A NOTE ON THE 'TWINS PARADOX'

Dan Bruiger, May 2023

The thought experiment based on Einstein's reasoning has one twin leaving earth in a spacecraft travelling at a significant fraction of the speed of light.[1] This observer turns around eventually and returns to earth, to discover that he or she has not aged as much as the twin who remains at home. However, this cannot strictly be an effect of the time dilation described in SR. Like length contraction, the effect of time slowing down is a *mutual* perception during the period of uniform relative motion. Each observer then perceives the other's clock as beating at a slower rate than their own clock. However, if either keeps a *record* of the other's time (e.g. by having the rate of a second onboard clock set by the time signals received from the other), then *that* clock will continually fall behind the "normal" one on board. But the returning twin's normal clock has not "really" fallen behind and should read the same as the other twin's normal clock upon being reunited. In other words, "time" does not dilate, nor does the clock slow down; rather, the sequence of signals received from the other is stretched out. The "stretched out" version of one is then (mistakenly) compared to the "normal" version of the other.

Nevertheless, Einstein gives a physical example based on ontological reasoning: a clock at the equator moves faster (with the earth's rotation) than an identical clock near the pole; it should therefore beat at a slower rate. I don't know if that experiment has been performed—where the clocks are (slowly) brought back together at one location or the other. But the difference in rate due to difference in gravitational potential (the clock at the equator is further from the center of the earth because of the earth's oblate shape) would have to be taken into account, as well as the fact that it is constantly accelerating (by changing direction in orbit, i.e., centrifugal force).[2] The experiment that *was* actually performed involved an atomic clock flown around the world in an airplane, which was returned to compare to the identical "stationary" clock on the ground. Upon return, the airborne clock did differ from its twin on the ground. But the inertial path of flight was not uniform motion in a straight line, nor subjected to the same gravity as at sea level.[3]

The twins paradox is usually explained by pointing out the asymmetry in the state of motion of the observers. The twin who blasts off must accelerate to reach speed—and the effects of acceleration are not mutual as they are for uniform velocity. What makes us say that it is the *spaceship* which accelerates, rather than the earth? It makes a real difference whether the space ship accelerates away from the earth or the earth accelerates away from the spaceship. The difference involves the huge difference in mass of these objects, and the fact that the spaceship moves differently relative to the stars than the earth does. Energy is expended by the spaceship to propel itself while the earth does no such thing. (It would require a great deal more energy to accelerate the earth away from the spaceship than vice-versa!) This suggests that mass is responsible for the asymmetry in the twin paradox.[4] But then it remains to explain (in a non-circular way) what mass is, what is responsible for it, or how it arises.

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[1] His argument in the paper has two clocks that have been synchronized in the stationary system then separated. One clock then is then made to move with velocity v toward the other and thus lags behind the latter because of the motion. However, in any case it must be accelerated to reach v.

[2] Both of those effects (of General Relativity) should give the appearance that the clock at the equator *ticks faster*, unlike the time dilation of SR.

[3] See the analysis by Ilaria Bonizzoni and Giuseppe Giuliani "The interpretations by experimenters of experiments on 'time dilation': 1940 - 1970 circa" arXiv:physics/0008012{physics.hist-ph}

[4] A new version of SR considers the velocity relative to the center of mass between observers, so that the effect would be symmetrical only if they have equal mass. See: Abramson, N.H. (2018) "Asymmetric

The change of lengths and of rates of clocks predicted in SR refer to mutual effects, as communicated between moving observers by means of signals, where either frame of reference can be equally considered at rest. Since the *local* measurement of length and time by each observer does not depend on signals, the question is whether motion through "space" in and of itself has some objective (ontological) effect upon dimensions locally measured. The principle of relativity says that *uniform* motion should have no such effect (for otherwise the system would not be inertial as supposed). That leaves the possibility that there could be an objective effect from *acceleration* or (equivalently) gravitation. On the other hand, the so-called "clock postulate" maintains that acceleration has no effect on the rate of clocks in addition to that of the instantaneous velocity.[5]

Special Theory of Relativity" Journal of Modern Physics, 9, 471-478. Clocks on earth and in orbit would differ because of the difference in mass between the aircraft or satellite and the earth. For two satellites of equal mass in orbit about each other, the effects of time dilation would be mutual.

[5] Instantaneous rate of change depends on data obtained over a period of time—e.g. instantaneous velocity defined as the time derivative (slope) of an actual path through space, during which there could be acceleration.