

Time Dilation without Relativity

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October 13, 2016

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***Abstract:** In spite of all the scientific experiments which have confirmed that Time Dilation as described in Albert Einstein's Special and General Theories of Relativity ^[1,2] is a **real** natural phenomenon, it seems many physicists and mathematics-oriented scientists are viewing Time Dilation as simply an "illusion" resulting from "relativity," no different than momentarily believing that when you look out the window of a train, the train station is moving, not the train car you just boarded. This paper will show that Time Dilation is a real natural phenomenon and is best understood separate from Relativity.*

There are two types of Time Dilation, one resulting from velocity, the other caused by gravitation. In a typical situation both types are being experienced at the same time.

Gravitational Time Dilation is experienced when you change your location relative to the center of the Earth's gravitational mass. The farther you are from the center of the Earth, the faster time moves for you. This was confirmed and demonstrated in a 2010 experiment performed by the National Institute for Standards and Technology (NIST) and reported in a paper titled "*Optical Clocks and Relativity.*"^[3] The NIST experiment showed that gravitational Time Dilation can be measured if you raise an atomic clock by just one foot. Of course, the difference in time is so small that it is difficult to describe, so they used this explanation:

For example, if two identical clocks are separated vertically by 1 km near the surface of Earth, the higher clock emits about three more second-ticks than the lower one in a million years.

In other words, if you have two atomic clocks, with one positioned at the surface of the Earth and the other positioned 1 kilometer above the surface, after one million years of ticking, the higher clock will have measured the passing of three more seconds than the identical clock

on the surface. In the actual NIST experiment, the clocks indicated a time difference measured in picoseconds (trillionths of a second).

So, while Time Dilation is real, it is not noticeable in everyday situations. However, the key point is that the time difference is real, it is measurable, and the difference in time can be viewed and measured by just one person. Those who argue that without a second “frame of reference” there can be no Time Dilation are simply wrong.

There are organizations which keep track of the time as measured by different atomic clocks, i.e., the “International Atomic Time” or TAI, from the French name *Temps Atomique International*. Most notably, the *Bureau International des Poids et Mesures* (BIPM) in Sèvres, France, keeps track of data produced from 391 atomic clocks distributed all over the world in 69 different institutes (as of October 2010).^[4] Most of the clocks are located at National Metrology (weights and measures) Institutes. And, of course, the BIPM has to cope with Time Dilation as they work to produce the “Coordinated Universal Time” or UTC (*Temps universel coordonné*), which is the primary time standard by which the world regulates clocks and time.

In the 1970s, it became clear that the clocks participating in TAI were ticking at different rates due to gravitational time dilation.^[5] The NIST’s clocks in Boulder, Colorado, were at least 5,430 feet above sea level, while an atomic clock in Stockholm, Sweden, would likely be less than 100 feet above sea level. Today’s TAI scale therefore corresponds to an average of the altitudes of the various clocks. Starting from Julian Date 2443144.5 (1 January 1977 00:00:00), corrections were applied to the output of all participating clocks, so that TAI would correspond to proper time at mean sea level (“the geoid”). Because the participating clocks had been on average well above sea level, this meant that the official TAI second slowed down by about one part in a trillion, i.e., the official second became about one picosecond longer.

And clocks also tick slower when they are moving at some velocity, such as moving with the Earth as it spins on its axis. In this 1905 paper “*On the Electrodynamics of Moving Bodies*” Albert Einstein wrote that “a balance-clock at the equator must go more slowly, by a very small amount, than a precisely similar clock situated at one of the poles under otherwise identical conditions.” That is because a clock at the North Pole is essentially stationary and just slowly turning in place, compared to a clock at the equator, which is moving with the Earth’s surface at 1,674 kilometers per hour around the Earth’s axis.

There have been many experiments to confirm Time Dilation by putting atomic clocks on airplanes and flying them around the world,^[6] or by comparing the passage of time on an atomic clock at the bottom of a mountain and again at the top of a mountain.^[7] And every day the atomic clocks aboard GPS satellites have to be adjusted by 38 microseconds to correspond with clocks on Earth. Due to the satellite’s velocity, time runs slower by 7 microseconds per day at the satellite’s location than it does on Earth, and due to the satellite’s altitude, time runs faster by 45 microseconds per day. ($45 - 7 = 38$) If the adjustments weren’t made, errors in global positions would accumulate at a rate of about 10 kilometers each day.^[8]

Naysayers argue that Time Dilation cannot be real. It would mean that Time moves more slowly at your feet than for your head. And that does not make sense – if you believe that Time is just a concept or an idea.

It makes perfect sense, however, if you examine the facts and evidence which confirm Einstein's conclusion that all time is local. The fact that we are **aware** of time and the passage of Time does not mean we invented Time. What it means is that we should try to **understand** how Time works.

The Twin Paradox Re-Visualized

Paul Langevin's so-called "Twin Paradox"^[9] takes on new importance when you stop trying to describe people magically viewing different clocks across trillions of miles of space. If you use just **one** clock that can be seen by both the traveling twin and by the stay-at-home twin, relativity no longer has any meaning to the experiment.

So, why not use a single **natural** clock - a pulsar? We just need to pick one that pulses at an easy-to-use rate -- say one pulse every 10 seconds. Using such a pulsar "clock,"

1 pulse every 10 seconds = 6 pulses per minute.
6 pulses per minute = 360 pulses per hour, or
8,640 pulses per day, or
3,153,600 pulses per year, or
31,536,000 pulses in TEN years, or
31,553,280 pulses when you include 2 leap year days.

So, let's assume that, on January 1 in the year 2500, a pair of astronomers who also happen to be 25-year-old twins, decide to perform a Time Dilation experiment. The two astronomers' names are Homebody Jones and Traveler Jones.

The experiment will involve Traveler Jones taking a space ship on a journey toward Alpha Centauri. Alpha Centauri is 4.3 light years away from Earth, and it is one of the nearest stars to our Solar System. Homebody Jones will wait back home on Earth.

Since there is no way for either twin to see what is happening with the other twin via some magical, instantaneous TV signal, Time Dilation will be measured by counting pulses from that distant pulsar.

The experiment is planned to take exactly 10 years, Earth time. They have determined that, aboard the space ship, Traveler Jones will have to travel at about 99.5% of the speed of light before the effects of Time Dilation will enable him to observe that same pulsar pulsing at an average of 1 pulse every 1 second.

As the space ship begins to accelerate, time starts to slow down due to time dilation aboard the space ship, and the number of pulses per minute from the pulsar appears to increase. Traveler records the pulses as arriving more and more quickly until the ship reaches its cruising speed where the pulses are recorded as arriving at a rate of slightly more than 1 pulse per second (to compensate for the time spent accelerating).

Life and time aboard the space ship, however, will seem to be ticking along normally. Traveler feels no effects from the slowing down of time aboard the ship. He still goes to bed at 11 p.m. as measured by various clocks aboard the space ship, he still gets up at 7 a.m., he still has to shave every morning, he still eats breakfast at 7:45 a.m., etc. He is unaware that his observational and cognitive powers have slowed down, it simply seems that everything outside of his space ship is going faster. To Traveler, the pulses from the pulsar are coming at a faster rate. He can also see that, from his perspective, planet Earth completes one orbit around the Sun about once every 36.5 days.

When he reaches a point in the direction of Alpha Centauri where they calculated he would need to turn around, Traveler does so.

Then, on January 1, 2501, according to the clocks aboard the space ship, Traveler arrives back on Earth. He is now 26 years old - biologically.

Homebody Jones is waiting at the spaceport. On Earth it is January 1, 2510. A comparison of elapsed time shows that Traveler experienced 1 year while, from Homebody's point of view, Traveler was gone for ten years. During that time, Homebody aged 10 years biologically. He is now 35 years old -- nine years older than his twin brother.

They compare the results of counting pulses from the pulsar, and both counts are exactly the same. From Traveler Jones's point of view:

**1 pulse (on average) every second = 60 pulses per minute.
60 pulses per minute = 3,600 pulses per hour, or
86,400 pulses per day for 365 days, plus
17,280 pulses to compensate for 2 leap year days equals
31,553,280 pulses counted during the ONE year trip.**

There were 31,553,280 pulses measured by both devices during the experiment. From his perspective, it took Traveler just 1 year to record that number of pulses. From Homebody's point of view, it took 10 years to record the same number of pulses. Neither twin counted more pulses than the other. And that means,

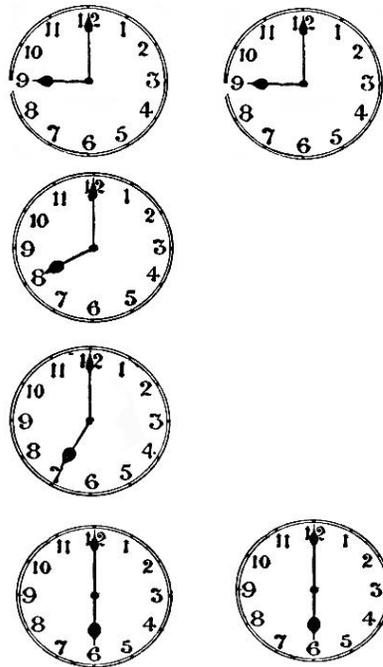
Neither twin was ever ahead of or behind the other in time.

No one went into "the future," and no one remained in "the past." The experiment simply confirmed "time dilation" and that all time is "local." Time slows down for a person or object traveling very fast.

If the Jones twins were to repeat the experiment with Homebody doing the traveling, the twins could once again be the same biological age. When Homebody returned, the twins would both be 36 years old - biologically.

Demonstrating Time Dilation

While Time Dilation has been repeatedly **verified** via experiments, those experiments involved travel and a lot of handling of the atomic clocks, which gives the naysayers some grounds for arguments. Someone needs to **demonstrate** Time Dilation with identical stationary clocks, so that a single observer (or a crowd of observers) can see all the clocks at the same time and can watch them tick at their different rates.



Time Dilation Verification Test

While the time difference between the six clocks in the illustration above would be just trillionths and billionths of a second and not easily visible by directly viewing the clocks themselves, there are devices which can show the time **difference** between atomic two clocks in billionths of a second. Therefore, if all six clocks are started at the same moment, the differences in time between the clocks would gradually accumulate on the display devices. The extra clocks at the bottom and top would further verify that the experiment isn't some kind of fluke. Those two clocks should measure time at the same rate as the clocks beside them.

Once again, the key point being made here is that Time Dilation works **without Relativity**. If a **single "observer"** can see all six of those clocks ticking in accordance with Gravitational Time Dilation, he can also see that **Relativity is not a factor in Time Dilation**. In other words, Time Dilation has been confirmed to be **REAL**, and it is time to move on to the next question: How does Time **work** if it passes at different rates in front of a single observer?

Time certainly isn't just a "concept." Concepts do not slow down when they get closer to the center of the Earth or when they travel very fast. Time certainly isn't a "process," since we can see that the biological process and other processes slow down when we create situations where Time slows down. Time controls the process, not the other way around.

The muon experiments^[10] indicate that time operates on a sub-atomic level, since a fast moving muon will "live" or exist longer than a slow moving or stationary muon.

We can all theorize about how Time works, but it's better if someone performs experiments to **demonstrate** how time works. The key points being made here are (1) Time Dilation is a real, it is a natural phenomenon, and it is not dependent upon Relativity; (2) although time may move at different rates for virtually everything and everyone, we all exist in the same "now;" and (3) there is much we do not yet understand about how Time works.

References

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[2] Albert Einstein – *The Foundation of the General Theory of Relativity* - 1916

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[4] Dirk Piester et al, - *Remote atomic clock synchronization via satellites and optical fibers* – March 2011

[5] https://en.wikipedia.org/wiki/International_Atomic_Time

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[7] <http://www.pbs.org/genius-by-stephen-hawking/episodes/episode-1/>

[8] <http://www.astronomy.ohio-state.edu/~pogge/Ast162/Unit5/gps.html>

[9] Paul Langevin – *L'Evolution de l'espace et du temps* - 1911

[10] https://en.wikipedia.org/wiki/Time_dilation_of_moving_particles