The physics of time doesn't contradict experience.

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Does time flow? Do we experience it as flowing? And does physics suggest that, 'really', time does not flow? In his recent essay for IAI News, Avshalom Elitzur notes that physics treats the flow of time as unreal and illusory, and suggests that his own 'spacetime dynamics' theory offers a way back for the reality of time flow.

The idea that physics contradicts our experience of time is certainly common. A century ago, Cambridge astronomer Arthur Eddington expressed his own frustration with the conflicting views of time he took from fundamental physics on the one hand, and our 'experience of growth and becoming' on the other. Physics, it seemed, implied that our everyday view of time is illusory. The fundamental laws of physics with which Eddington was acquainted contain no arrow of time; effectively, any process that could happen from past to future could also 'happen' from future to past. This clashed so much with our apparent experience of time that Eddington ultimately showed sympathy for a strikingly unscientific point of view, that "consciousness, looking out through a private door, can learn by direct insight an underlying character of the world which physical measurements do not betray." Put like that, the position is distinctly unattractive, which was ultimately Eddington's point. We are apparently stuck between two 'pictures' of time: either time is 'really' dynamic (it flows, it passes), as experience suggests; or it is 'really' static, as physics suggests.

So what is this special quality of time that is allegedly left out by physics? Is it something that we actually experience? And does our experience therefore provide evidence that our physical understanding of time is seriously incomplete? My aim here is to show that the situation is not as bleak as Elitzur suggested in his recent article for the IAI. Elitzur describes how physics 'ignores', 'eliminates', 'dismisses' key features of time, and requires a new approach in which things like the 'Now' and its motion are enshrined in fundamental physics. However, despite the age of this particular debate, it remains unclear what specific temporal properties are left out by fundamental physics, and what features of the physical world such properties would help to explain. On the contrary, the ways in which physics allegedly contradicts our intuitive picture of dynamic time are often significantly overplayed; in particular it is misleading to suggest that we experience time as dynamic in a way that contradicts the picture of time we get from physics. The 'static' picture we get from physics, I suggest, is perfectly rich enough to fit with the various special ways in which we experience and interact with time.

Physics has, since the early 20th century, been accused of 'spatialising' time, the prime culprits being Einstein's theories of relativity. Special relativity theory presents time and space as being intertwined through being represented using a single 'spatiotemporal' metric. The metric is a mathematical means of determining the spatiotemporal distance between two events, such as the flashes of two different light bulbs. Whereas classical physics takes the bulbs to be located at some definite spatial distance from each other, and the flashes to be at some definite temporal distance from each other (for example one happening 3 seconds prior to the other), relativistic

physics takes the events to have only a 'spatiotemporal' separation — a separation in four-dimensional spacetime — with the individual spatial and temporal distances between them relative to the rest frame of the person measuring them.

This four-dimensional way of representing things in the world has been accused of 'spatialising' time in that objects like you and I, ones that persist over time, appear on spacetime diagrams as lines that run from birth to death, with all moments in our life given equal weight in the depiction. There is no obvious animation in such a diagram – it's just a fixed, static representation of things across time –, nor is any point highlighted as special or privileged. However, tools of representation, like diagrams, need not possess the properties that they represent. For instance, I can depict a three-dimensional cube by drawing it on the two-dimensional surface of the piece of paper in front of me. The fact that the drawing is two-dimensional in no way means that it is somehow depicting a two-dimensional object; on the contrary, the cube it is representing is three-dimensional. Likewise, depicting one's life as a line in spacetime does not mean that it is depicted as devoid of animation, flow, becoming, and so on.

On the contrary, a popular way of understanding so-called 'static' theories of time is in a conciliatory mode: that static time is entirely consistent with our temporal experience. A static universe, after all, still contains the motion of things in space over time, and the change of objects' properties over time. It just doesn't additionally confer some special cosmic privilege or motion to some particular point in time -- the 'moving Now'. In fact, static time theorists don't take time to be literally static at all. Think of what it means for something to be static: static things are unchanging over time. We could in some sense imagine a three-dimensional universe that is unchanging over time: everything in the world simply stays relatively motionless and unchanging for eternity, but this obviously isn't what static time theorists believe. Rather they take the universe to be a four-dimensional entity in which time has a similar dimensional status to the spatial dimensions, with past and future things ultimately as 'real' as those around us in the present. So, could a four-dimensional spacetime be unchanging over time? Clearly, this would be problematic, since it would require a second time dimension relative to which four-dimensional spacetime is unchanging. Again, static time theorists believe in no such thing.

One such adherent of the static view, philosopher D.C. Williams, noted that passage realists are mistaken when thinking that 'they alone are "taking time seriously".' Williams suggested that the dynamic theorist thinks that there is 'something extra' in reality that is missed out by the static theorist's four-dimensional view, 'something active and dynamic, which is often […] described as "passage"' (Williams, 1951). Williams adds that this 'something extra' is a myth, 'one which is fundamentally false, deceiving us about the facts, and blocking our understanding of them.' Since Williams, it has been popular for static theorists to suggest that their view of time leaves nothing important out: everything in our experience of a moving, changing, temporal reality is fully accounted for by the 'static' four-dimensional view of time.

As with many philosophical notions, some of the standard ways of talking about dynamic time break down under analysis. What does it mean to experience time as flowing? If I sit by a river, I

can see the water flowing. The flow is the way the water appears to move continuously. We get a similar flow-like experience when we see any kind of motion around us, such as the cars passing by the office window, and even when we look at certain optical motion illusions, where a static image appears to us as though it's in some sense moving or animated. But do we also see time or the Now as flowing? This question immediately seems suspect; do we 'see' time at all? Maybe what's relevant is that we see motion and flow in the objects around us, and it is in that sense that time appears to flow. If that is the case, then it's not clear why the static time theorist has a problem to solve. They do not deny that objects move in the static world, just that their motion is understandable in terms of the relevant objects being located in different positions at different times.

As I've argued elsewhere (Farr 2020), there is a certain 'what-it's-like-ness' to seeing change and motion, what I call 'temporal qualia'. My suggestion is that it's this quality of 'seeing' moving and changing things that philosophers commonly mischaracterise as an experience of time as passing or flowing. Indeed, in the rare documented cases of 'akinetopsia', where subjects have a reduced or total inability to perceive motion, liquid coffee has been described as apparently 'frozen [. . .] like a glacier' (Zeki 1991), implying that a key sense of flow is partially lost in the subject's temporal experience. Is this flow-like quality of ordinary motion perception responsible for our sense that time passes? I'm inclined to think it's at least a large part of the puzzle. And the motion of one thing from here to there, and our perception of it, is certainly retained in the static theorist's picture of time. Moreover, our sense of motion is ordinarily not any kind of illusion — when we sense motion, it's typically because we've seen it. In this key sense, the 'feel' of temporal experience, the 'sense' of things flowing and moving in time, are not illusory, since they're ultimately tracking real change and motion in objects in the world – the kind of motion and change contained within the static time theorist's picture. On this understanding of our temporal experience, there is no further sense of the passage or flow of time itself to be explained away by the static theorist.

So, in summary, the 'static' view of time implied by physics in no clear sense deems our perception of time as erroneous or illusory. Rather, there is reason to be optimistic that the philosophy, physics, and psychology of time are far more compatible than has often been feared.

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