



# Kaila's interpretation of Einstein-Minkowski invariance theory

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## ABSTRACT

This essay explores Kaila's interpretation of the special theory of relativity. Although the relevance of his work to logical empiricism is well-known, not much has been written on what Kaila calls the 'Einstein-Minkowski invariance theory'. Kaila's interpretation focuses on two salient features. First, he emphasizes the importance of the invariance of the spacetime interval. The general point about spacetime invariance has been known at least since Minkowski, yet Kaila applies his overall tripartite theory of invariances to space, time and spacetime in an original way. Second, Kaila provides a non-conventionalist argument for the isotropic speed of electromagnetic signals. The standard Einstein synchrony is not a mere convention but a part of a larger empirical theory. According to Kaila's holistic principle of testability, which stands in contrast to the theses of translatability and verification, different items in the theory cannot be sharply divided into conventional and empirical. Kaila's invariantism/non-conventionalism about relativity reflects an interesting case in the gradual transition from positivism to realism within the philosophy of science.

## 1. Introduction

It is plausible that the first use of the term 'logical empiricism' is due to Eino Kaila<sup>1</sup> (1890–1958). He was an affiliate of the Vienna Circle since the late 1920s. Kaila visited Vienna occasionally and discussed with its members, especially Carnap, Feigl and Waismann. He was a prominent figure in the 20th century Finnish philosophy. Kaila wrote in Finnish, Swedish and German. Many commentaries of his work are authored in Finnish, so his philosophy is not that well-known to the English-speaking world. His major work *Human Knowledge* was originally published in Finnish (*Inhimillinen Tieto*) in 1939 but translated into English as late as 2014.

Among Kaila's writings there is one item that has received very little attention. This is his brief monograph whose complete title reads: *Einstein-Minkowskin invarianssiteoria. Tutkimuksia sen loogis-tietoteoreettisesta luonteesta ja sen luonnonfilosofisesta merkityksestä*. The work was published in the series *Ajatus*, an annual still run by the Philosophical Society of Finland. Kaila completed the manuscript but never saw the final publication. He died in the summer of 1958 whereas the book came out in the fall of 1958. The title could be translated as *Einstein-Minkowski Invariance Theory. Investigations into its Logical-Epistemological Nature and into its Natural Philosophical Significance*. I shall refer to it as EMIT. As the

title suggests, both [Einstein's 1905](#) and [Minkowski's 1908](#) contributions are discussed therein.

The purpose of this essay is to unravel Kaila's interpretation of EMIT. To that end, this essay applies the following structure. Section 1 lays out the relation between Kaila's logical empiricism and scientific realism. He was doubtlessly a critic of metaphysics. Yet his empiricism centers around the principle of testability, not the principle of verifiability. The principle of testability, together with his holistic philosophy of science, makes his empiricism more moderate compared to the preceding tradition of logical positivism (like Schlick's verificationism) or classical British concept empiricism (such as Hume's copy principle). The most significant difference to radical empiricism and positivism is Kaila's realist position in the philosophy of science. Section 2 works out Kaila's theory of invariances. This theory comes close to what we nowadays call structural realism. As will be explained, invariance comes in degrees: Kaila distinguishes between phenomenal  $\varphi$ -objects, physical  $f$ -objects, and physico-scientific  $s$ -objects. This is his contribution to the perennial problem of appearance versus reality. In his view, the more invariant something is, the more real it is. Section 3 focuses on the main topic of this essay, to wit, Kaila's EMIT. Two aspects stand out in his work. First, Kaila applies his general theory of invariances to the structure of four-dimensional spacetime. Second, he argues for a non-conventionalist

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<sup>1</sup> Kaila described his own position as "ein logischer Empirismus" in 1926 ([Niiniluoto, 2012](#), pp. 71–89).

understanding of the isotropy of electromagnetic signals. The result is a scientifically realist position concerning the theory of special relativity.

## 2. Logical empiricism and scientific realism

Kaila met with the members of the Vienna Circle first time in 1929 when he gave a talk at their meeting. Before that, in 1926, he composed an article on scientific and metaphysical explanations of reality in the spirit of logical empiricism (his term). The article does not flatter metaphysical explanations. The term ‘explanation’ is misleading here. Kaila thinks metaphysical visions do not succeed in explaining phenomena, but they make reality familiar to us.<sup>2</sup> In this context, Kaila (1926/1990: 428–30) refers to mechanistic and spiritualist conceptions of nature. Mechanistic intuitions are modelled on hard objects amenable to the sense of touch. This is the source of substance metaphysics and their essences. Spiritual outlooks, as exemplified by Schopenhauer, project human-like agency onto the natural world: water “urges” to dive into deep water; iron “longs” to a magnet; the opposite electric charges are “passionately” attracting each other (Niiniluoto, 2012, pp. 71–89).

Different thinkers construe different kinds of metaphysics based on their temperament. Instead of making reality familiar to us, scientific thinking is dominated by the principle of verification. This is how Kaila (1926/1990: 422–3) formulates the principle: “each proposition concerning reality must imply something determinate concerning experience, which is the basis of the truth or probability of that proposition.” He goes on to claim that “we are not in a position to judge the truth or probability of a proposition which not only goes beyond human experience but does not *imply* anything concerning experience” (Kaila, 1926/1990: 423). In brief, if a factual<sup>3</sup> proposition does not imply anything concerning experience, it is an instance of metaphysical, not scientific thinking.

Although Kaila uses the word ‘verification’ in his early career, we can see that already in the 1920s, he did not approve the positivist principle of verification. In a 1929 book that treats the contemporaneous world conception, Kaila reiterates the distinction between scientific and metaphysical thinking. The premise is that if we give up the principle of verification (which already at this point comes close to the principle of testability; more about this below), our debates would be completely arbitrary. We could not settle any debate between the contesters if the claims they make are unverifiable. Kaila (1929/1990: 459–60) is careful to add a qualification:

We shall again point out that the principle of verification *does not* contain the view that we cannot pass the “bounds of experience”. The view which requires thinking to be so restricted, clipping its own wings, is called “positivism”. As we reject metaphysics we also reject positivism. We claim that within positivism the principle of verification is misconstrued. We may pass the “bounds of experience” as much as we like, as long as we stay in touch with it in a way that the propositions we make *imply* something determinate concerning experience. In principle, we must be able to decide if our propositions are true or false. For instance, contemporary physics does not get along without “electrons”, which cannot ever be, due to their nature, “directly observed”. Yet their existence is, based on experience, doubtless.

There is a stark contrast between scientific and metaphysical theorizing. Kaila (1926: 427–8) mentions the concept of a substance. In explaining natural events, physics is not allowed to attribute anything more than properties which imply something determinate concerning experience. An electron’s mass and charge may be calculated from

<sup>2</sup> There is some analogy to Ladyman’s and Ross’s notion of a ‘locator’ as articulated in their *Every Thing Must Go*, section 2.3.4. I thank the referee for bringing this connection up.

<sup>3</sup> Excluding the truths of logic and mathematics.

measurable quantities, and inferred from observable phenomena like the radius of electron’s orbit in a magnetic field. Kaila emphasizes that currently (mid-1920s) physics posits electrons as the ultimate particles. They are not substances in the metaphysical sense. They are not hard, they must not be completely homogenous in their internal structure, they are not the absolute and final “substratum” of all material events.

As Kaila thinks the notion of substance is metaphysical and unknowable, he is also extremely critical of the concept of essence. Essences may not be grounded in substances because the notion of substance does not imply anything definite concerning experience. In his *Human Knowledge* (1939/2014: 173), he complains that the term essence

is missing from our everyday knowledge and scientific thought, wherever these have reached even a modicum of logical precision. No tailor speaks of the essence of coat; no contemporary physicist speaks of the essence of electricity, or an economist of the essence of money.

Kaila, perhaps echoing Carnap’s (1932/1959: 69) critique, reads Heidegger’s existentialism very intolerantly. Statements like ‘the essence of time is care’ are as sensible as statements like ‘the essence of coat is pocket’. He considers such statements to be merely lyrical expressions.

When Kaila’s critique of metaphysics and his principle of testability are juxtaposed, we can see that his conception of science is not positivist. This is his mature statement of the principle of testability in *Human Knowledge* (1939/2014: 146):

The principle of testability says no more than that every factual sentence must have some consequences with respect to experience. It does *not* imply that every factual sentence should be capable of a definitive verification or falsification. On the contrary, our first task will be to show that there is in fact not a single factual sentence of which it could be shown in the strict sense that it is true or false. A sentence of this kind can only be confirmed or disconfirmed to a greater or lesser degree by experience. And yet many empiricists, including many logical empiricists, have thought that every factual sentence should have to be able ‘in principle’ to be verified or falsified completely.

This principle is different from the principle of verification or the translatability thesis. We can see that Kaila changed his mind: In his youth he was sympathetic to verificationism and the translatability thesis. Later he considered them to be mistaken.<sup>4</sup> The testability principle neither requires that propositions are verifiable by direct sense experience, nor that concepts could be translated to observational language individually. Compare Kaila to Schlick or Hume. In his “Positivism and Realism” (1932, 1933/1959: 87), Schlick maintains that the meaning of words must be shown, that is, given in direct sensory experience, and “the *meaning* of every proposition is finally to be determined by the given, and by nothing else.” By applying the copy principle — roughly, the thesis that all simple ideas are caused by and resemble simple impressions — as Hume (1748/1777) explains it in his *Enquiry concerning Human Understanding* (2.9; SBN 21–2), “we may “banish all that jargon, which has so long taken possession of metaphysical reasonings, and drawn disgrace upon them.” Kaila’s mature epistemology and philosophy of science does not contain such stringent verificationist trends.

In the previous quote Kaila talks about confirmation and disconfirmation. He deliberately contrasts his position to the notion of a crucial experiment. In this context he lends his support to Duhem’s 1914 work *The Aims and Structure of Physical Theory*. Duhem calls the idea of a decisive experiment, an experimental procedure that declares the winner between rival theories once and for all, a “myth” and an “impossibility” (Duhem, 1914/1954: xxv, 188). Individual experiment does not prove or

<sup>4</sup> In his *Human Knowledge*, Kaila was somewhat uncertain about the status of the thesis of translatability. At that point, he did not eschew it completely. In EMIT (40, fn. 1), he describes the thesis as “principally erroneous”.

disprove a theory. Theories may not be translated into observational languages concept by concept, as the translation thesis requires. Scientific theories are highly idealized (Kaila uses the word “rationalized”) and confront experience as a whole. “We cannot therefore”, Kaila (1939/2014: 170) has it,

require of such a theory that each of its sentences have some determinate consequences with respect to experience, but only that the whole theory stands to experience in such a relation that experience can corroborate or undermine it. We must, then, give the principle of testability a broad interpretation, so that a theory in its entirety can be regarded as ‘one sentence’.

There are some similarities between Kaila's position in his *Human Knowledge* and what Quine would about ten years later propose in his “Two Dogmas of Empiricism”. The totality of our knowledge or beliefs forms a web “which impinges on experience only along the edges”. Science in its entirety “is like a field of force whose boundary conditions are experience. A conflict with experience at the periphery occasions readjustments in the interior of the field” (Quine, 1951: 39). Both Kaila and Quine think that science is not tested sentence by sentence, but the totality of theories confront experience. There is one very important difference between the two: Kaila upheld the analytic/synthetic distinction whereas Quine's holism denies the distinction.

It is not clear how precisely logical empiricism is to be reconciled with scientific realism. Typically, realist views lean on some version of truthmaker semantics. There is something out there in the world that exists independently of us, and in virtue of that being (entity, fact, state of affairs, structure etc.) our claims about reality may turn out to be truthful. Kaila, even in his mature philosophy, was very critical of the notion of substance. Characteristically, substance is self-existing. Some self-existing truthmaker is required for making sense of a realist ontological commitment.<sup>5</sup>

Kaila seems to have supported what we would call, in reference to Putnam, the “no miracle argument”. Kaila discusses the external world hypothesis. Even in his early career he thought it is very probable that there is a correspondence between our conception of the world and the world itself: “If such a correspondence did not obtain, it would be a ‘miraculous accident’ that the human world picture in fact can be used to predict observable phenomena” (Kaila, 1926/1990: 434; Niiniluoto, 2012: 71–89). To be clear, in this context Kaila talks at the level of worldviews. He mentions prediction but does not analyze scientific theories in detail. For his part, Putnam specifies that i) the theoretical terms in mature sciences refer to external, theory-independent reality, that ii) mature theories are approximately true, and that iii) the same term refers to the same thing even though it appears in different theories. Accordingly, “these statements are viewed by the scientific realist not as necessary truths but as part of the only scientific explanation of the success of science, and hence as part of any adequate scientific description of science and its relation to its object” (Putnam, 1975: 73). Kaila's pre-Kuhnian no miracle argument is silent about the problem of historical continuity/discontinuity of scientific theories. It is a broader claim about the relation of human cognition and the external world. Kaila says more modestly than Putnam that external world realism is highly likely.

As mentioned before, Kaila is a critic of metaphysics. Yet he does explicitly refer to “correspondence”. There must be *something* which corresponds to our theories. Already in his young age, his views were growing out of the positivist agenda. Kaila is not hence the typical instrumentalist about science as many of the positivists would be called. Logical empiricism is a more moderate version of empiricism which allows for science to grasp general, real structures.

Allowing the possibility or even the likelihood that our conceptions match to some degree with reality does not yet answer the question what

it is out there that corresponds to our propositions or theories. Ilkka Niiniluoto (1992: 102) and Matthias Neuber (2015) have argued that Kaila's realism hinges on the notion of invariance. He thinks the more invariant, or lawlike something is, the more real it is. The task of the next section is to set out the significance of Kaila's invariance theory.

### 3. Invariances: the primary objective of human knowledge

The most important factor about the acquisition of knowledge is the identification of invariances. In his *Concept of Reality*, Kaila (1941/1979: 150–1) uses “the term ‘invariance’ as a collective name for any kind of similarity, sameness, uniformity, lawfulness, constancy, analogy, structural identity (isomorphism)”. A paradigm example of invariance is a law of nature, as it exemplifies constant regularities among events. Kaila maintains that all fields of inquiry, whether physics or psychology, search for sameness, permanence, and changelessness. In a word, science is about the discovery of invariances. This kind of conception about the basic nature of our epistemic endeavors might seem one-sided. Kaila (1939/2014: 3–4) however notes that the use of invariances does not only belong to the established scientific fields. It is also a part of pre-scientific, everyday thinking.

Kaila separates three kinds of objects: phenomenal  $\varphi$ -objects, physical  $f$ -objects, and physico-scientific  $s$ -objects. They differ in their degree of invariance. He details the relation of these three objects in his posthumously published article on the perceptual and conceptual aspects of experience (Kaila, 1960/1976).  $\varphi$ -objects are phenomenal objects of our experience. This is how objects appear to us primitively. From  $\varphi$ -perspective, an oar in the water is bent.  $f$ -objects are physical, medium-sized dry goods. From  $f$ -perspective, an oar is rigid and straight, a hard wooden object.  $s$ -objects are defined by quantitative scientific research. From  $s$ -perspective, we can explain how the oar looks to be bent in the water when we consider Snell's law. When a ray of light refracts among media 1 and 2 with indices of refraction  $n_1$  and  $n_2$ , the angles  $\alpha$  and  $\beta$  are related by  $n_1 \sin \alpha = n_2 \sin \beta$ . Water's index of refraction is about  $4/3$ ; therefore, we see a bent oar. The range from  $\varphi$ -objects to  $f$ -objects to  $s$ -objects entails an increase of conceptualization.

Although Kaila does not think that the difference between the three objects is categorical, we necessarily need conceptualization to correct the raw information we receive from our senses. In his example, consider two weights on a table,  $A$  and  $B$ . They have the same mass.  $A$  is bigger in size than  $B$  as  $A$  is partly hollow inside. When we weight them in our hands it might feel that  $A$  is lighter. Kaila explains. Different visually observable sizes cause different anticipations about perceptual weights. This anticipation is not conscious. We are driven to use greater muscle force for lifting  $A$  and hence it will accelerate more rapidly. This makes it feel as if lifting  $B$  is a heavier task, as we do not prepare to lift that weight with such a great force. Perceptual errors are abundant in every-day life. The basis for claiming that the weight measured at the scale is real as opposed to the perceptual weight is that we are looking at the  $\varphi$ -objects from the viewpoint of  $f$ -objects, that is by the concepts produced by conceptual experience. The information we have on  $f$ -objects is explicated by a higher-level conceptualization, to wit, by a consideration of the definitions and laws of classical mechanics. Kaila equates intellectual development with a higher degree of conceptualization. Little children and nonhuman animals are locked in the phenomenal realm of objects (Kaila, 1960/1976: 43–4).

The invariance principle is most relevant for Kaila's epistemological and scientific realism. He uses it as a criterion of reality. Kaila (1941/1979: 185) notes that before him Helmholtz and Planck had expressed similar views: “Lawfulness is the essential precondition for the character of the real” (Helmholtz); “The real is what is constant” (Planck). Neuber (2015: 37) observers that Kaila comes close to a structurally realist view of physical science. This is how Kaila (1941/1979: 151) expounds on the relation between invariances and mathematically identifiable structure in the *Concept of Reality*:

<sup>5</sup> For truthmaking being expressive of realism, see Tahko (2016).

In all cases in which we speak of ‘invariances’, there is indeed always something that is ‘invariant’ in the literal sense [...] in any formal analogy, structural identity, isomorphism between two different domains, there is also some logically or mathematically definable ‘structure’, e.g. an equation, that is invariant with respect to the interchange of these domains.

The objective of acquiring knowledge is to capture invariant structures. In the interpretation of Neuber (2015: 37), physical reality is nothing but invariances. Kaila thinks that the only meaningful way to use the predicate ‘real’ is by contrasting it with ‘unreal’ or ‘illusory’. He traces this back all the way to Plato’s idea theory: ideas, as opposed to the ever-changing world that appears to our senses, are invariant. In Kaila’s case, there is relative reality because the objects of our experience range from the phenomenal to the physico-scientific. “*The ‘real’ is what is in some respect (relatively) invariant*”, Kaila (1941/1979: 185) has it. “Physico-scientific reality is the system of higher invariances of everyday reality, in which again a large part of the latter reality is adjudged as ‘illusion’ and eliminated”, he (*Ibid.*) continues.

Invariances are not dependent on our language although they are expressed with mathematical language. Metrical relations make measurement in the first place possible: they are “elementary facts which must be present independently of measurement” (Kaila, 1941/1979: 200). Many would disagree with Kaila on this point. In Reichenbach’s *Axiomatization of the Theory of Relativity* (original German publication in 1924), metrical relations are built up from elementary measurements. This project was later followed by Weyl and in the 1970’s Ehlers, Pirani and Schild.<sup>6</sup> Based on Kaila’s point, Neuber (2015: 38) interprets, “his invariantist approach comes very close to structural realism.” Kaila deliberately contrasts his position with Kant, or Kantianism. “It is wrong to say”, he writes in *Human Knowledge*,

that we know *nothing* of things-in-themselves: after all, we do know their structure. And if the extreme view turned out to be correct that our knowledge is in the last analysis just a matter of mere isomorphic representation, we would have to say that we know just as much about things-in-themselves as we do about appearances (Kaila, 1939/2014: 14).

Kaila’s position is clearly not phenomenalist or radically empiricist, because he provides an argument as to why our knowledge is not merely about appearances. Higher degrees of invariances enable us to correct merely phenomenal experiences of objects. Invariances are genuine, discoverable features of reality. One of the most invariant objects of physical science known to Kaila must have been the four-dimensional spacetime.

#### 4. Einstein-Minkowski invariance theory

Kaila prefers to call the special theory of relativity the Einstein-Minkowski theory of invariances. Both the original publication of Einstein (his 1905 article “On the Electrodynamics of Moving Bodies”) as well as Minkowski’s geometrical exposition (his 1908 Cologne lecture “Space and Time”) are of the central importance. In the Preface of EMIT Kaila notes two salient things concerning the “logical-epistemic” and “natural-philosophical” nature of the theory. Considering the logical-epistemic aspect, the definition of simultaneity provided by Einstein is not merely conventional. Kaila sees it as a part of a broader empirical theory of physics and interprets it in a non-conventionalist manner. Considering the natural philosophical aspect, the theory predominantly shows not that time and space are relative but that there is an invariant spacetime interval. The Preface is followed by four main sections. They are entitled I. What the Einstein-Minkowski invariance theory is about, II. The relation of physical theory to physical experience, III. The nature of

physical experience in light of the Einstein-Minkowski theory, and IV. On a few details concerning the Einstein-Minkowski invariance theory.

Before delving into EMIT, a clarification must be issued. In his analysis, Teuvo Laurinolli (2015: 159) observes that the contents of the sections of EMIT do not always properly reflect their respective titles. At times Kaila explores some highly specific issue not strictly related to the title of the section in question. This indicates that Kaila wrote EMIT to clarify his own thoughts on the matter. Occasionally EMIT reads like a reading diary. Even though the objectives of individual sections are not that clear to the reader, it is nevertheless clear that EMIT establishes two points already mentioned in the Preface: invariantism about spacetime and non-conventionalism about the one-way speed of electromagnetic signals. These two main points (with some miscellaneous analyses here and there) back up Kaila’s overall realist stand in the philosophy of science.

##### 4.1. Invariance theory meets spacetime

It is quite typical to introduce special relativity with two postulates, namely the invariance of the laws of nature in inertial frames and the constancy of the speed of light in a vacuum. Kaila starts his exposition from the Lorentz-Einstein transformation equations. They imply how spatial and temporal coordinates are transformed from one Galilean system (which Kaila equates with inertial frame of reference) to another. He takes these equations to be so important that they comprise the whole theory of special relativity. He notes that the two major features of these equations are that 1) the speed of light  $c$  is constant in all inertial frames of reference, and that 2) the transformation equations retain an invariant spacetime interval (EMIT 11–2). Both points relate to invariances.

In assessing invariance within relativity theory, Kaila mentions the familiar analogy to the Pythagorean theorem in the context of Cartesian coordinate systems. Although two spatial coordinates in two Cartesian coordinate systems differ,  $\Delta x \neq \Delta x'$  and  $\Delta y \neq \Delta y'$ , the hypotenuse  $d$  is invariant among the two systems:  $d^2 = (\Delta x)^2 + (\Delta y)^2 = (\Delta x')^2 + (\Delta y')^2$ . In relativity, the spatial and temporal coordinates differ in different inertial frames of reference,  $\Delta x \neq \Delta x'$  and  $\Delta t \neq \Delta t'$ , but the spacetime interval,  $s^2 = c^2(\Delta t)^2 - (\Delta x)^2$ , is invariant among the frames. Kaila compares the invariant relations of the Euclidean space and what he calls the “Minkowski world”: “In the four-dimensional ‘Minkowski world’ the same relation holds even in a higher-level sense” (*Ibid.*). There is more invariance in the four-dimensional theory as it contains one dimension more than its three-dimensional counterpart. He also mentions that the difference between Pythagorean-Cartesian and Minkowskian cases is that in the latter there is a negative quantity in  $\Delta s = \sqrt{-(c\Delta t)^2 + (\Delta x)^2 + (\Delta y)^2 + (\Delta z)^2}$ .

Emphasizing the role of invariances in physical theories is certainly not novel. Kaila (EMIT 74) is well-aware that this has been known since Minkowski: “Einstein’s relativization of time and space and the whole doctrine of relativity is only a step toward what is philosophically the main thing, that is spacetime invariance as noted by Minkowski”. Already in 1930, Dirac (1930/1958: Preface) assimilated “the growth of the use of transformation theory” into “the essence of the new method in theoretical physics”, to which he includes both relativity and quantum theory. The cognitively “important things in the world appear as the invariants [...] of these transformations” (*Ibid.*). Nozick (2001: 76) was clearly inspired by Dirac’s premise. He used relativistic invariances as a paradigm example of an objective structure in a way that is reminiscent of Kaila: “*space-time* is a true ontological entity, for only it, and not its lesser dimensional parts, shows something that is invariant under Lorentz transformations.” (Nozick, 2001: 77). In contemporary philosophy of physics, a more general notion of a symmetry is applied (for example, Saunders 2015) to account for invariances. According to Saunders’s (2007: 453) preferred formulation, “only quantities invariant under exact symmetries are real—thus relative directions, relative distances, and so on, under

<sup>6</sup> See Linnemann and Read (2021) for this point.



rotations and translations, etc.” Although there are notable similarities, Kaila's invariance theory is different from the aforementioned because it is integrated into his theory of the degrees of conceptualization. There is a range from phenomenal  $\varphi$ -objects to physical  $f$ -objects to physico-scientific  $s$ -objects. Our phenomenal experience of spatial and temporal dimensions is our primitive phenomenal cognition of our environment. At the highest degree of cognition, we mathematically grasp the interconnection of space and time: spacetime.

Kaila spends multiple pages expounding on the notion of an inertial frame. He maintains that kinematically geocentric and heliocentric accounts are equal. He notes that this is easier to comprehend when we imagine only two bodies, the Earth and the Sun. “It is a mere convention,” Kaila (EMIT 15) writes, “whether the applicable coordinate system is attached to the Sun or to the Earth, albeit attaching the coordinate system to the Sun makes the description simpler in the dynamical sense.” As Kaila thinks this is a conventional matter, the two alternatives do not have empirical truth-values or empirical content.<sup>7</sup> This does not mean that in Kaila's philosophy of science conventionality is unimportant. I shall get back to the role of conventions later in the section 4.2 that treats the light postulate.

Kaila mentions Newton's famous rotating bucket experiment to establish absolute motion. Newton thought that the concavity of the water in the last stage of the spinning bucket  $\square$  in the stage in which both the water and bucket spin, so that they are at rest with respect to each other — implies absolute motion regarding absolute space.<sup>8</sup> The concavity of the water in the bucket cannot be understood merely by a comparison to an immediate, observable surroundings. Therefore, Newton points out himself in the Scholium to the Definitions of his *Principia*,

that endeavor [of receding from the axis of circular motion] does not depend on the change of position of the water with respect to surrounding bodies, and thus true circular motion cannot be determined by means of such changes of position (Newton, 1687/1999: 413; contents of the brackets added by the author).

Kaila considers Mach's critique of Newton. Kaila writes that relativistic physics to some degree accepts Mach's point about the relativity of motion. Mach noted that both inertial and accelerative motions could be relative in relation to the distant stars and the whole mass distribution of the universe. No one could tell what happens to the water in the bucket in an otherwise empty space. The experiment is not done in isolation, so we simply do not know what the surface of the water would be if all other bodies were removed. We may only come up with fictions as to what might happen in that situation. “The one experiment [such as reported by Newton] only lies before us, and our business is, to bring it into accord with other facts known to us, and not with the arbitrary fictions of our imagination”, Mach (1893/2013: 232) concludes in his *Science of Mechanics*.

One might think that Kaila the logical empiricist would subscribe to Mach's criticism of Newton. After all, Mach is vehemently against reference to utterly unobservable structures of space and time. And many thought Mach became vindicated with the Einsteinian revolution.

<sup>7</sup> I suspect Kaila emphasizes the point about empirical truth-values, or probabilities, because he thinks analytic truths, like the truths of non-applied mathematics and logic, are true due to conventional, non-empirical reasons. Whereas logical truths have the truth-values of either 0 (false) or 1 (true), empirical propositions have probabilities ranging from 0 to 1. Kaila treats these matters in detail in Part II. Formal Truth of Theory and Part III. Empirical Truth of Theory of his *Human Knowledge*.

<sup>8</sup> Note that this is Kaila's interpretation. Rynasiewicz (1995) argues that the purpose of the bucket experiment is to show that absolute and relative motion can, in contrast to Descartes, be distinguished “by their properties, causes, and effects”. The revolving globes thought experiment (not discussed by Kaila in EMIT) enables us to infer the existence of absolute space.

Interestingly, Kaila does not seem to be siding with Mach. He points out Mach assumes action at a distance. Kaila himself seems reluctant in accepting non-mediated distant action. He notes that “material masses, from elementary particles to spiral nebulae, determine the structure of space in their vicinity” (EMIT 19).

Kaila is remarkably interested in the natural-philosophical significance of the notion of a field. He indicates, in reference to Weyl's *Space-Time-Matter* (1918/1921/1950), that based on modern physical understanding of the world, the notion of substance is obsolete. “Provided that quantum mechanics is right”, Kaila claims, “atomic systems [...] cannot be little bodies that endure in time but they must be (mostly very short) lines of waves as they may be present only in relevant parts of wavefields” (EMIT 22). If particles move in space the same way as waves proceed on water, we cannot meaningfully determine whether the particle located ‘here now’ is the same as another located ‘there then’. Waves are not distinctly located points. He thinks this is in contradiction with the genidentical axiom of mass points as proposed by Hertz. Consider mass point  $m$  at a time  $t_0$ . At any time  $+t$  or  $-t$ , there is only one mass point that is “the same” as  $m$ . In the Minkowski formalism, mass point  $m$  remains the same as its worldline connects certain mass point of the past to a certain mass point of the future. This potential contradiction sounds like a critical assessment of relativity. If fields prevail the way Kaila suggests, then we cannot talk about worldlines. He notes that in that case quantum physics turns out to be more fundamental than relativity. This does not mean he rejects the latter. Rather, relativity holds within some limits (EMIT 21–2).<sup>9</sup>

It is surprising that as Kaila is highly critical of the notion of a substance, he nevertheless enters speculation about some sort of “universal material field”. This speculation is not too far from the old notion of “ether”. “Empty space” is not really empty as it has certain geometric and physical properties; it is filled with what Kaila calls “electromagnetic” and “material energy” (EMIT 25). He does not elaborate on these concepts. He moves on to conjecture — but not support the thesis  $\square$  that the universal material field is a rehabilitation of Newton's absolute space (EMIT 27). This would lend credibility to the notion of a privileged frame. After reading forward, we can however see that Kaila's speculation does not lead him to think there is any absolute standpoint by which to judge any motions. The assumption of a privileged frame

would be blatantly in contradiction with the whole Einstein-Minkowski theory. One of its principal claims is that there is no such privileged frame. Already included in the “Galilean principle of relativity” is the equality of all frames with regard to mechanical phenomena [...]. If in the case of electromagnetic phenomena one cannot point to any absolute motion regarding a privileged frame,<sup>10</sup> this point is apparent in Einstein's magnet-conductor thought experiment in his 1905 article. See Norton (2014). but for instance the speed of light in each inertial frame remains the same constant  $c$ , does the assumption about the privileged frame have any physical content in the first place (EMIT 27–8)?

Next Kaila recounts his non-positivist stance. Mach and early Einstein, for example, thought that we should dispose of non-observable notions like absolute space, time and motion.<sup>11</sup> We have access to relative, observable motion. We can physically verify only one body's motion in relation to another one. Kaila says directly that such positivism is wrong (EMIT 28). He notes there is hardly any mathematical-physical theory which does not contain any non-observable items. Special relativity involves a fundamental mathematical structure, the spacetime interval. “By this the Einstein-Minkowski theory is similarly a theory about the

<sup>9</sup> In contemporary philosophy of science parlance, we might say that the theory of special relativity is truthlike or approximately true. For an extensive discussion, see Niiniluoto (2020).

<sup>11</sup> See Holton (1968), especially the section “Mach's Early Influence on Einstein”.

‘universal material field’ (EMIT 30). The notion of the “universal material field” is quite peculiar, as it is reminiscent of the notorious “ether”. Kaila’s reference to “ether” reads also like a reference to a mechanistic explanation. Earlier in his career, especially in the 1926 work on metaphysical and scientific explanations, he criticized mechanical explanations because they make reality familiar to us. As if length contraction, for example, should be explained in terms of compression of a body in relation to some material substance. This is reminiscent of the way objects appear to us primitively, how they feel, from the phenomenal standpoint. This is different from the geometric spacetime interpretation Kaila starts with and eventually subscribes to. What he says next shows that he does not reinterpret special relativity in any suspicious way. Special relativity

must be thought four-dimensionally in a way that the dimension of time in certain limits is equal to the spatial dimensions. By this the theory places “relativized” time in a much more significant position than what “absolute” time has in the classical picture of nature (*Ibid.*).

Here Kaila does not mention the concept of proper time,  $\tau$  (he does mention it on page 92). The reference to proper time is however obvious. Minkowski (1908/1923: 85) noted in his “Space and Time” that.

If we imagine at a world-point  $P(x, y, z, t)$  the world-line of a substantial point running through that point, the magnitude corresponding to the time-like vector  $dx, dy, dz, dt$  laid of along the line is therefore

$$d\tau = \frac{1}{c} \sqrt{c^2 dt^2 - dx^2 - dy^2 - dz^2}$$

The integral  $\int d\tau = \tau$  of this amount, taken along the world-line from any fixed starting-point  $P_0$  to the variable end-point  $P$ , we call the proper time of the substantial point at  $P$ .

Proper time is a frame-invariant quantity, an integral over an observer’s world-line. Its length depends on the specific path the observer takes through spacetime, but it is not dependent upon the frame of reference used to calculate it. Things come into being, follow another along the time-like worldline. None of this gets us back to the obsolete Newtonian time. Classical absolute space, time, and motion are not preserved. Kaila is careful to point out that the relativity of simultaneity destroys all this: “Now Einstein effectively shows that the resolution of the problem is simply the ‘relativization of time’ so that absolute simultaneity disappears” (EMIT 31). Observers traversing separate spacetime paths age differently. The spacetime explanation for this is that observers take different paths through spacetime with varying proper times. This is clearly expressed by the metric equation,  $c^2(\Delta\tau)^2 = c^2(\Delta t)^2 - (\Delta r)^2$ , which is applicable to any physical system’s trajectory (Holster, 2021).

On pages 63–5 Kaila considers the difference between perceptual and conceptual time. What is the relation between the experienced qualitative time and the measurable quantitative time? He includes duration and order within the qualitative domain. For our experience to be veridical, there needs to be some coincidence among the perceived duration/order and the physical intervals/ordering. Kaila claims that physical time is strictly connected to the relation of cause and effect. He briefly mentions the same cause, the same effect principle. He defines clocks in terms of closed cyclical systems. “In other words”, he writes, “a clock is each such physical system that executes classical causality in its simplest form” (EMIT 64). By this Kaila means that in the same circumstances the same things happen. The causal order is the basis for temporal order and the order we experience. In case we fail to perceive the order in such a way, we must conclude that our temporal experience is illusory.

Kaila does not spill much ink on the debate among presentism and

eternalism. He recognizes these doctrines but does not name them. In one paragraph, on page 65, it seems he sides with presentism. In this paragraph he also addresses the relation between the perceptual and the conceptual time. He asks us to listen to the ticking of a clock. The tic-tac interval in his example is half a physical second. Physical time is a sequence of durationless points. The present point separates the non-existent past and the non-existent future. When tic is present, tac will be in the future that does not yet exist; when tac is present, tic was in the past that does not exist anymore. The basic ontological assumption here is clearly presentist. What Kaila says next sounds a lot like the doctrine of the specious present. The tic-tac sequence “is in its entirety in the perceptual present, in the so-called presence-time, which has a certain duration” (EMIT 65). This finite presence-time is different from the point-time as described by physics. The duration of the ‘now’ we experience, as well as the change from the tic to the toc is the basis of our lived experience of time. In the view of Kaila, without the specious present and the change in what time we experience to be ‘now’ we could not have any knowledge of change and hence time. In this context, Kaila does not mention the concept of passage of time. Based on what at this point sounds like a presentist position, it is plausible that he thought passage in terms of the moving ‘now’ and changing tensed locations.

Towards the end of his monograph, Kaila does however lay out an eternalist argument. In his terminology, a feature of the Einstein-Minkowski theory is that in a “far-world” there are no present points. An indefinite number of such points would form “an absolute present-plane”, or how we may call it today, a hyperplane of simultaneity. Kaila does give some leeway to the eternalist credo based on the relativity of simultaneity. We may place the hyperplane of simultaneity as we wish; there is no unique foliation of spacetime. As “it does not have any meaning in the general world geometry [...] the past is as real as the present but — it must be added — also the future is as real as the past and the present” (EMIT 100).

Kaila subscribes neither to presentism nor eternalism explicitly. He does not have just one stance on this matter. I think we should interpret Kaila on this matter based on his overall invariance theory. From phenomenal perspective, there is an ever-changing specious present. This qualitative perception of ‘now’ separates the long-gone past, which we only remember, and the not-yet-existent future, which we may only anticipate. However, when we approach the issue from a scientific perspective by conceptualizing the relativity of simultaneity and the structure of Minkowski spacetime, we comprehend that there is no universal moment ‘now’. Therefore, a reasonable interpretation of Kaila is that he is sympathetic to presentism from the phenomenal dynamic viewpoint but sympathetic to eternalism from the physico-scientific viewpoint. The latter is more real than the former because it is more invariant. Past, present and future of our experience are transient, they change constantly; the special relativistic flat spacetime, which does not include the hyperplane of simultaneity, is invariant and not subject of change.

Based on the interpretation above, I have concluded that Kaila’s reasoning contains some presentist and some eternalist elements. Considering his invariance theory, there is nothing paradoxical about this. In the phenomenal domain we humans are presentists: we act like only the present exists but the past and the future do not. Yet when we consider the invariant spacetime structure, which under his classification exemplifies the highest degree of invariance humans can conceptualize, there is no room for a privileged present. There is no unique hyperplane of simultaneity in Minkowski spacetime, so the universally extended present does not exist. Instead, the past, the present and the future all exist. The reader might wonder how Kaila’s reasoning fits with the plethora of literature on presentism versus eternalism that is now available to us. It should be noted, however, that many of the landmarking papers in the field were published after his time. Rietdijk (1966) and Putnam (1967) published their classical statements of eternalism almost a decade after Kaila’s death. This spurred responses from Stein (1968), among others, who thought presentism may be preserved even in the

relativistic setting. Such dialectic, not to mention the voluminous literature that ensued, could not be apparent in EMIT. The dialectic takes place rather within Kaila's invariance theory.

What Kaila implies, but does not explicitly claim, is that there is no “temporal existence” in the “world construction” (theory) of Einstein and Minkowski (EMIT 100). We must assess the relevance of this thought carefully. By revoking “temporal existence”, he means the non-existence of absolute simultaneity in four-dimensional spacetime. Kaila claims that part of the invariances associated with the Euclidean-Galilean theory, such as temporal duration, the volume of a hard object and so on, are replaced by higher degrees of invariances as exemplified by the Lorentz-invariant spacetime intervals. Invariances in the Einstein-Minkowski theory regularly include one quantity more than its three-dimensional counterpart. There is a way to deduce the less invariant theory from the more invariant. The hierarchies of the theories, for Kaila, are determined by their degrees of invariances (EMIT 100–2). The four-dimensional spacetime is more invariant and so more real for Kaila than mere spatial and temporal dimensions. This is reminiscent of [Minkowski's \(1908/1923: 75\)](#) proverbial pronouncement: “space by itself, and time by itself, are doomed to fade away into mere shadows, and only a kind of union of the two will preserve an independent reality”.

#### 4.2. Non-conventionalism in relativity

Invariantism about spacetime, as explained in the previous section, fits with Kaila's scientific realism. The realist account of special relativity was challenged by another historically significant alternative, operationalism. This approach was made popular by Bridgman in his 1927 book *The Logic of Modern Physics*. According to Bridgman, “in general, we mean by any concept nothing more than a set of operations; *the concept is synonymous with the corresponding set of operations*”. In Einstein's original 1905 paper we can see an operationalist definition of simultaneity which reduces the concept of time to readings of clocks and measurable signals traversing between them. This positivistically-minded starting point renders absolute, imperceptible and non-measurable time a meaningless concept:

Applying this idea of “concept” to absolute time, we do not understand the meaning of absolute time unless we can tell how to determine the absolute time of any concrete event, *i.e.*, unless we can measure absolute time. Now we merely have to examine any of the possible operations by which we measure time to see that all such operations are relative operations. Therefore the previous statement that absolute time does not exist is replaced by the statement that absolute time is meaningless. And in making this statement we are not saying something new about nature, but are merely bringing to light implications already contained in the physical operations used in measuring time ([Bridgman, 1927/1958: 6](#)).

In reference to Bridgman's operationalist philosophy of science, Kaila comments that “it is evident that the whole manner in which Einstein argued for special relativity is positivistically colored” (EMIT 38–9).<sup>12</sup> Because of such positivism, Einstein favors conventionalism about the one-way speed of light. Kaila tackles Einstein's synchrony convention. Einstein presents it in section “Definition of Simultaneity” of his “Electrodynamics of Moving Bodies”. Kaila indicates that Einstein talks about the constancy of the speed of light in two senses. On the one hand, the constancy is an empirical generalization. On the other hand, the constancy is a mere convention.

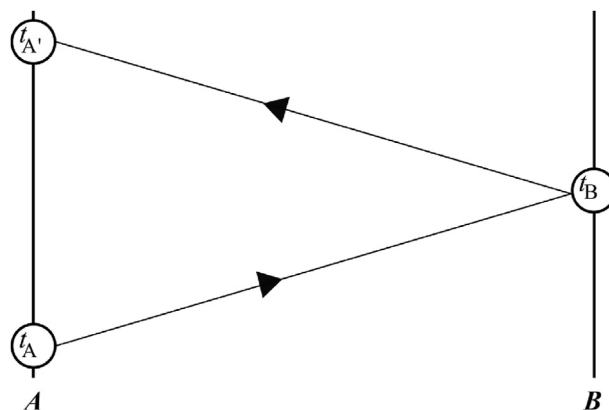
This is how Kaila reads Einstein. *A* and *B* are two different places. We can separate two different speeds of light. To follow Kaila's notation, there is *A–B–A* speed and *A–B* speed. The former is decided by one clock, the latter by two clocks. Considering the first case, we may determine the speed by sending a ray of light from *A* toward *B*, from which it is reflected

to *A*. As we know the distance *A–B*, we may calculate the speed of light on the roundtrip *A–B–A*. It is enough to use just one clock in this case, the clock situated at *A*. It would not matter what a clock at *B* indicates when the signal arrives at it. The Michelson-Morley experiment established the constancy of the roundtrip time of light (not with clocks but with an interferometer) and its independence of the velocity of the source of light. Einstein accepts that *A–B–A* speed is constant (EMIT 32–3). In his terminology,  $2\overline{AB}/t'_A - t_A$  is “a universal constant” that is “in agreement with experience” ([Einstein, 1905/1923: 40](#)).

Now we get to the synchronization problem. The *A–B–A* speed is constant, but if we want to ascertain the constancy of *A–B* and *B–A*, we need to use two clocks. The clock at *A* and the clock at *B* must tick at the same pace to show the same time. To apply the notation of Einstein, they show the same time provided that  $t_B = t_A + 1/2(t'_A - t_A)$ . After Einstein, [Reichenbach](#), whose book *Philosophy of Space and Time* (original German publication in 1928) is included in EMIT, added the epsilon synchronization parameter,  $\epsilon$ . The one-way speed of electromagnetic signals is constant if  $\epsilon = 1/2$  in  $t_B = t_A + \epsilon(t'_A - t_A)$ .<sup>13</sup> To elucidate the conventionality thesis, consider the [Fig. 1](#) and the [Table 1](#) below.

With the values used in the table, the roundtrip time is always two time units. The trips *A → B* and *B → A* last anything between larger than zero and smaller than two time units. In his popular book on relativity, a book that Kaila interprets in EMIT, Einstein claims that defining the one-way speed of light is up to our whim. “That light requires the same time to traverse the path” *A → B* and *B → A* is “a stipulation which I can make of my own freewill in order to arrive at a definition of simultaneity” ([Einstein, 1916/1920: 27–8](#)). There is no definite simultaneity relation among two spacelike separated events. Later in his “Autobiographical Notes” — also included in EMIT's references — [Einstein \(1949: 60\)](#) claims that “there is no such thing as simultaneity of distant events”. We cannot truthfully say that two distant events, like identical readings of clocks at *A* and *B*, happen at the same time. There is no fact of the matter.

Here Kaila departs from Einstein. The strategy he applies certainly does not postulate any hyperplanes of simultaneity. Recall his point about Minkowski spacetime structure: “This kind of present-plane



**Fig. 1.** Light leaves from *A* at  $t_A$ , arrives at *B* at  $t_B$ , and gets back to *A* at  $t'_A$ .

**Table 1**

$$t_B = t_A + \epsilon(t'_A - t_A), 0 < \epsilon < 1$$

$\epsilon$	$t_A$	$t_B$	$t'_A$
1/2	0	1	2
1/4	0	1/2	2
3/4	0	3/2	2

<sup>12</sup> Kaila however observes that Einstein's epistemological views did not remain the same throughout his life (EMIT 36).

<sup>13</sup> For a clarification on the notation of Einstein and Reichenbach, see [Jammer \(2006: Chapter 7\)](#).

[hyperplane of simultaneity] can in certain limits be attached as we wish, which implies that it has no meaning whatsoever in the general world-geometry [four-dimensional spacetime]" (EMIT 100; contents of the brackets added by the author). Kaila subscribes to the relativity of simultaneity, but he does not thoroughly subscribe to the conventionality thesis. Note that he does not say that there is nothing conventional in relativity: he argues that the isotropy postulate is not *only* conventional.

He begins his counterargument by considering the basic content of the Lorentz-Einstein transformation equations. A moving body, measured from a non-moving frame, is contracted to some degree. Vice versa, the reading of a moving clock, measured from a non-moving frame, is stretched to some degree. If we focus here on time dilation, we may state that the moving clock is dilated from the viewpoint of the stationary system. This inference is dependent on the premise of the isotropic speed of light which is needed to synchronize the clocks. The synchronization is done under the assumption that the  $A$ – $B$  speed of light remains constant. If some other convention than  $\epsilon = 1/2$  is made, the "slowing down of moving clocks" would not necessarily exist (EMIT 33–4). For there to be time dilation, for the whole notion to be meaningful, the two clocks under comparison must somehow be, at some point, in synchrony. If this is not the case, how could we say that the other clock runs slower than this? The underlying assumption is that the clocks are synchronous in the beginning, but then, after the one remains motionless and the other one moves, the moving clock is time dilated. Hence, the two clocks are in synchrony no more. "All this is ultimately implied by," Kaila (EMIT 34) maintains,

how the clocks of the moving system, following Einstein's simultaneity definition, are synchronized. The clocks of the moving system are synchronized so that the  $A$ – $B$  speed of light is going to be constant. If some other convention had been made, such phenomena (slowing down of moving clocks etc.) would necessarily not appear.

He makes almost the same point later in EMIT. There he adds that clocks must have some definite pace, that is, their periods should be isochronous (compared to each other at some point). Two clocks must first be synchronized with light signals, then they must operate isochronously, and *after* that we may veridically conclude that time dilation occurs. The whole synchronization process could not be only conventional as natural clocks exemplify time dilation. Thus Kaila (EMIT 71–2; the contents of the brackets added by the author) puts it as follows:

The whole discourse about "the slowing down of an atomic clock" presupposes that it has some definite (although decelerated) "constant pace" so that its recurring periods are isochronous, that is, "equal". If this presupposition was *not* made, it could not be counted what kind of relativistic interference effects should take place at  $A$  [the origin of the light signal]. But this presupposition is indeed the principle, which we lean on to arrive at the result that the constancy of the  $A$  –  $B$  speed is an empirical assumption.

If something is denoted a convention, there cannot be anything true or false, or right or wrong, with respect to that convention. "In that case", Kaila goes on, "no 'convention' could imply anything empirical, as if it did, this would indicate the 'rightness' or 'wrongness' of that convention" (EMIT 34). Clocks are not only human-made machineries. Whereas artefactual devices can be arbitrarily adjusted, there are many recurring physical systems whose lawlike behaviors we cannot affect. Among such systems are decaying elementary particles. The rate of these "clocks" slows down. Here Kaila uses quotation marks to refer to half-life decays.

<sup>14</sup> Kaila does not mention "mesotrons" specifically but he has a reference to Bradt's (1948) article "Why are we Studying Cosmic Rays?" On page 50 of that article Bradt explains, in reference to Einstein's special relativity and time dilation, how "mesotrons" survive from the atmosphere to the ground. This is a likely source of Kaila's view according to which elementary particles can be thought of as clocks.

In Kaila's context, time dilation was corroborated by the investigation of cosmic rays that produce muons (the historical name is "mesotron").<sup>14</sup> They are created at the Earth's atmosphere after which they travel to the ground. We would not detect muons in sufficient numbers on Earth without time dilation (and length contraction). Note that we cannot — this is one of Kaila's main points — make any sort of convention concerning the time dilation of elementary particles. He (EMIT 35) thinks

Einstein got it wrong when he thought that the advice he gave on how to synchronize spatially separated clocks and thus the determination of spacelike separated events is a sheer convention. If it were a mere convention, it could not concern clocks other than those clocks whose pace may be adjusted, so that they run according to Einstein's rule. "Atomic clocks" cannot be adjusted, but they nevertheless indicate time dilation.

Earlier in EMIT (13) Kaila notes that the special theory, unlike the general theory, is so enmeshed with contemporaneous atomic physics, so that "it has been proven right as much as can be hoped for". This addition is important considering Kaila's holistic empiricism. In a footnote on page 13 he cites Max Born's presentation from 1955, which was published in 1956, at a time very close to Kaila's writing of EMIT manuscript:

At present special relativity is taken for granted, the whole of atomic physics is so merged with it, so soaked in it, that it would be quite meaningless to pick out particular effects as confirmations of Einstein's theory (Born, 1955/1969: 109).

Kaila is a scientific realist in his mature philosophy. He sees special relativity in the same way as other pieces of well-established science.<sup>15</sup> The Einstein-Minkowski theory is "an empirical physical doctrine in the same way as for example some atomic theory" (EMIT 35). It is enmeshed with so much of contemporaneous high-energy physics that one cannot survey it as a stand-alone theory, in isolation of the rest of modern physics.

Kaila is not implying that there is nothing conventional in special relativity. He does not claim that the constancy of the one-way speed of electromagnetic radiation is provable by some crucial experiment. A requirement like this would be a step back to positivism. A suitable epistemology for physics abjures the translatability thesis. The more advanced epistemological approach is built around the principle of testability. I have already provided textual evidence for the centrality of the testability principle and highlighted its difference to the strictly verificationist theses of positivism and classical concept empiricism in the first section of this essay. Those quotes were drawn from his earlier, pre-1950s works. In EMIT (47), Kaila puts it as follows: the basic sentences of theories of physics "are never only empirical generalizations; they *always include conceptual ingredients that do not correspond specifically to experience.*" Scientific theories do not consist of fragmentary pieces that could be verified in direct experience one by one. Instead, theories confront experience as a whole.

## 5. Final remarks

Assessing Kaila's contribution from a broader history of philosophy of science perspective, we can see that his logical empiricism receded from positivism and steered toward scientific realism. EMIT provides an interesting example of this with its invariance and non-conventionalism. Spacetime invariance had been known long before Kaila. His original contribution was to apply his three-part invariance

<sup>15</sup> There is a clear contrast to Kaila's early career. In 1920 he published an article in which he was highly critical of Einsteinian relativity; he defended Lorentz's ether theory. This early work was however not, unlike EMIT, properly grounded in mathematical physics. Moreover, the empirical evidence in favor of special relativity was considerably stronger in mid-1950s than in early-1920s. Nowadays it is overwhelming.



theory to explain how we live in the phenomenal presentist realm of space plus time, but we are also mathematically capable of grasping the conceptually higher, more invariant spacetime eternalism. He argued that the one-way speed of light is part of the whole empirical theory of special relativity. The isotropy postulate is not a mere convention, an arbitrary assumption external to the theory. If isotropy of electromagnetic signals is only a stipulation, time dilation might not exist. As is evident from natural clocks as exemplified by muon decay, among other evidence, time dilation is real.

Today we probably would call EMIT, apart from “philosophy of physics”, “metaphysics of science”. It is questionable whether Kaila would have approved the metaphysical interpretation of his work as he used the word “metaphysics” frequently in the pejorative sense. Although this is partly a terminological dispute about the reputability of the term “metaphysics”, there is still some tension between Kaila’s logical empiricism and scientific realism. On the one hand, considering his logical empiricism, Kaila eschews metaphysics. On the other hand, considering his scientific realism, he maintains humans can acquire knowledge about the independent structure of reality. More precisely, Kaila thinks there is a correspondence between our conception of the world and the real invariant features of the world. It is highly dubitable whether such correspondence-realism can be formulated without any metaphysics.

EMIT has only appeared in Kaila’s native Finnish. Some things are lost in translation. I have done my best in translating several quotes from EMIT, but it is very difficult to get a sense of its archaic tone in English. It is not the most reader-friendly book as the author jumps from one topic to the other, often very quickly. I can still sympathize with Laurinolli’s (2015: 168) assessment of EMIT: some of its scattered paragraphs are “the golden chips of Finnish philosophy of science, to which the slightly dated style adds a charming patina”.

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