Is there a physical mechanism responsible for what we perceive as time?

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I suppose I could just answer the question with a "probably" and then be on my way, but that wouldn't be much fun, would it? Okay, this is like asking what the nature of color is. Is there really color in the universe? Was there color before beings with visual perception came along? Well, there are all of the ingredients to make color, but color is really "created" by a specific processing of colorless electromagnetic radiation by visually perceptive beings from within. In short – we turn colorless waves into color.

What about temperature? What is the nature of temperature? Can we, on a physical level, explore the reason why hot "feels" hot and cold "feels" cold? Right now, I am in a room that is 72 degrees Fahrenheit. I feel pretty good. I don't need a coat – I am comfortable. Earlier, the room was much colder. I was physically uncomfortable and it put me in an edgy mood. It's amazing how differently the two experiences "feel" because the average velocities of the air molecules in the room have changed. The universe has no sense of "temperature" but there are atoms and molecules moving with various velocities that allow us to experience various temperatures.

Okay, now for time. What is the nature of time? To answer that I could go on for 20 pages about what we perceive time to be, from both a philosophical and psychological perspective. But even if I did – wouldn't we be ultimately interested in identifying some fundamental physical description for what we experience as time?

Let's start with what we know. The first thing we know is that we are not sure what time is. Physicists and philosophers have been searching for an answer since the beginning of physics and philosophy. Entire books have been written about it. A few years ago, an entire issue of *Scientific American* was devoted to it. The bottom line is that we still don't have an answer. The second thing we know is that time appears to play a pretty important role in the workings of our universe. Put the two of those thoughts together and we can assume that we will learn a whole lot more about how the universe works on the very same day that we discover what time really is.

I think one of the first things we should do is look for any possible clues from the fact that the rate at which time "flows" is relative. We currently know of two things that affect the rate at which time flows: velocity and gravitational position. So, what if we could determine *how* these two conditions affect the rate at which time flows? Wouldn't learning more about what makes time speed up or slow down help us learn more about what time itself actually is? I think this would be a great direction to go in. And the easiest way to begin examining this is to look at the body of work that is the accepted description of the conditions that affect time's flow. That work is Einstein's Relativity.

Einstein's first condition for the relative nature of time was made public in 1905, when he proposed that moving clocks run slower than stationary ones. He concluded this because he was having trouble resolving the two postulates that his theory of relativity would be based upon. The first postulate was that Galileo's principle of relativity would be preserved. This means that a frame of reference moving with constant velocity would enjoy the same laws of physics that a stationary frame would. If I am standing on a tennis court and throw a tennis ball straight up, it will come straight down. If I am on a train that is moving with constant velocity (often referred to as an inertial frame) and throw a tennis ball straight up, once again, unless it hits the ceiling, it will come straight back down to me. The moving train has become an independent inertial frame of reference. His other postulate states that the velocity of light should be considered constant, regardless of the velocity of the light source. Einstein knew that these postulates couldn't coexist unless some modification was made.

This is because Einstein imagined a traveler on a train with the ability to see a light beam generated from the back of the train car pass by him while the train is moving. Einstein said that the traveler would have to see the beam go by him at the exact speed of light – no more, no less. Otherwise, he would be able to tell that he was moving, and that would be a violation of Galileo's principle. Meanwhile, if an unsuspecting rancher on the edge of town happened to be looking in the windows of the train as it was rushing by him, he would see the light beam traveling faster than the speed of light, since the velocity of the moving train would get added to the original velocity of light, thus producing a new, higher velocity. Did I just say light traveling faster than light? Yeah, I guess I did. Well, anyway, the point is that it would appear that the man on the train and the rancher on the ground would not see the beam of light projecting with the same velocity. Since the constancy of light was Einstein's second postulate, something would have to give.

Einstein's resolution to this apparent conflict was to make time itself relative. What a concept! This suggested that clocks in different parts of the universe could run at different rates if they have different velocities. Einstein needed both the traveler and the rancher to see the beam of light propagating at the same speed and he concluded that this could be possible if we consider that time itself must run slower for the traveler on the train. He wouldn't notice because everything about his time would be running slower. This would allow his traveling frame to adhere to the principle of Galilean Relativity. If he pulled all of the shades down, he would not be able to conduct any experiment on the train to prove that he is moving (if the ride were quiet and smooth enough, that is) and his frame would observe the same laws of physics as his stationary friends on earth. Meanwhile, if the shades were pulled back up, since time on the train would be running slower than on the surface of the Earth, the rancher would see a train go by whose time is going slower than his, and this would adjust the light beam to the same constant speed of light that Einstein said it should remain as. This was Einstein's very reason for time being relative. He later described time as not being absolute but rather an inseparable connection between time and light velocity. This would make the rate at which time passes something that could speed up or slow down in order to preserve the constancy of the light signal velocity for various observers traveling at various velocities. And, by the way – the velocity of the train wouldn't slow its time by an amount that we would even notice but it would slow it just enough. It turns out the faster something moves, the more dramatic the slowdown effect is. So a rocket ship whizzing by the rancher would produce a much larger time-rate difference than the train.

So what can we learn about time from this? Can we establish a mechanism from this aspect of Einstein's theory? Let's continue and find out.

It turns out that after much analysis, Einstein's theory was met with some criticism. The relative nature of time seemed to solve one problem but it created another. Critics began to ask why the object in motion had the preferential privilege of slowing time while the stationary object did not. This was a big deal because Galileo's relativity, which was Einstein's first postulate, stated that the laws of physics should be the same in a moving vehicle as they are for a stationary observer. This suggests that all inertial motion is relative and each moving frame is its own independent system that is subject to the same physical laws. So, as the traveler on the train is whizzing by the rancher and the rancher decides to turn on his flashlight, the traveler would see the rancher's light beam potentially moving with a velocity faster than the constant value. Because of this, one could certainly make the argument that from the point of view of the traveler, it would be the rancher's time that would need to slow down.

This created a paradox because Einstein had already committed the traveler's time to run slower than the rancher's for the entire journey. So, if the train stopped and the traveler compared his wristwatch time with the rancher's (which would have been in sync before the traveler got on the train) the traveler's watch would be running behind the rancher's. They would no longer be in sync because time elapsed slower for the traveler while the train was moving.

There are two ways we could attempt to resolve this paradox. One way is to try to show that something is happening for the traveler during his inertial motion that is not happening for the rancher. It is interesting to note that there have been many attempts to do this, all the while insisting that somehow the first postulate (Galileo's relativity) would still remain intact. This has been done with the construction of world line graphs, space contraction theories and creative applications of the relativity of simultaneity concept. This, however, is not the way that Einstein resolved it. In 1918, Einstein published a paper that addressed this paradox. In it, he proposed how a traveler could experience a slower passage of time during a journey, compared to a stationary observer without violating Galileo's relativity.

Einstein's answer was that there is no preferential experience for the traveler during the constant velocity phase of the journey. In order to preserve the constancy of the light signal velocity, the traveler's time would slow down from the perspective of the rancher, but at the same time, the rancher's time would slow down from the perspective of the traveler. There is nothing wrong with your eyes. You really read what you thought you just read.

But how could that be? How can the traveler see time slow down for the rancher while at the same time the rancher sees time slow down on the traveling train? It doesn't make sense. Any other time we compare two things, we can rely on an equal but opposite assumption. If I am running faster than you, then you are running slower than me. If you have more money in the bank than I do, then I can also say that I have less money in the bank than you do. If I am taller than you, then you are shorter than me.

But apparently, if your clock is running slower than mine, than my clock is also running slower than yours. What do you say we go back to talking about color or temperature? Well, okay then, if this mind-blowing concept is true, then how does the traveler's wristwatch show a time that is running behind the rancher's when they reunite? They would each experience a slowdown from the perspective of the other, so then what happened to the traveler that didn't happen to the rancher? Answer: he accelerated.

What does that have to do with time?

Well, it turns out that between Einstein's first paper on relativity in 1905, and his paradox resolution of 1918, he was pretty busy. He came up with a nice little concept called General Relativity. This dealt with (among other things) how gravity would play a role in affecting space and time. From 1907 to 1916, Einstein fine tuned this theory that began with a simple but clever observation.

Einstein observed that someone in freefall would not feel gravity. They would be falling because of gravity, but they themselves would not feel gravity as they would while sitting in a chair. This means that if two people were each in their own elevator car, one freefalling from the eightieth floor of a high-rise and the other in outer-space with plenty of oxygen, they would both feel the same thing – no gravity. The person in the outer-space elevator car would feel weightless. She could take objects out of her purse and let go of them and they would all float in mid-air (along with her) in the elevator car. And what about the person in freefall back here on Earth? She would feel the same thing. See, once the elevator begins its freefall, then the elevator, the person, and all of her belongings would all fall at the same rate. So to the person in the falling elevator, it would seem like she is in zero gravity in outer-space. That is, until the elevator hits bottom.

Next, Einstein entertained the opposite scenario. Let's say that the person on the eightieth floor has the good fortune of not having her elevator cable snap. Then she, along with all of the rest of us will feel gravity. But if the outer-space elevator has a cable attached from the top of the elevator to a rocket ship that is accelerating through space, that person will also feel gravity as the floor is constantly "pushing" upward. Einstein then equated a gravitational field equivalent to a coordinate system in a state of acceleration. However, Einstein observed that unless relative time crept into this story too, we would have another problem on our hands.

This is because Einstein imagined light pulses being generated from the floor of the accelerating, outer-space elevator and traveling to the ceiling. He also imagined separate light pulses generating from the ceiling and traveling to the floor. Now, the light from the floor is traveling to the ceiling as the ceiling is constantly moving away from the pulses. Meanwhile, the pulses from the ceiling are traveling to the floor as the floor is moving toward those pulses. So without the insertion of relative time, the floor will see pulses with higher frequency than the ceiling is generating them and the ceiling will see pulses with lower frequency than the floor is actually generating theirs. But when Einstein figured that time on the floor of the elevator must be running slower than time is on the ceiling, then everything worked out. And since he had already deemed a gravitational field equivalent to an accelerating coordinate system (in this case, an elevator) he deduced that clocks will run slower on the surface of the Earth than they would at the top of a very tall building. Not much slower, but slower nonetheless. This was Einstein's second condition for the relative nature of time.

Before I go any further, it should be noted that both of Einstein's conditions have been experimentally verified. It is true beyond a shadow of a doubt that precise atomic clocks run noticeably slower on the ground than they do in a more elevated position. It is also true that objects moving at very high velocity experience a time dilation as well.

Now, back to our traveler on the train. In 1918, Einstein equates the acceleration that the traveler experiences (as his train slows down and turns around and reaccelerates toward his stationary friend) as being the lower position in a gravitational field. This will have a time slowing effect for the traveler that the stationary rancher will not also experience. So even though they are each observed to have a time-slowing effect from the perspective of the other during the inertial part of the trip, the symmetry is broken during the acceleration phase as the traveler experiences an extra time dilation. And when they compare wristwatch readings, the traveler's is running behind the rancher's without paradox and with Galileo's principle still intact.

Simple right? So, if this theory is completely correct, what does it tell us about the nature of time? For starters, it proposes that there is not one method for time dilation, but two. That is truly amazing if you think about it: A concept as fantastic as time dilation being able to occur by two completely separate methods.

Is there a mechanism that we can draw out of either of these methods? Let's look at the increased velocity first: The rancher saw the traveler's time slow down after his velocity increased. So from the perspective of the rancher – the traveler increased velocity and as a result, experienced time dilation. But the rancher's time also slowed down from the perspective of the traveler and the rancher did absolutely nothing. This means that in this model, there can be no mechanism associated with this action. The best we can do is say that time dilation must be some sort of co-effect of increased relative velocity.

Okay, how about the acceleration/gravity condition? This would appear to have more of a cause and effect relationship since the one who accelerates experiences something that the other does not. And if I move through various altitudes in a gravitational field, I will speed up or slow down my clock, depending on my unique distance from the surface of the Earth. Again – an apparent cause and effect.

So, we have to figure out the nature of time, knowing that a couple of clues are 1) there are at least two different ways to alter the rate of its flow and 2) one of the ways has no apparent mechanism, and the other one may or may not have a mechanism. No wonder no one has figured out the true nature of time. How could anyone propose a mechanism to fit in with that mess?

Is it possible that there is something wrong with the theory? What if there is a different explanation for why time is relative? Consider the following:

Einstein's resolution to the paradox places the traveler in a gravitational field for some of the journey, even though the traveler is changing position with respect to his stationary counterpart. This is important to note because Einstein's original reason for time slowing in a gravitational field was from an equivalent to an acceleration model, where two clocks were trading light signals at fixed distance from one another. This is how the floor clock was able to have more pulses than the ceiling clock, which is what warranted the need for the clock slowing to begin with.

So, in 1911, Einstein made a specific observation about light pulses traded between fixed distances in an accelerating coordinate system, and reasoned that the clocks should run differently so that there is no discrepancy with regard to the light pulses. Next, Einstein stated that the same effect would be observed between two points of different altitudes in a gravitational field. But then in 1918, he attempted to resolve the paradox of 1905 by considering the traveler to be in the lower position of a gravitational field, even though that coordinate system had two points with changing distances, which was different from the model he used to invoke a time dilation to begin with. I hope you followed that.

And that's not all. Let's take another look at Einstein's theory of simultaneous time dilation for the traveler and the rancher. Is it possible for each of them at the same time to see the other's time running more slowly? Anything is possible, I guess, but can we show whether this is really what happens or not? Well, it turns out that GPS satellites operate on the premise that velocity and gravity both slow down the flow of time. In fact, they are proof of it.

If both of Einstein's time slowing factors were ignored, the atomic clocks in the satellites would be running at a different rate than the clocks on Earth. The whole tracking system would be useless. But the clocks are adjusted to run at a different rate before they launch so that when they orbit the Earth at an altitude of 11,000 miles, the prelaunch adjustment is the exact compensation needed for the clocks to run in sync with the clocks on the ground.

Without a pre-launch adjustment, the altitude of the satellite gives the satellite clock a high enough gravitational position to speed its clock rate by about 45,000 nanoseconds per day. Doesn't seem like much, but a huge number in the world of atomic clocks. The other time-altering condition – velocity, causes the satellite clock to run about 7,000 nanoseconds per day slower. So a 45,000 nano speed-up combined with a 7,000 nano slow-down, produces a net effect of a satellite clock that runs 38,000 nanoseconds per day faster than its counterpart on Earth. But with a prelaunch rate adjustment of around 38,000 nanoseconds per day, the satellite clock thankfully runs in sync with our ground clocks.

So the million-dollar question is: Is the ground clock also considered to be in sync with the satellite? If Einstein is correct, the answer would have to be no. For example: if prior to launch, an atomic clock were gravity adjusted only, then while in orbit, it would be running slower by 7,000 nanoseconds. And according to Einstein's theory, the satellite would simultaneously view the ground as running 7,000 nanoseconds slower from above. But as a consequence of rate adjusting the clocks 38,000 ns/day prior to launch, the satellite clocks should actually perceive the ground clocks as running 14,000 nanoseconds slower than they are. But this is not what happens.

If you want to know why I think we have been so stuck on the time question is that for decades, we have felt obligated to limit ourselves to a theory of time that fits within the confines of Einstein's/Galileo's relativity. And while it is true that Einstein should be credited for successfully predicting the two conditions that exploit the relative nature of time, his suppositions for why these conditions affect time's flow cannot possibly be true.

So where does that leave us? Well, my opinion, for what it is worth, is that we should be exploring possible mechanisms under the assumption that Galileo's principle is not completely valid. If I am in a spaceship traveling 99% the speed of light, yes, my tennis ball will still go straight up and down and my flashlight will still pump out a beam with a velocity that doesn't violate any laws, but how could we possibly know that every single law and behavior is the same for me at that speed? What if there is a clear cause and effect relationship between increased velocity and the slowing of time? What if, for example, the true mechanism for "time" is something as simple as the playing out of a bunch of fundamental behaviors on the subatomic level?

What if time is nothing more than a bunch of electrons, quarks, W particles, gluons, muons and more, engaging in their fundamental behaviors because there exists the energy to do so? And what if these fundamental behaviors play out in part because of the fields that these particles are swimming in. There are fields that go along for the ride, such as electric fields, and there are fields that may not be along for the ride, like the proposed Higgs field. There could also be other fields that we don't know about. What if particles that are increasing velocity through fixed fields and dragging their own fields along are somehow affecting the rate in which their fundamental behaviors can occur? What if the faster they move, the more difficult it becomes to engage in their fundamental behaviors? On such a quantum level, the behaviors could even be described as having probabilities of happening. If high velocity lowers their probability, they would need more opportunity before achieving a successful outcome, which on our macro level we would just recognize as a longer period of time.

We know that the average lifespan of a muon is around 2.2 microseconds. We also know that muons traveling with high velocity live longer. So what is happening during those 2.2 microseconds that give a muon an extension during high velocity? Is motion affecting its ability to turn into a W particle? Is the W particle's ability to produce an electron also dampened? Is there a smooth path of transition from the muon's existence to its decay that is similar to water slowly boiling on a burner? Would high velocity to the muon be like lifting a pan of water off of the burner a little bit so the water takes longer to hit its boiling point? Or is the velocity just lowering the probability of a single event that, like a switch can be flipped from "exist" to "decay?"

I think it is helpful knowing that gravity is the other condition because in that example, particles can be considered, for all practical purposes, motionless while still experiencing a slowing of time. Is it possible that this big clump of mass we call Earth is having some dynamic interaction with the Higgs field (or some other unknown field) around particles near Earth that would create the same net effect as particles moving through fields and thus slowing the rate at which they can engage in their fundamental behaviors?

Any potential interactions that occur among particles, forces and fields should be examined. After the LHC experiment is completed, we will certainly know more about the Higgs particle and its field (or lack thereof). I am pretty sure that the experiment will provide verification of the Higgs on some level, but we will have to wait and see. The Higgs field could play a role in affecting the rate of fundamental behaviors. Whatever the mechanism is, whether it be Higgs or something else, it would have to be something capable of affecting all behaviors for all known particles and forces. One problem with the Higgs is that it has the potential for playing an integral role in weak force activity, but may not have any influence over massless photons or gluons. It is still worth looking into. Who knows? At high velocities, different particle behaviors may not all be affected to the exact same degree? An inertial frame which contains all types of particles and their force carriers moving through various fields at near-light velocity, may one day be able to detect its own inertial motion by observing various fundamental behaviors operating at different relative rates as compared to rates in low velocity.

I never met Galileo Galilei, but I'm pretty sure that if he was able to reflect today on his observation of birds, butterflies and water drips below the deck of a moving boat over 350 years ago, he wouldn't be kicking himself for not considering the possibility that tiny unseen particles might be doing something slightly different while moving with incredible velocity. Why would he, since we still haven't detected any difference with today's technology? But who knows what tomorrow will bring? Only time will tell.

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