Essay on Time (1)

By Michael Lee, Founder of the Institute of Futurology
June, 2012

Since the future is a phase of time, we need to know what time is in order to understand the future. How can we acquire knowledge of the future if we do not know what it is?

The prevailing conception of time in physics, in my view, is the theoretical keystone of futurology.

Einstein showed in his 1905 paper, which launched his theory of Special Relativity, that time is not some sort of clock in the sky that ticks at the same rate for everyone. It still comes as a surprise to me every time I am reminded that time is neither universal nor separate from space.

The man chosen in December 1999 as Time's Person of the Century wrote in his 1916 book *Relativity*: "…there is no more common-place statement than that the world in which we live is a four-dimensional space-time continuum."[1] This deceptively simple sentence, written by the great man with a tinge of irony, is perhaps the most revolutionary scientific statement ever made.

[1] Einstein *Relativity* (1916) 65.

In the history of science, the notion of a four-dimensional world is equivalent in its world-changing impact to the Copernican Revolution which dethroned earth from its fixed, central position in the solar system. Space-time, and other aspects of the theory of relativity, corrected aspects of the Newtonian worldview which had prevailed for more than two centuries (218 years, to be exact).

What does it mean to live in this four-dimensional world of space-time identified by Einstein?

He pictured space itself as a three-dimensional continuum because "it is possible to describe the position of a point (at rest) by means of three numbers (co-ordinates) x,y,z."[2] The number of coordinates by which an object may be measured determines how many dimensions it has at its position in space. For example, the surface of the earth is two dimensional, encompassing longitude and latitude, but when one adds height above sea-level, a third dimension is introduced.

Cox & Forshaw (2009:5-6) refer to this 3-D space as a kind of giant box containing all the objects in the universe, including us.[3] Special relativity added a fourth value of time to space's three coordinates to form a 4-D continuum. We exist in this 4-D space-time.[4]

[2] Einstein *Relativity* (1916) 65.
[3] Cox & Forshaw *Why does E=mc*²? (2009) 5-6. "Our grid…defines an arena within which everything exists, a kind of giant box containing all objects of the universe. We may even be tempted to call this giant arena 'space'."
[4] Cox & Forshaw *Why does E=mc*²? (2009) 101.

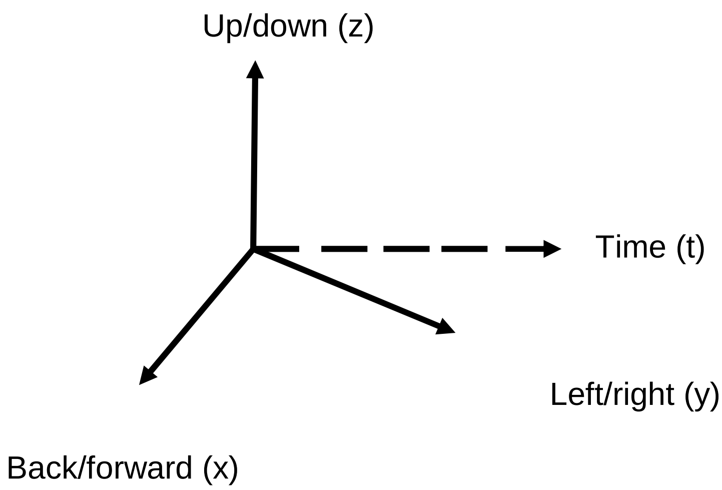

Figure 1: Fourth dimension of time (t) added to three space dimensions (x,y,z)
© Institute of Futurology

In Figure 1, time is a core co-ordinate used to measure motions and positions of objects in space: “An event, wherever it has taken place, would be fixed in space…by the three perpendiculars, *x,y,z* on the co-ordinate planes, and with regard to time by a time value *t*.”[5]

Let us suppose for a moment that you or I are the object being measured with these four co-ordinates. This experience could be visualised as a person inside a time bubble located itself within a 3-D space “box”.

[5] Einstein *Relativity* (1916) 39.

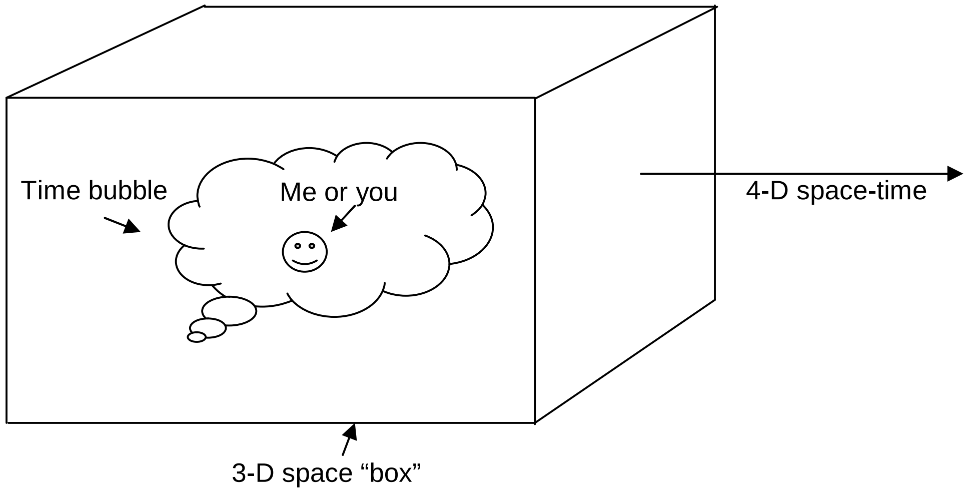

Figure 2: Living in four-dimensional space-time

Throughout our lives we are moving organisms within a 4-D reality where we have four potential directions, namely, up/down, right/left, forwards/backwards and *motion in time*. Einstein refers to these co-ordinates several times as magnitudes,[6] or measurements of important dimensions, which can be expressed in numerical values. He argued that the time co-ordinate "plays exactly the same role as the three space co-ordinates".[7] Space-time is a fusion of time and three-dimensional space.

Hawking describes space-time as follows: "…time and space are intertwined. It is something like adding a fourth direction of future/past to the usual left/right, forward/backward, and up/down…In space-time, time is no longer separate from the three dimensions of space."[8]

[6] Einstein *Relativity* (1916) 39.
[7] Einstein *Relativity* (1916) 67.
[8] Hawking & Mlodinow *The Grand Design* (2010) 99-100.

He characterises the past as the "backward" direction of time and the future as its "forward" direction. Our motion through time is just as real and just as important as our motion through space. It is interesting that Canadian Indians, for example, use language to express time as a form of distance, describing an elder has having "covered a long distance".[9]

Through his theoretical marriage of space and time, Einstein, in effect, spatialised time. He embedded time within space. The demystification and spatialisation of time in space-time makes it easier to gain scientific knowledge of the future. Since we already know a great deal about the spatial world in which we live, including the laws and principles by which it operates, we can better understand how time works as an extension of space in its role as part of space-time. The spatialisation of time enables us to build far clearer pictures of time's behaviour than previously. In turn, this gives insight into how the future works.

Newton's clockwork universe was replaced as the governing worldview of science by Einstein's more counter-intuitive, dynamic space-time world. In it, everything is relative to everything else except that its one cosmic constant is the speed of light. This has a blindingly fast and absolute speed of 299,792, 458 metres per second.[10]

---

[9] Bell *Foundations of Futures Studies – Human Science for a New Era,* Vol 1 (2003) 130.

[10] Mermin *It's About Time - Understanding Einstein's Relativity* (2005) 20. "..the speed of radar is the same as the speed of light..all forms of electromagnetic radiation (light, radar, radio, x-rays, gamma rays, TV signals, for example) have the same speed in empty space." We know that the speed of light is a constant of nature – that is the speed of light is the same for everyone:"There is overwhelming experimental evidence that the speed of light has the same value c with respect to any inertial observer." Mermin *It's About Time - Understanding Einstein's Relativity* (2005) 11.

Einstein discovered that, with the exception of light, all measurements of time and space, as well as events, are relative to the reference point from which they are observed. The word “relative” here is opposite to words like “absolute”, “universal” and “invariant”. The latter word means “quantities that everybody can agree on regardless of their frame of reference”.[11] “Relative”, by contrast, may be defined as: dependent upon changing frames of reference, where measurements of an object or event vary quite literally according to the vantage point from where they are viewed. For example, the event of a train passing an observer on an embankment would be perceived and measured differently by a passenger *on* the moving train.[12]

Einstein used this well-known example of the moving train in relation to an embankment to illustrate that motion is relative to the point of reference from which measurements of aspects of objects, such as speed, direction, etc., are made. Measurements of time and distance, too, vary according to where the observer is placed and whether he/she is at rest or in motion. This idea of the non-universality of measurements of time and distance constitutes the “relativity” within relativity theory.

---

[11] Mermin *It’s About Time - Understanding Einstein’s Relativity* (2005) 79. The frame of reference is the point or perspective from which an object is viewed and it could be at a state of rest, or inertia, or it could be a moving position.

[12] What relativity theory also shows is that there is no absolute motion or fixed centre to a universe in constant motion, but only relative motion, that is, motion as observed in relation to a chosen reference frame or point. The invariant or constant in the relative universe of Einstein is the speed of light, not any given geographical location in space. Since light’s speed is invariant, it is independent of all frames of reference: “This remarkable property of light – that its speed does not depend on the frame of reference in which it is measured – is today called the principle of the constancy of the velocity of light.” Mermin *It’s About Time - Understanding Einstein’s Relativity* (2005) 27. The speed of light is thus absolute, not relative. Einstein even postulated that a train’s motion is relative to the embankment it passes and, at the same time, the *embankment is in motion relative to the train* (my italics). See Einstein *Relativity* (1916) 69.

In relativity theory, time is *not* the same for every person or object in all positions and at all speeds, even though we instinctively sense it *should* be: "…according to classical mechanics, time is absolute, i.e. it is independent of the position and condition of motion of the system of co-ordinates… in the theory of relativity…time is robbed of its independence."[13]

To arrive at his relativistic understanding of time, Einstein conducted thought experiments involving stationary and moving clocks. He concluded that clocks in motion must move ("tick") more slowly than stationary clocks because the light emitted by the moving clock has further to travel than the light emitted by a stationary clock. The light in both cases travels at exactly the same speed, being absolute. For a clock in motion, the ticks literally take longer. Time measured by the moving clock, as a consequence, becomes marginally slower than would be the case for a stationary clock.

If time slows down, or changes, when objects are travelling at speeds, it cannot be a process or phenomenon which is independent from space in any meaningful sense. And it is not only speed that changes the actual rate of time.

---

[13] Einstein *Relativity* (1916) 66.

Gravitational mass also alters time's rate: "The stronger the field, the greater the effect (which is known as 'gravitational time dilation')."[14] Gravitational time dilation happens on earth and out in the planetary spheres. On earth, the time dilation effect is miniscule but real nonetheless. Close to black holes, however, *time slows down almost to a complete stop*: "…suppose that identical twins spend the night in bunk beds. One sleeps a meter above the other. The next morning, the twin who slept in the top bunk is a few trillionths of a second older…Close to a black hole, clocks run far slower than in empty space. Near the event horizon, the effective surface of the black hole, clocks come almost to a complete stop."[15] A black hole's gravity causes extreme time dilation.

The same force that distorts the rate of time, also warps space, strongly curving it.[16] Objects, for example, literally shrink at high speeds.[17] Moving objects have been shown to shrink along the direction of their motion in an extraordinary phenomenon known as the Fitzgerald contraction:[18] "Having accepted the fact moving clocks run slower than stationary ones, we are forced to conclude that moving sticks are shorter than stationary ones."[19]

Time, then, is relative. The relative nature of time is often illustrated by the fascinating twins paradox.

---

[14] Falk *In Search of Time* (2008) 173. This latter occurrence can be seen in the design of GPS systems which make allowances for the fact that clocks tick faster in weaker gravitational fields.
[15] Adams & Laughlin *The Five Ages of the Universe* (1999) 116.
[16] Adams & Laughlin *The Five Ages of the Universe* (1999) 117.
[17] Cox & Forshaw *Why does* $E=mc^2$? (2009) 54.
[18] Mermin *It's About Time - Understanding Einstein's Relativity* (2005) 55. "Any inertial observer will find that the length of a meter stick moving past him in a direction parallel to its length with uniform velocity v is less than the length of a meter stick that is stationary with respect to him…"
[19] Mermin *It's About Time - Understanding Einstein's Relativity* (2005) 55.

This is a thought-experiment whereby one twin is imagined to travel in a high-speed rocket close to the speed of light for several years (see Figure 5 below). When this space-travelling twin returns to earth, he/she will literally be a younger person than the earth-bound twin: "If one twin goes to a star 3 light years away in a super rocket that travels at 3/5ths the speed of light, the journeys out and back take 5 years in the frame of the earth….but the twin on the rocket will age only 4 years on the outward journey, and another 4 years on the return journey. When she gets back home, she will be 2 years younger than her stay-at-home sister, who has aged the full 10 years."[20]

This example seems like science fiction but it is based on scientific fact. It shows decisively that the nature of time is altered by spatial factors like speed.

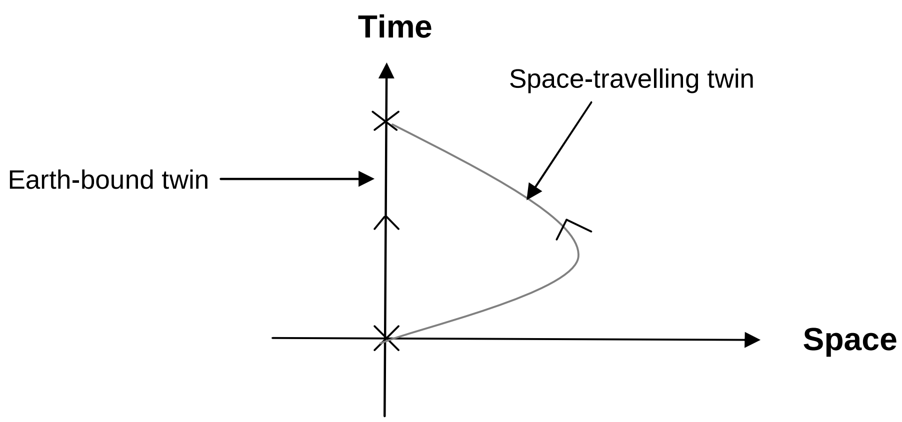

Figure 3: Illustration of the twins paradox
© Institute of Futurology

[20] Mermin *It's About Time - Understanding Einstein's Relativity* (2005) 123.

Einstein's model of space and time has been described as "the foundation on which all of modern physics rests..."[21] Yet the theory has not been fully absorbed by most people as part of our way of experiencing the world: "its basic notions are in direct contradiction to certain simple, commonplace notions that almost everyone fully grasps and believes, *even though they are wrong*." (my italics)[22]

The fact that Einstein's well-proven theory of time is highly abstract may be one of the main reasons why humanity, outside the realm of physics, has not yet taken on board the implications of his extraordinary conceptual discoveries. Certainly the study of the future has not yet embraced the far-reaching implications of his conception of time.

Extract from *Knowing our Future – the startling case for futurology.*

Note: this is the first of a series of essays on time. In Essay on Time (2), Lee will look at how Stephen Hawking deepened our modern understanding of time.

[21] Cox & Forshaw *Why does E=mc*²? (2009) xi.
[22] Mermin *It's About Time - Understanding Einstein's Relativity* (2005) vii.