Twin Paradoxes

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Several paradoxical aspects of the twin problem of special relativity theory are reviewed, with the conclusion that none has been permanently resolved.

1. Introduction

There are several forms and numerous "resolutions" of the famous twin paradox. In the earliest form, due to Einstein, a space traveler traverses at uniform speed v a closed polygonal path, on each leg of which his motion meets the requirement of rigorously inertial motion characteristic of special relativity theory (SRT). At each vertex of the polygon the traveler's "jump" to the new inertial system is marked by no change in his clock setting—the initial clock setting on each new leg of the journey being stipulated to be identical to the final reading on the previous leg. Under these conditions the theory predicts that if the total duration of the journey is measured by an (inertial) "stay-at-home" observer fixed at the initial vertex to be T, then the total elapsed proper time of the traveler will be T/γ, where $\gamma = 1/\sqrt{1-v^2/c^2}$. Thus the traveler ages less or "stays younger" than the stay-at-home for travel trajectories of any shape (as approximated by a polygon).

Later forms have simplified the polygon to a single out-and-back trajectory at constant speed v, either employing a single non-inertial traveler who is accelerated at the turnaround point of the journey, or else employing three inertial observers—one who stays at home, one who goes out, and one who comes back. In either case the clock-setting convention stipulated above for vertices of the polygon is applied at the turnaround point. As before, SRT predicts that the traveler's clock, on return, will show less elapsed time for the completed journey than the stay-at-home's clock by a γ -factor.

2. Primary Paradox: Symmetry-Asymmetry

Such an asymmetry of aging is not inherently paradoxical. The traveler has manifestly experienced energy state changes not experienced by the stay-at-home. These physical differences may well affect differently the running rates of their co-moving clocks—just as gravity potential energy state changes (are known from other theory and observation to) affect such clocks. Nevertheless, there is a paradox here, in that the theory, SRT, that predicts the observed *asymmetry* of elapsed time intervals is itself founded upon a relativity postulate generally considered to assert a *symmetry* among inertial observers and frames regarding their measurements. This postulated symmetry is in fact explicitly expressed by the Lorentz transformation, which shows *clock rates* between two inertial systems in relative motion to be measured symmetrically. That is to say, timekeeping symmetry is a feature of the Lorentz group. *How is it then, that symmetrical clock-rate measurements can give rise to asymmetrical elapsed time-interval measurements?* Let us call this the "primary paradox."

Most twin paradox resolvers restrict their attention to this primary paradox. Typically, they show that rigorous applications of the Lorentz transformation to the out-and-back motions, with clock settings matched at the turnaround point (vertex) as stipulated above, lead to the elapsed time asymmetry; whereas clock rates are symmetrical between traveler and stay-at-home during each moment of the journey (*i.e.*, each "measures" the other's clock as running always slower than his own). This seeming contradiction between clock-rate symmetry and elapsed-time asymmetry is usually explained in terms of the "relativity of simultaneity." Observers at rest in the outgoing and incoming inertial frames have different ideas about distant simultaneity. At the instant of turnaround the outgoing observer, according to SRT, measures the distant stay-at-home's clock reading as $T_1\left(out\right)=(D/v)\left(1-v^2/c^2\right)$, given that the trip started at time zero, where D is the length of the outgoing or incoming journey as measured in the stay-at-home's rest frame. [Derivations are omitted here.] At that same instant and place of turnaround the incoming observer measures the distant stay-at-home's clock reading as $T_1(in)=(D/v)\left(1+v^2/c^2\right)$. In passing we note that the average of these two distantly-measured time values, $[T_1(out)+T_1(in)]/2=D/v$, agrees with the stay-at-home's measured time of the distant turnaround event; so in this instance the relativity of simultaneity is removable by averaging.

At the turnaround event the incomer's clock, by stipulation, is set to equal the reading $(D/v)/\gamma$ of the outgoer's clock at that event. (The γ-factor comes either from the Lorentz contraction of D measured by the outgoer or from the time dilation of the outgoer's clock measured by the stay-at-home.) By symmetry, the incomer ages the same amount as the outgoer in covering the same travel distance

D at the same speed v, so the traveler's total aging is $\left(2D/v\right)/\gamma$. Such is the stay-at-home's deduction about the traveler's aging. The stay-at-home's measurement of his own aging is of course $2D/v$, in agreement with the traveler's "staying young" by a γ-factor.

The aging attributed by the traveler to the stay-at-home is much trickier. The usual approach is to take the incomer's word for the stay-at-home's age at the turnaround event, $T_1(in)$, and to add to it the incomer's inference about the stay-at-home's aging during the return leg of the journey, which is seen to be $(D/v)/\gamma^2$ (one gamma factor from the Lorentz contraction of the distance D and the other from clock-slowing attributed by the traveler to the clock of the relatively-moving stay-at-home). The total aging attributed by the traveler to the stay-at-home is then

$$T_1(in)+(D/v)/\gamma^2=(D/v)\left(1+v^2/c^2\right)+(D/v)\left(1-v^2/c^2\right)=2D/v,$$

in agreement with the stay-at-home's own measurement and with the accepted result (observationally confirmed by CERN and GPS data) that the traveler's total aging noted above, $\left(2D/v\right)/\gamma$, is less than that of the stay-at-home by a γ-factor.

It will be observed that, although the theory thus comes up with the "right answer," it does so by a method widely viewed as illegitimate. For the fact that the incoming and outgoing inertial observers disagree on the stay-at-home's clock reading at the event of turnaround, $T_1(in)\neq T_1(out)$, is normally construed by relativists to mean that such distant clock-readings are "meaningless." (See McCrea's[1] refutation" of Dingle. Another term often used is "irrelevant.") Their meaning is merely a *conventional* one, born of the "Einstein clock-setting convention." That is, since different inertial observers disagree about them, they have no objective validity and are not useable for making legitimate deductions about physical facts. Yet that is exactly what we have done above in determining the traveler's "measurement" (or inference) of the stay-at-home's aging. We used the supposedly meaningless quantity $T_1(in)$ in deducing the right answer, $2D/v$. Had we used the equally meaningless "measurement" of the outgoer, $T_1(out)$, we would have got a wrong answer,

$$T_1(out)+(D/v)/\gamma^2=(2D/v)\left(1-v^2/c^2\right).$$

So, how is it possible that outgoing and incoming inertial observers are "equivalent" (*per* the symmetry of the Lorentz group), yet only the "measurement" by one of them leads to the right answer?

Suppose we require SRT to be strictly consistent with itself. (Here we adopt a purist viewpoint.) The relativity principle, as embodied in the Lorentz group, declares all inertial observers to be in some sense equivalent. When inertial observers disagree on their "measurements," such measurements—as a reflection of this principle, so embodied—must seemingly be either irrelevant to physics or meaningless. The incomer cannot be "right" and the outgoer "wrong," for that confers a preference incompatible with the symmetry properties of the Lorentz group. The very fact of observer disagreement is to be taken as proof (or definition) of "meaninglessness" of the associated measurements. The measurements of $T_1(in)$ and $T_1(out)$, if either of them is irrelevant to physics, may thus be judged equivalently meaningless, hence both irrelevant to physics. Consequently we can rule out the use of *either* $T_1(in)$ or $T_1(out)$ in calculations of other observable quantities. But, deprived of both these quantities (and of all similar inferences of distant simultaneity)—the theory cannot be used by either the traveler or the stay-at-home to make any legitimate inferences whatever about total agings during the journey. Viewed from this purist perspective, SRT defaults on the topic: It lacks any rigorous way of dealing with it, consistently with its own logical structure as expressed in the measurement symmetry of the Lorentz group.

The traveler must thus, strictly speaking, consider the stay-at-home's "total aging" as itself a meaningless concept. The same must be true for the stay-at-home's inferences of distant simultaneity, once we have ruled out such inferences by inertial observers in general. Since the concept of total aging during the journey is obviously physically *meaningful* for both traveler and stay-at-home—is in fact "absolute," in view of co-location of the associated events—paradox is conserved. The claim of SRT's "self consistency" in *explaining* how asymmetrical elapsed times result from symmetrical clock rates is, from the purist's standpoint, void. The attempt logically to deduce asymmetry from symmetry has failed. Asymmetry comes into established analyses[2] only through the asymmetrical introduction of the meaningless number $T_1(in)$. The primary paradox is not resolved, despite the fact that a Minkowski space diagram clearly shows the elapsed time asymmetry … and experimental evidence leaves no room for doubt about the factuality of that asymmetry in nature. Nature is unambiguous; she has simply not been meaningfully described. The reason is presumably SRT's limitation to description of inertial motions by the symmetrical Lorentz transformation—which seems to exclude the possibility that physical work done asymmetrically on clocks in altering their states of motion, or any other physical cause, is to be recognized as affecting *clock rates* asymmetrically in an objective way.

3. Second Paradox: Relative Clock Rates

Paradox resolvers are usually content to show (perhaps spuriously, as argued above) that all paradox vanishes from the twin problem when the symmetry-asymmetry aspect is dealt with. But their resolutions always entail the assumption (based on the Lorentz transformation) that each of two inertial observers measures the other's clock as running slow. This in itself seems paradoxical enough to merit analysis as a second paradox. The basic scenario pictures a space traveler on some arbitrary closed polygonal path measuring the stay-at-home's clock at every moment throughout the journey as running slower than his (the traveler's) own clock. Yet upon his return the traveler finds that the stay-at-home has aged more, not less, than himself. He is not supposed to be surprised by this outcome, because SRT has purportedly told him all about the actual (opposite) elapsed time asymmetry to be expected. But I argued above that a rigorous application of the special theory—which bars resort to the "meaningless"—blocks such a deduction. So, the traveler has every right to be surprised.

If the traveler's co-moving (proper-time) clock runs at some rate that we may designate *R*, the Lorentz transformation tells him that the stay-at-home's clock runs continually at rate R/γ, whereas observation at the end of the journey tells him that the stay-at-home's clock must instead have run continually at the rate $R\gamma$. [A simple time transformation formally reflecting this factual state of affairs is $t'=\gamma t$, with inverse $t=t'/\gamma$. This shows a reciprocal symmetry, as supported, *e.g.*, by GPS evidence[3]. It corresponds to a physically *objective asymmetry* of clock proper-time running rates in different motional (or gravitational) states—in apparent disagreement with the Lorentz transformation.] How does SRT deal with this apparent rate discrepancy? Many stories are told.

One told by Taylor and Wheeler,[2] although not on the cutting edge of current SRT expository fashion, may serve as typical. Their claim is that at the turnaround event of the out-and-back motion a distant clock resetting or clock phase-jump occurs, such that the outgoer's notion of distant simultaneity is replaced by the incomer's notion—which subsequently prevails. That is, $T_1(out)$ is replaced by $T_1(in)$, and the latter is relied upon thereafter by the traveler as his basis for inferences about the stay-at-home's aging. We have seen that this leads to the right answer, but at the cost of ascribing meaning to the "meaningless" quantity $T_1(in)$. To make any operational sense of this approach, we must suppose the traveler to recognize that prior to the turnaround event a false story about distant simultaneity told him by SRT has misled him about the stay-at-home's clock reading; that a clock phase resetting is necessary to correct this misleading impression; and that, after the resetting, the theory has given up its tricks and is subsequently telling him the truth. But the resetting in question is a change from $T_1(out)$ to $T_1(in)$ attributed by the traveler *to the reading of the distant stay-at-home's clock*. Thus it corresponds to no operation performed by any observer. Nobody can actually *do* this resetting. It has to take place not physically but by analytic consensus, under the aegis of a Minkowski diagram or the equivalent. Its locus is the head of the traveler, where it acts to modify his inferences.

Being that as it may, there remains the difficulty faced by the traveler to reconcile (in his head, the locus of his inferences) with his *personal experience* what SRT is telling him. By that theory he has been told, prior to the turnaround event, that the stay-at-home has aged comparatively little, some small amount $S = T_1(out)$ (equal to the outgoing traveler's own self-measured aging, $(D/v)/\gamma$, divided by γ). He has been told this as a physical ("measured") fact. At the event he is told to forget all that and to switch ideas about distant simultaneity—consequently to infer a sudden great advance of the stay-at-home's age, a jump J in that age. [$J = 2Dv/c^2$.] He is further told that after the event the stay-at-home ages another small amount S during the return journey (by symmetry of the outgoing and incoming legs of the total journey). Thus the stay-at-home's total aging inferred by the traveler is not $2S$ but $2S + J = 2D/v$, which is γ times greater than the traveler's own total aging during the journey, as it should be.

Suppose, based on an assumption of the steady running of idealized clocks, or upon our experience of actual clocks left undisturbed, we impose a condition of *uniform running* rates of all clocks, regardless of their motions. If time is measured in seconds, and clocks tick once each second, then the outgoing observer (according to SRT) measures the stay-at-home's clock as ticking S times during the outbound leg of the journey, and the incoming observer symmetrically measures the stay-at-home's clock as ticking S times during the inbound leg; so the two of them measure a total of exactly $2S$ ticks of the stay-at-home's clock during the whole journey. Nevertheless, we have seen that the traveler attributes to the stay-at-home's clock a total of $2S + J$ ticks because of a time jump J or clock resetting resulting from the relativity of simultaneity. Yet our condition of uniform clock running, dictated by experience, tells us that if $2S + J$ ticks of the stay-at-home's clock occurred during the whole journey then during the outbound half of the journey $\left(2S + J\right)/2 = S + J/2$ ticks of that clock must have occurred. By symmetry, since inbound and outbound legs cover the same distance D at the same speed v, $S + J/2$ ticks must also have occurred during the inbound half of the journey. But if only S of those ticks were "measured" during each of the inbound and outbound legs, then the outbound and inbound observers must each have lost track of J/2 ticks. A total of J ticks seem to have disappeared. That is of course ridiculous, as shown by any of the numerous published analyses of electromagnetic signals exchanged between traveler and stay-at-home, emitted at regular rates throughout the journey.

Since the traveler personally measures (receives signals betokening) all $2S+J$ ticks of the stay-at-home's clock, it appears to be false that he "measures" only $2S$ of those ticks or signals. But that is what SRT (the Lorentz transformation) insists upon. Thus relativists accept that $2S$ ticks are "measured" and $2S+J$ ticks received. That is indeed an apparent paradox, but it is readily explained within the ambit of SRT. The key to this aspect of the problem is to be found in the details of the measurement procedure. The $2S$ "measurement" is performed, not by a single observer, but by a spatially extended set of co-moving observers at rest in a moving inertial frame (each of whom is personally present locally at the emission of one of the successive ticks), whereas the $2S+J$ ticks are received by a single inertial observer (the traveler, a particular member of that set). The fact that space affects time, according to the Lorentz transformation, implies that the spatial displacements of the co-moving set members affect their collectively measured time flow rate, thus accounting for the failure of the moving traveler to "measure" J of the ticks. Such an explanation will satisfy most relativists. However, since all measurement procedures are identical between the traveler and the stay-at-home, whatever may be said in this regard about the one can be said about the other, and no explanation of the observed asymmetry can be given without introduction of the moral equivalent of the one-sided J-jump (an inference of the traveler only).

But what is the traveler to make of this quantity *J*? Let us suppose him to be not a mathematician but an ordinary astronaut. As such, he possesses certain experiences of real life to draw upon, which do not include miracles or magic. He knows that in all his personal experience he has never encountered a biological process that undergoes anything analogous to a clock resetting, time skip, or phase jump. He therefore must be skeptical of any theory incorporating measurement methods that imply an aging discontinuity *J*. The traveler could believe a genuine aging *rate asymmetry*—that he stays steadily younger than his earthly twin. That would contradict none of his experiences, because he has no direct experience of travel at "relativistic" speeds. But the claim that time skips, or that biological clock phases can jump, challenges not only his experience but his credulity—not to mention the testimony of his earth-bound twin, the witness most directly concerned. Clock rates thus furnish the material for another form of paradox that the theory has produced but not fully resolved.

Defenders of the theory will point out that the clock-phase jump of the stay-at-home is not real because it is only an attribution or inference by the traveler, not something directly observed by anyone. This of course is true, but it is no mitigation of the paradox. What kind of theory is it that obtains its right answers by concatenating manifestly false stories? In this case the right answer given by SRT is the (differing) elapsed times of traveler and stay-at-home between the events of departure and return … but this truth is attained only through the necessary telling of what appear to be lies about the stay-at-home's clock behavior. In order to fit with the right answer of great aging of the stay-at-home, it must be a lie that the stay-at-home's clock runs slower than the traveler's. The theory asks the traveler to celebrate a truth attained through mutual compensation of apparent falsehoods: Falsehood #1, that the stay-at-home's clock appears to run slower than the traveler's; falsehood #2, that the stay-at-home's clock appears to jump.

A better face can be put on these apparent falsehoods by recognizing them as *artifacts* of the traveler's measurement method (employing a spatially extended set of clocks co-moving with the traveler, as mentioned above). But the simple truth, thoroughly obscured by these artifacts, is that the stay-at-home's clock runs *steadily faster* than the traveler's. In principle, every (idealized proper-time) clock runs uniformly at *some* rate, without jumps. This is a basic premise of proper time. The observed outcome in the twin problem fits only with the stay-at-home's clock having run steadily faster (by a γ-factor) than the traveler's. This is the objective fact, embodying experience with clocks as idealized quantifiers of "time." It is hidden by SRT's Lorentz transformation, which asserts an apparent clock-rate symmetry, rather than the observed clock-rate reciprocity. This obscuration (call it, to be generous, a paradox) is in no way mitigated by the acknowledged capability of the theory to account correctly for the asymmetry of elapsed times; for the theory itself (by hypothesizing an unrealistic dependence of timekeeping on distance) has unrealistically *severed the logical connection between clock rates and elapsed times*—by depicting the former as symmetrical and the latter as asymmetrical. No longer, says SRT, do these two have to exhibit mutual consistency—because we have adopted a method of "measurement" that artificially precludes such mutual consistency (a) by employing a spatially extended set of measurement devices instead of a single detector, (b) by attributing to space an influence on time for which there has never been direct observational evidence.

4. Another Paradox: The Meaning of Meaninglessness

The concept of "meaninglessness" alluded to above merits some attention to its paradoxical aspects. It is not a concept that arises spontaneously within any physical theory, but is one introduced from outside to hide (by a master stroke of verbal obfuscation) discrepancies between theory and experience. Besides SRT, is there any other physical theory in which meaninglessness plays a role? Yes, meaninglessness is a well-known last resort for saving cherished theory of any kind. In Newtonian mechanics the concept emerges wherever imaginary velocities occur, and often where unrealistic negative values of positive-definite parameters arise. In Maxwell's field theory meaninglessness is traditionally applied to the "advanced solutions." These are in conflict with experience, hence unwanted, hence swept under the rug as physically meaningless. Mathematically, they are just as good (*i.e.*, just as meaningful) as the accepted retarded solutions; but physically they lack plausibility or relevance. They are indispensable to the mathematical structure of electromagnetic theory, but bear no readily discernable relationship to physical experience. Common sense says to junk them and for once common sense is listened to. That any physical theory should incorporate manifestly non-physical elements is surely in some degree paradoxical—although perhaps not more so than the basic premise of theoretical physics, that mathematics can describe physical experience (meaninglessness being always handy to gloss-over any incident shortcomings). Our invention and application of the concept of meaninglessness to the results of a particular theory is actually a vote of confidence in that theory—since without it we should be forced to acknowledge that the theory erred.

So it is with the quantity J discussed above. It may best be considered meaningless, not only operationally but conceptually; since it corresponds to nothing either physically existing or operationally measurable, but is purely the product of an arbitrary choice to honor the SRT conception of "distant simultaneity" of the incoming traveler rather than the outgoing one … although both are inertial observers supposedly "equivalent." As Orwell might put it, the incoming inertial observer is more equivalent than the outgoing one. Such an arbitrary choice seems directly analogous to that involved in choosing Maxwell's retarded solutions over his advanced ones. In both cases, no stronger argument can be found than plausibility. One choice gives the "right answer"—the answer we are determined to get—the other the "wrong answer"—the one we are determined not to get.

Yet in this case even plausibility suffers, inasmuch as only the twin-problem assertions of a third party, the stay-at-home inertial observer, are truly plausible—for only they show the timekeeping *symmetry* (reflecting the spatial and speed symmetry) of outgoing and incoming legs of the journey that fits with common sense. The elapsed half-journey times on the two legs of the full journey ought to be equal … and only the stay-at-home (according to SRT) "measures" them to be so. (Recall that the traveler who attributes symmetrical aging $2S$ to the stay-at-home thereby gets the wrong answer … the right answer, $2S+J$, being apparently asymmetrical between the two legs of the journey.)

It is significant that the dubious "jump" quantity J is entirely absent from the stay-at-home's account. For this reason we can say that only his account is plausible. And in fact if we listen only to his account we are assured of getting the "right answer." (As a point of history, I seem to recall that one of the earliest twin paradox "resolutions" labeled the inertial observer a "good observer," and the accelerated one a "bad observer." The more it changes, the more it is the same.) We choose to listen to another account involving the fictitious J (if we do listen) only because we wish to make a genuflection toward an ideological principle—that of motional relativity, interpreted as implying equivalence of inertial observers. It is that genuflection which enmeshes us in paradox and forces us to wrestle with implausibility. Indeed, if the genuflectors were to get down on both knees instead of one, they would have to give as much weight to $T_1(out)$ as to $T_1(in)$—hence as much to the wrong answer as the right one.

If we would admit up front that the customary understanding of the relativity principle, as implying a symmetry of proper timekeeping among inertial systems (fostered by a corresponding symmetry of the Lorentz transformation), is just plain *wrong*, and that the CERN and GPS evidence points directly to an objectively asymmetrical (but reversible) rate-slowing of any clock that has had work done on it, we would be spared need for the above-mentioned genuflection and its attendant paradoxes. (And we would learn some physics.) But we would thereby also be spared SRT and its attendant truths, such as that "now" is an illusion, that we live "in" Minkowski space, or that, when clock A appears to run slower than clock B, clock B appears to run slower than clock A. And no card-carrying, pain-seeking physicist wants to be spared those particular barbed truths.

The upshot is that the various twin-related paradoxes force us to re-examine our interpretation of the relativity principle. Trouble arises whenever, impelled by the Lorentz transformation, we insist that time measurements be "equivalent" in different inertial systems. Is there any simple way of avoiding this trouble? Yes, of course there is. As long as we confine our statement of the relativity principle to its original form—that the *laws of nature* are the same in all inertial systems—trouble cannot arise. For this allows clock running rates to be affected (objectively altered) by the physical energy-imparting actions needed to alter the inertial states of motion of matter. An objective alteration of a clock's running rate in a new inertial system merely changes the meaning of the "second" in that system—hence it can be corrected by a compensatory alteration (*à la* GPS[3]) of time units. (So says Newton's Principle of Similitude.) The laws of motion or of nature remain invariant under changes of inertial system, in conformity with the just-stated, strictly limited, form of the relativity principle.

The Lorentz transformation fails to exploit this Similitude loophole in the relativity principle—a loophole whereby an objective asymmetry of proper timekeeping among inertial systems might be introduced into physical theory to honor directly the facts of observation. Instead, the Lorentz transformation goes beyond minimum requirements of the relativity principle to specify a rigorous symmetry of "measured" clock rates incompatible with the steady (non-jumping) running of clocks, measurements being made in an unrealistically contrived way by means of extended sets of detectors, compensated by an equally contrived dependence of time on space. (The latter derives from the assumption that Maxwell's equations must hold in all inertial systems—an assumption challenged in Ref. 3.) In short the Lorentz group incorporates a symmetry of "measurement" results not demanded by the original form of the relativity principle. The fact that this artificial symmetry can be made compatible with observation through an equally artificial conception of "measurement" via extended clock sets does not alter the possibility of shortcutting past these model artificialities by means of alternative theory descriptive of a factual (objective) timekeeping asymmetry resulting directly from asymmetrical physical causes.

In his SRT Einstein postulated the presence *on demand* of Gedanken reference frames in various inertial states of motion. He devoted no attention to the energy expenditures necessary to produce such states of motion through state *alterations* in the real world—or to the possible related effects on timekeeping of those energy expenditures. (The real world is a place wherein no matter arrives at a state of motion through postulation, only through being put into it by physical action.) The price exacted for this insouciance is the loss of any possibility of finding a physical cause for the observed phenomenon of time dilation. So enthusiastically has this price been paid by physicists that they no longer seek physical causation and would oppose any suggestion of the possibility, as incompatible with what they "know" about kinematics. If Nature thrust a physical cause upon them, they would not know what to do with it. Thus the door is closed permanently to exploration of alternative descriptive approaches. This closing has been done deliberately by physicists to their own beloved physics. If you doubt it, consult the announced editorial policies of established physics journals.

The twin paradoxes provide tantalizing glimpses of possibilities for more physically-based theories directly incorporating observed physical asymmetries of timekeeping. These may, *but need not*, be built upon ether hypotheses, since we have noted their possible compatibility with the original relativity principle (referring to "laws of nature"). In light of human nature (mob psychology) it is axiomatic that no alternative to SRT, no "test theory," will receive a fair hearing until arrival of the millennial era (also known as the "Second Coming") in which physicists become motivated to re-examine the foundations of their discipline. In that imaginary era they will begin to practice some of the humility to which their current arrogance lays claim.

5. Incidental Paradoxes: Spacetime

Among ancillary paradoxes implicated in the twin affair, that of SRT's central concept of *spacetime* stands out as worthy of attention. The idea that time is in some deep sense the same thing as space was historically the brainchild of Minkowski, but the geometrical language he employed to embody it proved useful to Einstein for his more general theorizings, and was soon incorporated integrally into the special theory. This idea is from the start paradoxical in the context of SRT conceived as physics, since a spatial dimension is plainly a single-valued quantity, a measure of linear extension marked by a single number. Time, in contrast, is subtler, not only in the sophistication of the devices needed for its measurement but in its basic conceptualization. Unlike space, it refuses to hold still. In the real world it has an inexorable tendency to "flow" or slip away. There is nothing we can do about this, but we can accept it and measure it by means of repetitive processes, called "clocks." These enable us, with the help of "calendars," to seize and label (but not to retrieve) a "moment of time" as epoch or date. But they also enable us, entirely apart from moments and labels, to speak of "clock rates." These we can imagine as correlated with the *flow of time*—although of course only relative significance can be attached to such a locution. Thus the parameter "*t*" we use mathematically to represent "time" can be conceived as serving a dual or bi-valued purpose: to designate a particular point in the flow or to represent the flow itself. From the ambiguity created by use of a single word and parameter for these two communicative purposes stems much confusion. Further ambiguity arises from whether "time" is endowed with a local or nonlocal connotation.

No such complexity attaches to the orthogonal space parameters *x*,*y*,*z*. Regardless of what may be assumed about the "state of motion" of hypothesized physical ethers, there is no logical compulsion to introduce a concept of "flow" in connection with space. Relatively to our laboratory, a point of space can be revisited, a point of time cannot. When a space dimension is asserted to be equivalent to a time "dimension," an essentially single-valued descriptor is being equated to an essentially bi-valued one. The subtleties of "time" and its measurement are swept away and discarded as if they did not exist. The only way this can be sold to a gullible public (or profession) is as "insight." That it may be, or that it may be NOT. It would be wise, or at least prudent, to consider the jury (after a century of SRT's *spacetime symmetry* hype) still out. Our era seems to be unique in its ability to manufacture physical "symmetries" out of the unsuspected infelicities of our physical models. We then have the fun of "breaking" those symmetries. That fun has yet to be exploited in regard to spacetime symmetry.

The distinction pointed out in Section 2 between clock rates and elapsed times is directly related to the bi-valuedness of time noted here. In the case of sinusoidal signals this bi-valuedness is marked explicitly by phase and frequency parameters. SRT in the twin problem emphasizes the split between these two concepts by making clock rates (when "measured" as symmetrical between two inertial observers) incompatible with elapsed time intervals (asymmetrical). [*Cf*. the "primary paradox," above.] This is like finding a method of "measurement" capable of making phase measurements of a sinusoid incompatible with frequency measurements. Thus SRT by its nature forces attention to a distinction between two aspects of "time," while asserting no such duality of space. That is, the "flow" aspect of time is distinguished from the "date" aspect (which undergoes the jump J), as a typical feature of the twin paradox resolution. Is it not paradoxical, then, that a theory that builds upon the radical concept of "spacetime," without a hyphen, should invoke the bi-valuedness of the linear time concept, in contrast to the single-valuedness of the linear space concept, merely to treat the first problem of non-uniform motion it encounters? But enough … Of the making of SRT paradoxes there is no end.

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