Time as an Empirical Concept in Special Relativity

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Abstract: According to a widespread view, Einstein's definition of time in his special relativity is founded on the positivist verification principle. The present paper challenges this received outlook. It shall be argued that Einstein's position on the concept of time, to wit, simultaneity, is best understood as a mitigated version of concept empiricism. He contrasts his position to Newton's absolutist and Kant's transcendental arguments, and in part sides with Hume's and Mach's empiricist arguments. Nevertheless, Einstein worked out a concept empiricism that is considerably more moderate than what we find in the preceding empiricist tradition and early logical positivism. He did not think that the origin of concepts is in observations, but in conventions, and he also maintained a realist ontology of physical events, which he thought is necessary for his theory. Consequently, his philosophy of time in special relativity is not couched in terms of an anti-metaphysical verificationism.

I

Among philosophers and historians of physics, it is common belief that the formulation of special relativity (SR) centered around a positivistic principle of verifiability. [1] For

[1] The verificationist reading includes, by and large, Gerald Holton, "Mach, Einstein, and the Search for Reality," *Daedalus* 97, no. 2 (Spring 1968): 636–73, Lawrence Sklar, "Time, Reality and Relativity," in *Reduction, Time and Reality: Studies in the Philosophy of the Natural Sciences*, ed. Richard Healey (Cambridge University Press: Cambridge, 1981), 129–42, James Robert Brown, "Einstein's Brand of Verificationism," *International Studies in the Philosophy of Science* 2, nro. 1 (1987): 33–54, John D. Norton, "Einstein, The Hole Argument and the Reality of Space," in

example, William Lane Craig has argued in depth that Einstein subscribed to an anti-metaphysical verificationism. He contends that "it is now widely acknowledged that at the philosophical roots of Einstein's theory lay an epistemological positivism […] which issued in a verificationist analysis of the" concept of time.[2]

In this paper, I shall question the verificationist reading of Einstein's position on the concept of time, that is, simultaneity. We clearly do find an operational definition in Einstein's original 1905 SR article, and an empiricist account of concepts manifest in the plethora of his philosophical writings. But it is wrong to assume that any of this amounts to a verificationist, anti-metaphysical positivism.

Einstein argued for a concept empiricism, roughly in the same way as Hume and Mach had done before him. This gave him the means to challenge the absolute simultaneity in Newton's natural philosophy and the *a priori* character of time in Kant's transcendental idealism. Time is neither an absolute imperceptible structure nor an *a priori* form of sensibility. Instead, the concept of time, expressly the notion of

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Measurement, Realism and Objectivity, ed. John Forge (*Australasian Studies in History and Philosophy of Science* vol. 5, Dordercht: Springer, 1987), 153–88, Cheryl Misak, *Verificationism: Its History and Prospects* (London and New York: Routledge, 1995), William Lane Craig, *The Tenseless Theory of Time: A Critical Examination* (Dordrecht: Springer, 2000), *Time and the Metaphysics of Relativity* (Dordrecht: Springer, 2001a), *Time and Eternity: Exploring God's Relationship to Time* (Wheaton, Illinois: Crossway Books, 2001b), and "Introduction" in *Einstein, Relativity and Absolute Simultaneity*, ed. Craig and Quentin Smith (London and New York: Routledge, 2008), 1–10.

[2] Craig, "Introduction," 3. As verificationism has been rejected by post-positivist contemporary philosophers of science, Craig urges that an alternative interpretation of the theory's formalism should be preferred. According to him, a neo-Lorentzian interpretation, which maintains an absolute frame of reference (which in his view is the God's frame) and absolute simultaneity, is the correct rendition of SR. Accordingly, the eternalist block universe model and the static B-theory of time should also be discarded, and a tensed A-theory presentism with its theological underpinnings turns out eventually to be the winning philosophical interpretation of SR.

simultaneity, should be treated as empirical. After abjuring absolute and *a priori* time (as well as absolute space and absolute electric fields), Einstein was able to reconcile the two seemingly irreconcilable postulates of SR, the light and the invariance principles.

But this is where Einstein's sympathies toward empiricism and positivism end. He frequently stated that the origin of our concepts are in the "free creations of the human mind."[3] This is very different from radical empiricism as expressed, for example, in Hume's copy principle. And Einstein did not accept the positivist aspiration to eliminate metaphysics. He dissociated observation of an event and the event itself. In the positivist program, such dissociation would have been an example of meaningless metaphysics. But in SR, an event must happen before and independent of the observer, because the observed temporal order might be different from the order of the events in a particular reference frame.

To provide an argument to challenge the verificationist position, the rest of this paper is structured as follows. In the next section, I will explicate the core of the verificationist reading. The subsequent sections shall then examine the relevant pre-relativity accounts of time's concept. In the third section, I will analyze the non-empiricist arguments of Newton and Kant, focusing deliberately on the relation between concepts denoting temporal order and observations. In the fourth section, I detail the alternative concept empiricist theory as found in Hume and Mach. Although such a treatment presents many well-known philosophical doctrines, they are necessary for understanding

[3] Albert Einstein and Leopold Infeld, *The Evolution of Physics: From Early Concepts to Relativity and Quanta* (New York: Simon and Schuster, 1966), 31.

Einstein's stance. In the fifth section, I display Einstein's concept empiricism and its application in his argument for the relativity of simultaneity. In the sixth section, I argue that his concept empiricism differs from radical empiricism championed by Hume and the positivism espoused by Schlick. In the end, I conclude that Einstein's philosophy of time as it relates to SR does not instantiate anti-metaphysical verificationism. His position is best understood as a mitigated, realism-compatible empiricism.

II

In the original publication of SR, "On the Electrodynamics of Moving Bodies,"[4] Einstein provides an operational definition of time. According to Craig, in this issue his "verificationism comes through most clearly."[5] Craig understands verificationism as a doctrine according to which "statements which cannot be in principle empirically verified are meaningless."[6] In Einstein's formulation,[7] a description of time

> has no physical meaning unless we are quite clear as to what we understand by "time." We have to take into account that all our judgments in which time plays a part are always judgments of simultaneous events.

According to this definition, "the pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events" provides meaning to the statement "train arrives at the station at seven o'clock." Clock synchronization rests on a convention

[4] Albert Einstein, "On the Electrodynamics of Moving Bodies," in *The Principle of Relativity* (Dover, 1923), ed. Hendrik Lorentz, Einstein, Hermann Minkowski and Hermann Weyl, trans. W. Perrett and G. B. Jeffery, 35–65.
[5] Craig, *Tenseless Theory*, 130.
[6] Craig, *Time and Eternity*, 47.
[7] Einstein, EMB, 39.

that a light signal sent from observer *A*'s clock to observer *B*'s clock takes as much time as the reflected signal getting back from *B* to *A*. Although the round-trip time is constant, the light's trip between *A*–*B* and *B*–*A* might differ; the one might be shorter, and the other longer. Einstein thinks this a convention: it is not a fact of nature that the time light travels from *A* to *B* is the same as it travels from *B* to *A*.[8] We cannot experimentally confirm the convention about light's speed regardless of direction, because we already presuppose how to determine distant simultaneity.[9] Synchronizing clocks *A* and *B* at the same place is unproblematic, but moving one of the clocks to create a distance between them will result to time-dilation, and hence desynchronization.

Craig argues that Einstein's operational definition means the reduction of time to our measurement of it. According to this view, Einstein makes an inference from empirical undetectability to non-existence. "Such an inference is clearly verificationist, and therefore positivistic," Craig notes.[10] Without clocks, observers, and inertial frames, statements "about temporal relations which are metaphysical in character" are nonsense. Or so the verificationist reading suggests.[11]

In the subsequent sections, my aim is to challenge such widely held view on Einstein's putative verificationism concerning the concept of time in SR. I will argue that his position should be understood as a nuanced empiricist view, not an anti-metaphysical

[8] Wesley C. Salmon, "The Philosophial Significance of the One-Way Speed of Light," *Noûs* 11, no. 3 (September 1977): 253–292, at 254.
[9] Bradley Dowden, "Time Supplement" (*Internet Encyclopedia of Philosophy*, ISSN 2161-0002, http://www.iep.utm.edu/time-sup/), Section 13.
[10] Craig, *Metaphysics of Relativity*, 82.
[11] Craig, *Tenseless Theory*, 133.

positivist creed. To that end, the relevant history of the subject matter will be first discussed in sections three and four.

III

Newton is clear that time itself is unobservable. It is different from our relative measures, like clock-time. The quantity of time, along with those of space and motion, cannot be "conceived solely with reference to the objects of sense perception," he writes in the Scholium to the Definitions of his *Principia*. [12] If time and space were defined only in observational and measurable terms, one could not make a distinction between absolute and relative motions. In Newton's dynamics, force is the true cause of body's change of motion, that is, acceleration. He explains his position both in "De Gravitatione" and in the *Principia*: "Force is the causal principle of motion and rest [...] The causes which distinguish true motions from relative motions are the forces impressed upon bodies to generate motion."[13]

Newton's definition of time is grounded on the laws of dynamics. "The distinction between equal and unequal time intervals," Robert DiSalle notices, "is implicit in the distinction between inertial motion and motion under the influence of a force [...] equal intervals of time are those in which a body not subject to forces moves equal distances."[14] We can mathematically grasp that a body subjected to a constant net force

[12] Isaac Newton, *The Principia. Mathematical Principles of Natural Philosophy*, ed. trans. I. Bernard Cohen, Anne Whitman, ass. Julia Budenz (Berkeley: University of California Press, 1999), 408.
[13] Newton, "De Gravitatione," in *Newton: Philosophical Writings*, ed. Andrew Janiak (New York: Cambridge University Press, 2004), 36 and *Principia*, 412.
[14] Robert DiSalle, *Understanding Space-Time. The Philosophical Development of Physics from Newton to Einstein* (Cambridge, England: Cambridge University Press, 2006), 20–21.

moves absolutely unequal intervals of time, and that a body not subjected to forces moves absolutely equal intervals of time. This requires an independent, absolute, mathematical time, which passes equally from past to future. This gives us an objective measure of simultaneity and succession: simultaneous events are absolutely simultaneous as the time-difference between them is zero, and the time-difference between successive events is an absolute duration.[15]

Newton did not operate only with assumptions and definitions that back up his formulations of the laws of motion. He provides an argument based on an experiment carried out with a rotating water bucket.[16] As the argument is so familiar, it does not have to be spelled out here. It suffices to note that explaining the rotational, accelerative motion of the water, a fixed structure of space that is not apparent to our senses in the experiment is required as a benchmark.[17] If forces are exerted on bodies, they truly, not just relatively, move. The distinction between absolute and relative motions in space implies an absolute non-observable structure of time as a fixed standard.

Another influential non-empirical position on time can be found in Kant's *Critique of Pure Reason*. Deviating from Newton's account, Kant does not focus on the concept of time (and space) by using substantives. Rather, he focuses on the adverbial use of this

[15] John Earman, *World Enough and Space-Time. Absolute versus Relational Theories of Space and Time* (Cambridge, MA and London, England: MIT Press, 1989), 8.
[16] Newton, *Principia*, 412–413.
[17] Andrew Janiak, "Isaac Newton" in *Oxford Handbook of British Philosophy in the Seventeenth Century*, ed. Peter R. Anstey (Oxford: Oxford University Press, 2013), 96–115, at 106, puts the point eloquently: "Although we cannot detect absolute space itself, since Newton conceives of it as empty and imperceptible, we can detect the inertial effects of rotating bodies (in this case, the concavity of the water)."

concept. We do not experience things in time but temporally.[18] In the second section of "Transcendental Aesthetics," Kant encapsulates his position:

> Time is not an empirical concept that is somehow drawn from an experience. For simultaneity and succession would not themselves come into perception if the representation of time did not ground them *a priori*. Only under its presupposition can one represent that several things exist at one and the same time (simultaneously) or in different times (successively).[19]

Time is necessarily given *a priori*. It is a form of sensibility. Without human subjective preconditions, no temporal order would appear. Reality in itself is atemporal. Thus Kant puts it as follows: "Time is therefore merely a subjective condition of our (human) intuition [...] outside the subject, is nothing."[20]

Kant's transcendental argument is essentially based on showing the inadequacy of the empiricist conception of time. In particular, he is not satisfied by the way it intends to explain the origin of temporal concepts. Kant tackles an account like one provided by Locke in his *Essay*.[21] For Locke, succession of perceptions enables us to experience the passage of time. This reasoning has the following problem. When we are aware of the passage of time by means of a succession of perceptions, do we not already assume, prior to our perceptions, a temporal construct? For how could we reconstruct a past

[18] Adrian Bardon, *A Brief History of the Philosophy of Time* (New York: Oxford University Press, 2013), 33.
[19] Immanuel Kant, *Critique of Pure Reason*, ed. trans. Paul Guyer and Allen W. Wood (New York: Cambridge University Press, 1998), 162.
[20] Kant, *Critique*, 164.
[21] John Locke, *An Essay concerning Human Understanding* ed. abrid. Kenneth P. Winkler (Indianapolis, Cambridge: Hackett Publishing, 1996), 79.

sequence of perceptions if we did not already employ the idea of a succession? Conceiving perceptions as standing in a temporal order does not seem possible were there no cognition prior to and independent of the perceptions. The Kantian solution to this difficulty is that the representation of perceptions in temporal order is grounded in the *a priori* elements of cognition.[22]

Kant waterproofs his case by claiming that "this *a priori* necessity [...] grounds the possibility [...] of the relations of time." Time "has only one dimension: different times are not simultaneous, but successive."[23] In this way, the transcendental argument explains the way we experience time, and its unidirectionality, that is, why to us humans it appears that time passes from past to future.[24]

IV

In the tradition of empiricism and positivism, we find a very different position on the concept of time compared to the absolutist and transcendental arguments. Here I will concentrate on the accounts of Hume and Mach, since they have been the most influential for Einstein's formulation of SR, a theory that renders the concept of time empirical.

Hume's premise is that every simple idea resembles some simple sensory impression. A simple impression causes its idea; an idea is a copy of its impression. All ideas,

[22] See also Adrian Bardon's conclusion in "Empiricism, Time-Awareness, and Hume's Manners of Disposition," *Journal of Scottish Philosophy* 5, nro 1 (January 2007), 47−63, at 60.
[23] Kant, *Critique*, 162.
[24] Matias Slavov, "Ajan havaitsemisesta: onko aika empiirinen käsite?" in *Havainto*, ed. Hemmo Laiho and Miira Tuominen (Turku: Painosalama Oy, 2018), 233−240, at 235.

including complex, general or abstract, have their ultimate origin in simple impressions.[25] Ideas stand for both the mental content and the material of thinking. Because language is distinct from our mental imagery and thought, we might still be employing terms without impression-based ideas annexed to them. To ensure that such suspicious discourse is meaningful, Hume suggests that we use the copy principle as a cognitive test.[26] "If a proper use were made of it," he notes, we could "banish all that jargon, which has so long taken possession of metaphysical reasonings, and drawn disgrace upon them."[27] The procedure of applying the principle is as follows:

> When we entertain, therefore, any suspicion, that a philosophical term is employed without any meaning or idea (as is but too frequent), we need but enquire, *from what impression is that supposed idea derived?* And if it be impossible to assign any, this will serve to confirm our suspicion. By bringing ideas into so clear a light, we may reasonably hope to remove all dispute, which may arise, concerning their nature and reality.[28]

What about the concept of time? Can it stand the former test? If we consider the absolute and the transcendental arguments, the answer is an abrupt no. In his argument for absolute time, Newton refers to an unobservable structure to explain observable phenomena, the laws of motion (more specifically, to explain the distinction between

[25] David Hume, *A Treatise of Human Nature*, ed. David Fate Norton and Mary Jane Norton (Oxford: Clarendon Press, 2007), 1−7.
[26] For this point, see William Edward Morris, "Meaning(fullness) Without Metaphysics: Another Look at Hume's "Meaning Empiricism.'" *Philosophia* 37, nro. 3 (September 2009), 441−454.
[27] Hume, *An Enquiry concerning Human Understanding*, ed. Tom L. Beauchamp (Oxford: Clarendon Press, 2000), 21.
[28] Hume, *Enquiry*, 22. See also "Abstract" to the *Treatise*, 648−649.

absolute and relative motion). There are no impressions of such putative structure. Kant, for his part, argues that the concept of time necessarily requires an *a priori* element of cognition. This is also contrary to the copy principle, as the principle presumes that there are no innate ideas, or any kind of *a priori* cognitive factors whatsoever, like forms of sensibilities or categories, prior to sensuous impressions.[29]

From Hume's viewpoint, the (abstract) idea of time is derived from perceivable change. This change is identifiable with simple successive impressions or with relative motions of objects. This is realized, for example, by hearing successive musical chords or by observing motion. By hearing a sequence of different chords, or chords and pauses, we can abstract the idea of time, as there occurs a perceptual change. No one auditory impression, like an ongoing chord, can cause the idea of time, because there is nothing changing in the object. Likewise, an immobile object and its motionless surrounding do not cause the idea of time. If an object is moving relative to a stationary observer, or the observer is moving relative to a stationary object, there appears change, and we acquire time's idea. If the observer were moving with a moving object with the same relative velocity, no perceptual change occurs, and hence there is no source for experiencing time.[30]

[29] Slavov, "Ajan havaitsemisesta," 236.

[30] Slavov, "Empiricism and Relationism Intertwined: Hume and Einstein's Special Theory of Relativity," *Theoria: An International Journal for Theory, History and Foundations of Science* 31, nro. 2 (May 2016), p. 247−263, at 257. Interestingly, J.M.E. McTaggart, "The Unreality of Time," *Mind* 17 (1908), 456−473, at 459, becomes close to Hume's position as he argues that "a universe in which nothing whatever changed (including the thoughts of the conscious beings in it) would be a timeless universe."

"Time," in Hume's account, "is nothing but the manner, in which some real objects exist."[31] The manner in which objects that are relevant for our notion of time exist depends on the observer/reference-object relation. There is no one absolute or universal time—no perception evidences that the putative time itself flows equably across putative empty space. There are instead many times depending on the relation between the observer and the perceived objects.

Mach forged such empiricism into the language of physics. He argues that changeless time, along with absolute notions of space and motion, are "metaphysical obscurities" that should be disposed of physics. In his *Science of Mechanics*, he asserts:

> It is utterly beyond our power to *measure* the tune changes of things by *time*. Quite the contrary, time is an abstraction, at which we arrive by means of the changes of things [...] With just as little justice, also, may we speak of an "absolute time"—*of a time independent of change*. This absolute time can be measured by comparison with no motion; it has therefore neither a practical nor a scientific value; and no one is justified in saying that he knows aught about it. It is an idle metaphysical conception.[32]

Mach's contention that "no one is justified in saying that he knows aught about" absolute time is based on his skepticism concerning the conclusion of Newton's rotating water bucket experiment. Newton's case rested on comparing the motion of the water to its immediate surroundings, namely the bucket. But the whole mass distribution of

[31] Hume, *Treatise*, 64.
[32] Ernst Mach, *The Science of Mechanics*, trans. Thomas McCormack (Chicago, London: Open Court, 1919), 224.

the universe surrounds the bucket; the room in which the bucket is located, the room's building, planet Earth, the objects of our solar system, distant stars, and so on. Would the surface of the water be concave also in an entirely empty space, if all the mass and points of reference around it like distant stars were removed? Mach's answer is that we do not know whether there would be any difference between spinning and non-spinning, acceleration and inertial motion, and motion and rest. If there were no other material, no fixed benchmarks for comparison, we would not necessarily experience acceleration.[33]

Newton's absolutist argument, Mach thinks, is unacceptable precisely because it is non-empirical: "No one is competent to predicate things about absolute space and absolute motion; they are pure things of thought, pure mental constructs, that cannot be produced in experience." Supplementing laws of motion with such an absolute unobservable structure is a meaningless extension for Mach, "as no one possesses the requisite knowledge to make use of it." Likewise, absolute time in itself that flows equally "cannot be produced in experience."[34]

V

Einstein became acquainted with the empiricist tradition by reading the works of Hume and Mach in a reading circle in Bern, shortly before devising SR.[35] He clearly supported

[33] Brian Greene, *The Fabric of the Cosmos: Space, Time, and the Texture of Reality* (New York: Alfred A. Knopf, 2004), 37.
[34] Mach, *Mechanics*, 229.
[35] On the reading circle and the list of readings, see Don Howard, "Albert Einstein as a Philosopher of Science," *Physics Today* 58 (December 2005), 34–40, at 36. For Einstein's acknowledgements of Hume and Mach, and their relevance for the discovery of special relativity together with his contribution to the revision of the 19th century electrodynamics, see John D. Norton, "How Hume and Mach Helped Einstein Find Special Relativity," in ed. Mary Domski and Michael Dickson, *Discourse on a New*

concept empiricism and realized it in his argument for the relativity of simultaneity. This quintessential result of SR enabled him to show that the seemingly irreconcilable postulates of the theory, the light and invariance principles, are mutually compatible.

Although Einstein's breakthrough in relativity of simultaneity is (partly) related to his philosophical analysis in the early 20th century when he was a young person, throughout the rest of his life he also staunchly defended concept empiricism.[36] Some of the following quotes from his philosophically oriented texts (here I have selected "On the Theory of Relativity," "Physics and Reality," and "Autobiographical Notes") verify his commitment to concept empiricism:

> The fundamental principle here is that the justification for a physical concept lies exclusively in its clear and unambiguous relation to facts that can be experienced.[37]

Method: Reinvigorating the Marriage of History and Philosophy of Science (Chicago and La Salle, Illinois: Open Court, 2010), 359−386, and Norton, "Einstein's Special Theory of Relativity and the Problems in the Electrodynamics of Moving Bodies That Led Him to It," in *Cambridge Companion to Einstein*, ed. Michel Janssen and Christoph Lehner (New York: Cambridge University Press, 2014), 72−102. Note that I do not want to imply that SR was solely Einstein's brainchild; many mathematicians and physicists certainly took part in its formulation, including Lorentz, Poincaré, and Minkowski. For this point, see Michel Jansen and Christoph Lehner, "Introduction" to *Cambridge Companion to Einstein* (New York: Cambridge University Press, 2014), 1−37, at 11.

[36] For a list of quotes to substantiate this point, see Slavov, "Hume and Einstein," 252−253. It should be added that conventionalism was drastically important to Einstein. In Don Howard's words, "Einstein, Kant, and the Origins of Logical Empiricism" in *Language, Logic, and the Structure of Scientific Theories*, ed. Wesley C. Salmon and Gereon Wolters (Pittsburgh: University of Pittsburgh Press, 1994), 45−105, at 48, Einstein did not believe in "a clean, principled distinction between the empirical and the conventional."

[37] Einstein, "On the Theory of Relativity," Lecture at King's College, London in 1921, published in *Ideas and Opinions*, ed. Carl Seelig trans. Sonja Bargmann (New York: Dell Publishing, 1981), 240−243, at 241.

> ... concept [...] owes its meaning and its justification exclusively to the totality of the sense impressions which we associate with it.[38]

> Concepts [...] get "meaning," viz., "content," only through their connection with sense-experiences.[39]

A pronounced example of Einstein's adherence to empiricism regarding the concepts of time and space can be found in his *Meaning of Relativity*:

> The only justification for our concepts and system of concepts is that they serve to represent the complex of our experiences; beyond this they have no legitimacy. I am convinced that the philosophers have had a harmful effect upon the progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism [...] This is particularly true of our concepts of time and space...[40]

When time is conceived of as an empirical concept, it can be adjusted and put "in a serviceable condition," as Einstein says. To adapt Einstein's illustration based on the midway method,[41] consider three inertial frames in which observers A, B, and C are located, as imaged in figure 1:

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[38] Einstein, "Physics and Reality," trans. Jean Piccard, *Journal of the Franklin Institute* 221, nro. 3 (March 1936), 349−382, at 270.
[39] Einstein, "Autobiographical Notes," in *Albert Einstein: Philosopher-Scientist*, ed. trans. Paul Arthur Schilpp (New York: Open Court, 1949), 1−96, at 13.
[40] Einstein, *The Meaning of Relativity*, trans. Edwin Plimpton Adams, Ernst G. Strauss and Sonja Bargmann (London: Routledge, 1922), 2.
[41] Einstein, *Relativity. The Special and the General Theory*, trans. Robert W. Lawson (London and New York: Routledge, 2002), 27.

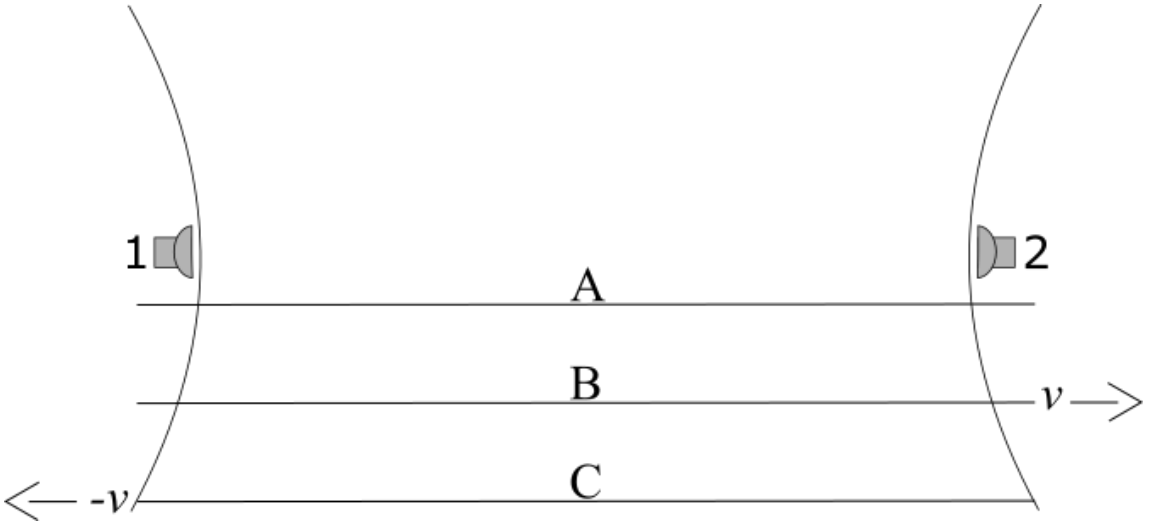

Figure 1

Two lamps are switched on at the far ends of A's frame, at points 1 and 2. B is moving from left to right with an inertial speed *v*, and C from right to left with an inertial speed –*v*. When the light waves are reaching the observers, the situation is like in figure 2:

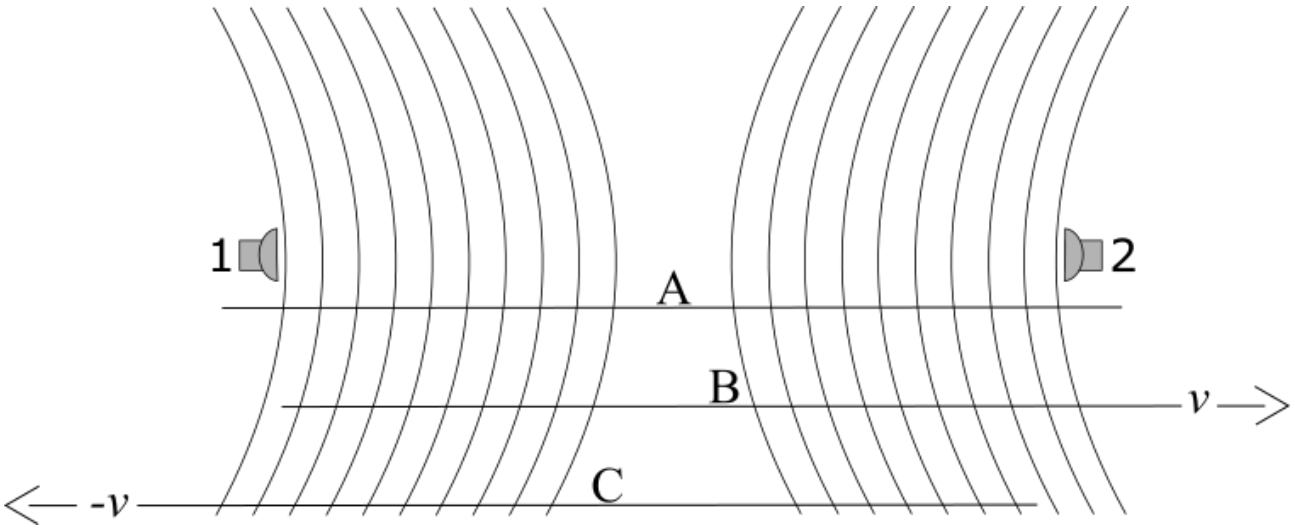

Figure 2

Observer A perceives the lights coming from the lamps simultaneously. The observer B perceives light coming from point 2 before point 1 because she is hastening toward the light wave coming from point 2 and away from point 1. The third observer C

perceives the light coming from point 1 before the one from 2. If the two postulates of SR are true, there exists no grounds for neither absolute time order of events (absolute simultaneity) nor direction of time (unidirectionality).[42]

This fundamental result of SR is in stark contrast with both the Newtonian and Kantian arguments on time's concept. It declines the absolute and universal concept of time, as well as its putative *a priori* status in cognition. Unlike in Newton's argumentation, there is no determinate flow of time from 'earlier' to 'later' across space. No time in itself exists; it is relative to inertial frames of reference. And unlike in Kant's argumentation, time ordering and direction of time are not founded in the *a priori* forms of human intuition. Simultaneity is by no means intuitively or *a priori* clear and meaningful concept. Instead, temporal concepts refer to observations, and these observations enable us to justify our notions of simultaneity and succession.

It is evident that Einstein favors the empiricist argument over the absolutist and transcendental arguments. However, I shall submit next, radical empiricism and the positivist tradition have also their defects. These positions are in tension with a crucial ontological commitment required by SR, the reality of physical events.

[42] There are still certainly other strategies to argue for time ordering of events. This can be done, for example, with a causal analysis which insists that causes are prior to effects in time. Likewise, one can provide an explanation for the direction of time by referring to a psychological account, in which we remember the past and anticipate the future, but never vice versa, and by referring to the second law of thermodynamics, which states that in an isolated system the total amount of entropy always increases or remains the same. For an evaluation of these strategies, see Bardon, *Brief History*, 112−119. The example of Einstein I treat is exclusively confined to an inertial frame of reference in which there are two spacelike events that are in each other's absolute-elsewhere.

VI

Einstein distances himself from radical empiricism. Its main problem is that it cannot separate the observation of and the happening of an event. SR stipulates realism concerning physical events: Events exist independently and prior to their observation. Consider an inertial frame of reference in figure 3:

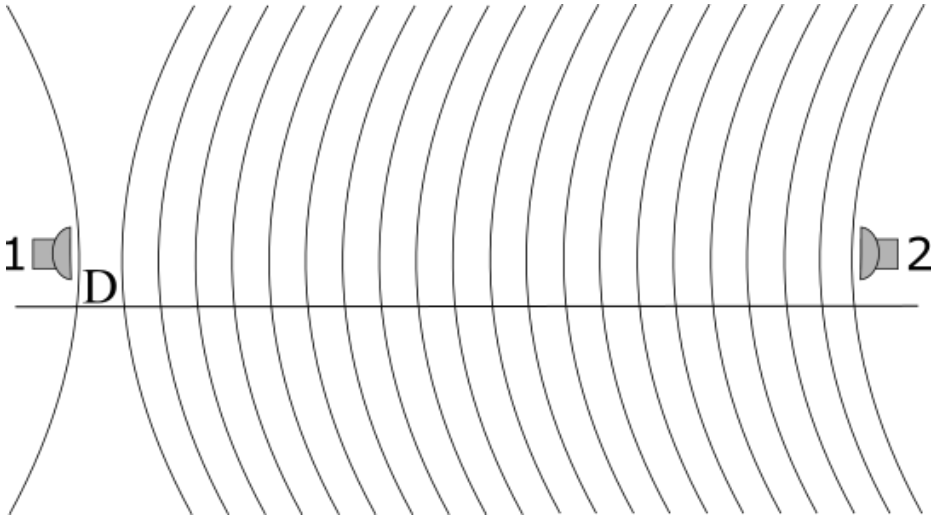

Figure 3

Two lamps are switched on at points 1 and 2. Observer D perceives the flashes of light simultaneously. Are the two physical events that cause the observations, the switching of lamps at points 1 and 2, simultaneous? No, because they do not truly occur at the same time. Mere perception of time order does not suffice to judge whether the events are simultaneous or not. D's perception of the events is simultaneous but the actual events causing the perceptions are successive. This is because the light wave coming from point 2 moves with an absolute speed *c* over the frame's axis. The only correct conclusion must be that the event 2 really happened before the event 1.[43] If we fail "to

[43] Dowden, "Time Supplement," Section 12, provides a simple formula to calculate the time in which an event truly happened in a specific frame: $t_p = t - \frac{x}{c}$, where t_p

differentiate between "'simultaneously seen' and 'simultaneously happening,'" we could not reach this conclusion, as Einstein has it.[44]

This conclusion is not based on some arbitrary convention. There is only one right answer to the question "in which temporal order the events 1 and 2 occur in this particular frame," and all answers that contradict it are false. This does not mean that we are forced to choose the frame. The world does not come with an inertial frame of its own; we need to set it up. "But once a frame is chosen," to quote from Bradley Dowden's treatment of the issue, "this fixes objectively the time order of any pair of [two spacelike related] events."[45] Moreover, to add a point of detail, it is possible that the time order of a pair of events is absolute. This is the case with timelike related events in observer's light cones.[46] We may apply the notions of absolute past and absolute future, if light, or some signal whose velocity is less or equal to electromagnetic spectrum frequency, from an earlier event reaches a later event.[47] In other words, the earlier event is in the later event's absolute past if and only if the earlier could have caused the latter, but not the other way around.[48]

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denotes the time of the actual happening of the event at point p, t the time when the observer sees the event, x the distance between the event and the observer, and c the speed of light.

[44] Einstein, "Physics and Reality," 358.

[45] Dowden, "Time" (*Internet Encyclopedia of Philosophy*, ISSN 2161-0002, http://www.iep.utm.edu/time/).

[46] For Hermann Minkowski's original exposition of this point, see his article "Space and Time," in *The Principle of Relativity* (Dover, 1923), ed. Hendrik Lorentz, Einstein, Minkowski and Hermann Weyl, trans. W. Perrett and G. B. Jeffery, 73–91, at 84.

[47] Mauro Dorato and Marc Wittman, "The Now and the Passage of Time. From Physics to Psychology." *Kronoscope* 15, nro. 2 (2015), 191–213, at 195.

[48] Dowden, "Time Supplement," Section 3. For a thorough mathematical proof of this point, see C. W. Rietdijk, "A Rigorous Proof of Determinism Derived from the Special Theory of Relativity," *Philosophy of Science* 33, nro. 4 (December 1966), 341–344.

Subscribing to simultaneity in relativity requires a realist commitment to such ontic categories as, for example, events, structure and causation. Empiricist and positivist traditions typically eschew such metaphysical theorizing or even try to eliminate it.[49] The following commitments are still required. There is a physical *event* at a certain point in space before any observer perceives it. There is a self-sustaining *structure* of electric and magnetic fields, which can and do form electromagnetic waves that carry energy and information with an absolute speed, like light. Electromagnetic waving is also *causally* responsible for delivering information.[50]

Providing a systematic ontological account of event, structure, and causation is beyond the scope of this paper. Nevertheless, I trust my argument establishes that radical concept empiricism cannot fully incorporate its epistemology into SR. It is not able to encompass a realism like one required by the theory. To further amplify this point, consider one implication of concept empiricism: ontic categories are nothing but bundles in the mind. What really exists, or what we can be sure of, are perceptions. This implication can be associated with events, structures, causation and bodies. Regarding the ontology of bodies, Yumiko Inukai presents her radical empiricism interpretation of Hume:

> The external bodies that could be affirmed consistently in Hume's system are no different from perceptions. For Hume, strictly speaking, only perceptions exist,

[49] For example, Rudolf Carnap, "The Elimination of Metaphysics Through Logical Analysis of Language," in *Logical Positivism*, ed. Alfred J. Ayer (New York: The Free Press, 1959), 60−81, Moritz Schlick, "Positivism and Realism" in *Logical Positivism*, ed. Alfred J. Ayer (New York: The Free Press, 1959), 82−107, and Alfred J. Ayer, "Demonstration of the Impossibility of Metaphysics," *Mind* 43 (1934), 335−345.
[50] Slavov, "Ajan havaitsemisesta," 237–238.

> constituting both the internal and external worlds *for us*, and these worlds are known to us in our experience. I call this aspect of Hume's empiricism "*radical* empiricism." It is radical because Hume does not move from what is available in sensible perceptions to what bodies are in the extramental world in the way Locke sometimes does.[51]

If this is the correct rendition of radical empiricism, then it is not consistent with even common sense realism. Hume is however notoriously enigmatic on this issue. For example, in the *Treatise*, Hume claims that perceptions in the mind "depend upon natural and physical causes."[52] If this were his actual position, there might be a way to reconcile his copy principle with the argument for the relativity of simultaneity. If one acknowledges that visual and auditory impressions have a common natural causal origin, then Hume could reason as follows. In an inertial frame of reference as depicted in figure 3, the observer D sees the flashes simultaneously, but she hears the sounds coming from the switching of the lamps successively. This would give her an empirical basis to conclude that the events causing simultaneous perceptions are not themselves simultaneous, but successive.

But in the *Treatise* we find a remarkably skeptical argument that seems to demolish a positive attitude toward realism:

> As to those impressions, which arise from the senses, their ultimate cause is, in my opinion, perfectly inexplicable by human reason, and 'twill always be

[51] Yumiko Inukai, "Perceptions and Objects: Hume's Radical Empiricism," *Hume Studies* 37, nro. 2 (November 2011), 189−210, at 205.
[52] Hume, *Treatise*, 275.

> impossible to decide with certainty, whether they arise immediately from the object, or are produc'd by the creative power of the mind, or are deriv'd from the author of our being. Nor is such a question any way material to our present purpose. We may draw inferences from the coherence of our perceptions, whether they be true or false; whether they represent nature justly, or be mere illusions of the senses.[53]

Are our perceptions caused by mind-independent nature? Or are they the fabric of our own minds? And what about a divine creator: did God install our perceptions in our minds? Here Hume seems to be a genuine skeptic about what or who is causally responsible for the origin of impressions. He is not a representational realist like Locke.

Einstein himself recognized this problem. In his article for Bertrand Russell's volume to the *Library of Living Philosophers,* he argues that

> following his [Hume's] critique, a fateful "fear of metaphysics" arose which has come to be a malady of contemporary empiricistic philosophizing […] However, I see no "metaphysical" danger in taking the thing (the object in the sense of physics) as an independent concept into the system together with the proper spatio-temporal structure […] it finally turns out that one can, after all, not get along without metaphysics.[54]

[53] Hume, *Treatise,* 84.
[54] Albert Einstein, "Remark's on Bertrand Russell's Theory of Knowlege," in *Ideas and Opinions,* ed. Carl Seelig, trans. Sonja Bargmann (Crown Publishers: New York, 1981), 18-24, at 24.

Einstein deliberately rejects the Humean bundle view of physical objects, which conceives "the 'thing' as a 'bundle of qualities,'" as well as the positivistic "fear of metaphysics." He does not think that there is any "metaphysical danger in taking" a physical object to have an independent existence.[55]

We might think that later formulations of empiricist philosophies, like the doctrines of logical positivism, are consistent with SR. After all, the positivist movement emerged together with relativity. But in this respect, logical positivism faces similar problems as Hume's copy principle.[56] In his article "Positivism and Realism," Moritz Schlick comments on Einstein's critique of Newtonian and Kantian presuppositions on time's concept. He notes that

> Einstein's analysis of the concept of time […] consists in nothing but the analysis of the *meaning* of our statements about the simultaneity of spatially separate events. Einstein said to the physicists (and to the philosophers): you must first state what you *mean* by simultaneity, and you can do this only by showing how the proposition "two events are simultaneous" is verified. But with this you have *completely* determined its meaning.[57]

He continues to explicate how the concept of time, in this case, simultaneity, is defined:

[55] Slavov, Hume and Einstein, 254.
[56] However, Schlick's position on the problem of realism seems not to be the same as Hume's. Schlick is opposed to the Kantian distinction between the world as it appears for us and the world as it is in itself. He thought that this distinction is a meaningless metaphysical doctrine. He did not deny that nature in physics and every day parlance is the reality that surrounds us. What he denies is that this nature is the "'transcendent world' of the metaphysician." Schlick, "Positivism and Realism," 101.
[57] Schlick, "Positivism and Realism," 89–90.

> In the example of simultaneity the analysis of the meaning, as is appropriate for the physicist, is carried only to the point where the decision regarding the truth or falsity of a proposition about time is based on the occurrence or non-occurrence of a definite physical event.

Here Schlick mentions "a definite physical event," which is ontologically necessary for SR. But he erroneously assimilates physical events with a "reference to the occurrence of certain data, or as one generally says, certain 'sense-impressions.'"[58] As has been shown so far, and which is evident from figure 3, the sense-impression of an event is not the same as the event itself, because it is really light that provides the information to the observer about the occurrence of the event. Einstein is a realist about statement 'there is a difference between an observation of and happening of an event.' Such realism is in stark contrast with verificationism. This doctrine maintains that a meaning of a statement should be reduced to its verifiability. If such reduction is impossible, then the statement is cognitively meaningless. But one cannot simply reduce a metaphysical claim that distinguishes appearance and reality into a statement describing merely observable state of affairs.

Based on this section of the paper, it should be concluded that Humean radical concept empiricism, or its later positivist modifications, are too narrow views for providing a cogent account for the concept of time in relativity. These doctrines are not consistent with the argument for the relativity of simultaneity, and therefore with SR. Einstein was

[58] Schlick, "Positivism and Realism," 90.

fully aware of such caveats, and he did not subscribe to a radical version of concept empiricism or positivist verificationism that eschews metaphysics.

VII

Coda. By arguing that time is an empirical notion, Einstein is not committed to a radical Humean concept empiricism, which states that the ultimate origins of our simple ideas are in sensuous impressions. And he does not, as is evident from his realist ontology of events that is necessary for the argument for relativity of simultaneity, subscribe to the elimination of metaphysics which the logical positivist program sought through its principle of verifiability. Einstein's philosophy of time regarding SR is best understood as a mitigated form of concept empiricism. It allows the conventional origin of our concepts and sustains a realist ontology concerning physical events. In a word, time is an empirical concept.[59]

[59] I wish to thank Sheldon Smith and Emma Sillanpää-Slavov for discussion and comments. I have presented this paper at Philosophical Society of Finland's Colloquium in January 2017 at the University of Turku (that resulted in a Finnish publication "Ajan havaitsemisesta" which I have used selectively in this paper) and at the Socratic Society of Portland State University in November 2017. I acknowledge the critical feedback and interesting questions I received from the audiences.