is resolved by using CSR.

Observations on the ladder paradox

According to Wikipedia, Oct. 2014:

> *The ladder paradox (or barn-pole paradox) is a thought experiment in special relativity. It involves a ladder, parallel to the ground, travelling horizontally and therefore undergoing a Lorentz length contraction. As a result, the ladder fits inside a garage which would normally be too small to contain it. On the other hand, from the point of view of an observer moving with the ladder, it is the garage that is moving, so it is the garage which will be contracted to an even smaller size, thus being unable to contain the ladder. This apparent paradox results from the mistaken assumption of absolute simultaneity. The ladder fits into the garage only if both of its ends are simultaneously inside the garage. In relativity, simultaneity is*

relative to each observer, and so the question of whether the ladder fits inside the garage is relative to each observer, and the paradox is resolved.

The Ladder paradox is meant to apply to Reciprocal SR, nevertheless, as we have shown above, all length related effects of RSR are apparent (not physically real), therefore it has no real relevance. On the other hand, from the point of view of CSR, the paradox also does not apply, because all observations are made from the stationary frame, which makes them real, and the ladder is contracted more than the garage as long as it is moving faster, thus fitting in it without a problem.

Under CSR, if the ladder's stationary length is equal to the garage's stationary length, the following real conditions apply:

- ✓ If the ladder (F_r) approaches the garage (F_t) at a faster speed $(v_{rt} > 0)$ relative to F_s than the garage, the ladder will fit within it, because the ladder is physically contracted more than the garage.
- ✓ If the ladder approaches the garage at a slower speed $(v_{rt} < 0)$ than the garage, the ladder will not fit within it, because the garage is more contracted than the ladder. This would be a real physical effect, without any contradiction.
- ✓ There is no problem if the ladder and the garage are traveling at the same speed $(v_{rt} = 0)$.

As you can see, under CSR, there is no need to resort to relative simultaneity or to an absolute IRF, in order to render the ladder paradox inapplicable.

I suspect all RSR length paradoxes and contradictions can be resolved by applying CSR, with the caveat of some real physical effects, as in the Ladder paradox. You can think of CSR as relativity with an external motional reference. I leave it to the reader to try CSR with other length paradoxes.

Comparative frequency decrease

For the sake of further completeness, let's take a look at CSR in terms of clock frequency decrease. Paralleling equations *(1)* and *(2),*

(5) $f_t = f_0\sqrt{1-\left(\frac{v_t}{c_0}\right)^2}$, where,

f_t is the decreased frequency of a clock moving with the center of the earth at velocity v_t (as observed from F_s),

$f_s = f_0$ is the real/absolute frequency of the clock as observed at F_s.

Also,

(6) $f_r = f_0\sqrt{1-\left(\frac{v_t+v_{rt}}{c_0}\right)^2}$, where,

f_r is the decreased frequency of a clock (as observed from F_s) moving at a velocity $v_r = v_{rs} = v_t + v_{rt}$ relative to F_s,

v_{rt} is the velocity at F_r relative to F_t.

A good exemplary test for CSR would be the Twin paradox. Let's take a look at it.

The Twin paradox

According to Wikipedia, April 2016,

In physics, the twin paradox is a thought experiment in special relativity involving identical twins, one of whom makes a journey into space in a high-speed rocket and returns home to find that the twin who remained on Earth has aged more. This result appears puzzling because each twin sees the other twin as moving, and so, according to an incorrect naive[1][2] application of time dilation and the principle of relativity, each should paradoxically find the other to have aged more slowly.

This paradox also gets rendered irrelevant to RSR because of the apparent nature of its physical results. On the other hand, applying it to CSR, results in the following physically real effects:

- ✓ On the forward trip, according to *Eq. (6)*, the travelling twin ages slower than the one on earth.
- ✓ On the return trip, because of the negative sign of its return speed, the travelling twin ages faster, because of the slower comparative speed of the earth relative to F_s.
- ✓ Furthermore, depending on the speed of the return trip, the travelling twin could return older, the same age or younger that the twin on earth. Older if the return trip is faster than the forward trip, the same age if equal and younger if slower.

Again, strange physical effects occur, but without contradictions. Additionally the paradox gets resolved, without resorting to changes in acceleration or switching of IRFs.

CONCLUSIONS

So far we have found that SR can predict the tested kinematic physical effects properly, as long as its formulation is applied from a third stationary IRF. Obviously all possible paradoxes need to be resolved before declaring CSR as a catch all.

The following are the salient conclusions of this monograph:

- ✓ All physical effects of Reciprocal SR are apparent, because of its lack of an external motional reference.
- ✓ There is no need for SR to consider either variant spatial or variant temporal dimensions.
- ✓ Clock frequency decrease is a more acceptable relativistic effect than time dilation.
- ✓ A third stationary reference frame F_s can always be used to formulate CSR.
- ✓ Physical properties measured at F_s are physically real and are identical in value to those at an absolute (definable or not) IRF.
- ✓ Without an external motional reference, RSR's formulation is correct but not useful for determining its real physical effects accurately.
- ✓ For a small v_t compared to c_0, both limits of CSR reduce to RSR, which means that RSR is accurate enough, thus making it a practical scenario as long as one reciprocal IRF, such as F_t for example, is exclusively chosen as the stationary IRF for comparative measurements.
- ✓ Using CSR, there is no need to resort to relative simultaneity, absolute IRFs, changes in acceleration, changes of IRFs, or any other additional conditions to SR in order to render paradoxes inapplicable.

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About the Author

Bernardo Sotomayor Valdivia is an independent scientific researcher born in León, Nicaragua. He has degrees in Physics and Systems Engineering, as well as advanced studies in Information Systems. He participated in the US space program, including the Viking program at Jet Propulsion Laboratory, NASA, in Pasadena CA and was for many years Chief Technology Officer for various start-ups in e-commerce within the US. He now writes on Infrarealism and Infophysics.

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Bernardo Sotomayor Valdivia

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