Review of: "Zeno and Einstein"

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Potential competing interests: No potential competing interests to declare.

Dear Ted,

This is a thought-provoking essay. I am a biomedical scientist interested in time in the context of the physics of perception and also in Leibniz's contribution to physics. I am close to the position given by Richard Arthur in his *The Reality of Time Flow*. I have some thoughts about the case you argue, given below. However, I am not quite clear what your conclusion is and it may be that either by modifying your text or simply by dialogue that this can be clarified, perhaps for others as well as I.

The first thing I would throw into the pot is that 'reality as we experience it' is known to 'us' in the form of representations that some parts of a brain send to other parts in a code that has evolved to be useful to us. Perhaps the most relevant aspect is that, since the representations operate in real-time, temporal features of what is represented must be encoded in spatial relations between signals. As far as we know the encoding is in electrical potentials, so there are no 'flavours' available other than amplitude and spatio-temporal relations, and temporal relations are used up by 'frame sequence'. Our sense of motion is then not based on anything moving but on a spatial relation. Cells in the retina decide that there is movement in the world and send messages saying 'there is movement', not by sending messages in different places at different times that mimic movement. Somewhere deeper in the brain some interpreting unit or units can sense 'motion at a point' without there being any paradox in the dynamics. Why spatial aspects of a dynamic relation should encode 'it's moving there' is a mystery but one acknowledged at least since Descartes.

You appear to be urging us to 'trust reality', but as indicated above, experienced reality is at least as much an artifice as abstract thought. As Leibniz realised, it can only be a well-founded illusion. In that context it is reasonable to consider that time, motion and simultaneity might not exist – or at least might not be reliable concepts for understanding reality- which is presumably what Parmenides wanted to tell us.

My own exploration of physics, both in perception and at a fundamental level, is that time describes two real elements, neither being quite what our brains are wired to represent. I don't think anything moves but, again, there is something that does what we think movement does. I think simultaneity is a mistaken idea hard-wired into the way our brains collate nearby information - useful but wrong. As I see it the message of relativity is simply that – that there isn't such a thing as simultaneity because 'now' is local' just like 'here', in spacetime being just 'here-now'. As you indicate, this may have nothing to do with time dilation, just that time and space are metrics of dynamic relations and events cannot follow without some time separation. A God's eye view that could judge 'true simultaneity', in the process violating locality, is not part of

any reality we can expect to exist.

The other point I would raise is that I don't think quantum theory tells us that field excitations (aka 'particles') 'progress in time' according to a 'wave function', even if most textbooks say that. The wave equation provides a field of values in a Hilbert space, not in space and time. The field values relate to possible sites of measurements in spacetime for an infinite number of possible excitations of a certain type (given by boundary conditions) but for any actual excitation only one value is involved – the one where the measurement actually occurs for that excitation. We have no reason to think the other values are anything more than a reflection of the regular periodicity of probabilities for different possible excitations – rather as a bus timetable tells us the periodicity of the probability of a bus arriving. The results of the 'Aspect' experiments testing Bell's theorem that confirmed the consistency of quantum theory make it clear that no 'progression of states in time' is possible. The only possible explanation is that the excitation occurs as a single indivisible event as a result of the universe 'integrating over all notional paths' and creating a new event accordingly. You suggest that "Quantum mechanics establishes a barrier beyond which pure reason cannot penetrate.". But this sort of analysis is exactly the sort of thing that Leibniz proposed, using the 'Pure Reason' that Kant misguidedly decided to Critique. There is only a problem with quantum theory is we try to shoehorn it into the concepts our brain coding is wired into at birth. The point of science is to override the inconsistencies in that coding.

The upshot is that time must be two things. One is a metric within an excitation that, like space, has no direction per se. Space and time provide the extent of a 'block microcosm' or 'here-now' within which there is no need for movement or before or after. The other is the sequence of excitations that is directional, but has no need for metric, being just a causal nexus network.

Things appear to us to move because we are tracking aggregates of events that form significant local patterns in the EM field. The patterns track across and we could call them 'things' but if we wanted to do a Zeno type analysis we would be back to block microcosms and sequence and no movement. The situation may be very much like trying to see that for a message tracking left across an LED matrix nothing actually moves. LEDs go on and off. It can be extraordinarily difficult to persuade one's brain of that but it is the reality.