# A Regional Scientific Image of Time

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*Abstract*

Doing metaphysics by building on empirical sciences is a very controversial matter. This paper outlines a middle road between the Scylla of denying the possibility of metaphysics and the Charybdis of doing metaphysics a priori. This is possible if, on the one hand, we accept a moderate form of scientific realism. On the other, we establish a logico-epistemological framework adequate to face the underdetermination of metaphysical theses with respect to our best scientific theories. The case of the debate between eternalism and presentism tests my perspective. In this case study, the result is that both ontological hypotheses have their realm of validity. In other words, the fragmented scientific image of the world is reflected in an equally disjointed metaphysical perspective.

*Keywords*: Physical theories, Empirical metaphysics, Reality in time, Presentism, Eternalism.

## 1. Introduction

Though we have a partially clear perception of space, Augustine's famous quotation certifies that time is much more elusive (*Confessions* XI, 14). Even in our best scientific theories, time is something quite variegated. In classical and quantum non-relativistic mechanics, time stays in the background as an independent variable. In relativistic physics, on the other hand, time can change both its topology and its metric. Moreover, whereas space can be directly perceived through sight, no sensory organ can directly perceive time. Finally, experimental psychology shows that experienced time depends strongly on the content of our perception (Wearden 2016). To sum up, the common-sense term "time" seems to refer to something quite ephemeral and multifarious. Therefore, we assume that time is not something substantial.

This situation, however, has not impeded philosophers from trying to establish what time is. In this paper, I attempt to accomplish an aspect of this task, following a quite naturalistic metaphysical approach. I will limit myself to discussing only one metaphysical peculiarity of time defined in a very minimal way: the contraposition between restricted forms of *presentism* and *eternalism*. To explore this issue, I will move from our best physical theories. At the same time, I do not endorse a strong scientific realism, which usually brings scholars to accept

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eternalism arguing from special relativity theory. On the contrary, I limit myself to what I call "model-theoretic realism," which I will discuss in what follows. The conclusion that emerges from this investigation of our best scientific theories is a sort of *regional representation of time*, according to which presentism is favoured in certain contexts and eternalism is supported in others.[1]. In other words, by ascribing a partial truth to the Newtonian theory, it becomes possible to reconcile at least partly the eternalism imposed by special relativity theory with our strongly presentist intuition. I am sure that this is not the definitive theory of time since physics will undoubtedly change in the future; however, this may be so far a viable alternative.

We have assumed that time is not a substance. Moreover, we presuppose that the instants of time are a set endowed with an irreflexive, transitive relation "<", whose intuitive meaning is "before that". In specific physical contexts, "<" could also be total and antisymmetric, but it is not always the case. Indeed, in special relativity, it is not always possible to establish an order between two events, and in general relativity, closed time curves are possible.

We will be concerned not directly with time, but with what is in time, since eternalism and presentism concern the reality of what happens in time. On the one side, we have the presentist position: there is only what happens at a single instant, i.e., the moving now; on the other side, the eternalist: there is all of what happens at every instant. During the discussion, we do not face the delicate problem of *becoming* except in a very cursory way. Note that there is something deeply muddled in this kind of debate. Indeed, presentism seems to imply not only that at each instant, only what happens at that instant is real, but also that at each instant, only one instant is real! To give sense to this apparently meaningless statement, I will introduce an *epistemic time* in the framework in which we will develop our discussion. More on this later.

Many scholars doing metaphysics focus only on proposing theories that are compatible with our best scientific theories (Lowe 2001). Many others consider metaphysics a walking dead man (Price 2009). Here I propose a middle road. From the anti-metaphysicians, I accept the idea that the essence of reality is something intensely opaque to the human mind and that through our best scientific theories, we can catch only a few fragments of this "Leviathan". From the metaphysicians, I take the language, the subtle distinctions, and the analytical instruments they have established.

Our scientific knowledge is not a coherent set of well-delineated laws. On the contrary, it is a tangle of models, which sometimes converge and sometimes diverge wildly. These models can catch only a tiny part of reality since they are based on idealisations and approximations. For this reason, we must be ready to accept a regional result, as I am proposing here. This result could be provisional, and only future scientific theories will better clarify the situation.

Section 2 briefly outlines the method I will follow in the paper. In section 3, I sketch a helpful semi-formal system to assess the question of whether either eternalism or presentism holds. Section 4 presents the restricted forms of eternalism and presentism we will investigate. In section 5, I show how in Minkowski spacetime,

[1] I intend "favouring" as a weaker justification than "supporting". The same method of investigation is applied to time-travel by Fano and Macchia 2016, coming out with similar regional results.

eternalism is supported. In section 6, I outline the model-theoretic realism I am endorsing. In section 7, we will see that in Newtonian spacetime, presentism is favoured. In section 8, I will address a significant issue threatening the regional image of time that resulted from the preceding analysis. Concluding remarks sum up.

## 2. The Method

My paper builds on a few presuppositions about how to do metaphysics in strict collaboration with empirical sciences. First, the main difference between metaphysics and empirical sciences is terminological, i.e. metaphysical hypotheses are couched in terms like "property", "relation", "dependence", "part", "whole", "space", "time"[2] etc., which are not typical of scientific discourse. Moreover, metaphysical statements have a more general character, and therefore they are pretty bold and underdeterminate. Results coming from empirical sciences can suggest to us which metaphysical theory is more plausible. In other words, doing metaphysics from science entails that the former is fallible as the latter. There exist many different semi-formal definitions of the metaphysical terms.[3] Only empirical confirmation can decide which is correct and in which cases. Second, we consider our best scientific theories formulated as a set of models which could be subsumed under a certain set-theoretical predicate.[4] Here models are idealised and approximated representations of object domains. Third, we assume that if the model *M* satisfies the theory *T*, and *T* is our best explanation of *M*, then *T* says something partially true about *M*.

Here a brief digression on the meaning of the term "best explanation" is in order. If we want to do metaphysics from science, we could not intend the term pragmatically, as Carnap (1950). Indeed, "best explanation" refers to that theory, which we have good scientific reasons to believe that it catches most aspects of the considered domain of objects without being too complex. Sometimes it is not easy to give a clear answer to the question of which is the best explanation according to this definition. However, the criterion mentioned above—inspired by Lewis' best system theory of natural laws—could guide us. Therefore, if one wants to know something about *M* could and must look at *T*. Fourth, to say something metaphysical empirically justified on *M*, one must find a common semi-formal language *L* in which both *T* and the metaphysical notions we are interested in are regimented. The metaphysical thesis *P* is probably true for *M*—as represented by *T*—if in *L* it occurs that *P* is derivable from *T*. Moreover, the metaphysical thesis *P* is probably false for *M*—as represented by *T*—if in *L* it occurs that *P* contradicts *T*. In the end, if the metaphysical thesis *P* in *L* is compatible with *T*, T supports neither *P* nor ~*P*.[5]

[2] The terms "space" and "time" are typical also of mathematical physics, but generally, in these contexts, they do not concern either the whole space or the whole time, as in metaphysics. Be that as it may, the border between science and metaphysics is not completely well-defined.

[3] Here it is necessary to ask who decides these definitions. Following Machery 2017, I think that a posteriori conceptual analysis of which metaphysical notions are relevant is in order.

[4] Inspired by Suppes 2002.

[5] Here the terms "derivable", "in contradiction", and "compatible" cannot have a strict logical sense. Indeed, in establishing *L*, we are compelled to assume so-called "bridge laws between science and metaphysics", which must be discussed on a case-by-case basis.

## 3. The System

Take a propositional calculus in which it is possible to analyse the structure of sentences. That is, individual constants, functions, and predicate letters enrich the calculus. One of the predicate letters is the identity "=" between individual constants or individual functions, which is reflexive, symmetric and transitive, i.e., an equivalence relation. Sometimes languages of this kind are called "quantifier-free first-order logic". They are decidable and used above all in theoretical informatics.

Now we introduce a few metaphysical notions. "Properties" and "relations" are regimented as one-place and many-place predicates, respectively. "Events" are regimented as sentences containing only individual constants, predicates, functions and the conjunction of these. In $L$, there is also an infinite and *dense* set of individual constants $\{t\}$ among which an *irreflexive*, *antisymmetric* and *transitive* relation "$R$" holds. Predicates are established by the theory $T$ that best explains the domain of objects $M$. For instance, in material point mechanics, "$U(a, t_1) \wedge C(a, t_1)$", that is, "the material point $a$ at time $t_1$ is in the point $C$ with velocity $U$" could be an event.

Enrich further this propositional logic with the standard temporal operators ($H$, $G$, $P$, $F$), whose intuitive meanings are:

*H*: it has always been the case
*G*: it will always be the case
*P*: it has at some time been the case
*F*: it will at some time be the case

They are regimented only by the axioms of minimal temporal logic. If $\alpha$ and $\beta$ are sentences:

1. $G(\alpha \to \beta)\to(G\alpha \to G\beta)$
2. $H(\alpha \to \beta) \to (H\alpha \to H\beta)$
3. $\alpha \to GP\alpha$
4. $\alpha \to HF\alpha$

Note that our system regiments two notions of time: the set of individual constants $\{t\}$, which represents the time of the domain of objects and the epistemic time expressed by the operator $G$, $H$, $F$, $P$.[6] Moreover, on $\{t\}$ the partial order "$R$" applies, whereas the time governed by the operators "$H$, $G$, $P$, $F$" respects only the minimal temporal logic. In other terms, $\{t\}$ is the time of McTaggart's B-series, whereas the operators "$H$, $G$, $P$, $F$" refer to the A-series. This logic is provided with standard inference rules as well:

*Modus Ponens*,
If $\vdash \alpha$ then $\vdash G\alpha$ and $H\alpha$.

Call this language $L_{AB}$. It is necessary to introduce this double time to avoid misunderstandings. If I locate myself in a certain point of spacetime, this is an objective fact. However, I do not know whether my present is subjective or objective.

[6] Schlesinger (1980) introduced this idea to face McTaggart's paradox. However, the epistemic time here proposed is devoid of ontological commitment. Moreover, in this way, we bypass Dorato (2006)'s and Savitt (2006)'s criticism that the debate between presentism and eternalism is empty.

If it were objective, what happens at a different time from mine would be unreal, whereas if it were only subjective, all events could be real. In the following, we will see better how this machinery works.

Before concluding this section, a few words on the notion of epistemic time are in order. No one doubt that our experienced time flows, even if this sensation is not clear and the term "flow" could be misleading. Perhaps, to convey this feeling, it would be better to say that there is an intuitive semantics of terms like "now", "yesterday" "in a minute" etc. These terms do not refer to static relations between temporal instants. Prior's temporal logic establishes a language adequate for these terms. Now, the metaphysical question is to determine whether this terminology is only a subjective instrument, or it has also a real referent. For this reason, we introduce the epistemic time, that is merely subjective. Only the comparison with physical theory will suggest whether this language is objective as well. To avoid misunderstandings, I repeat that the individuals $\{t\}$ appearing in $L_{AB}$ are not the reference of the dynamic operators "*H*, *G*, *P*, *F*". Only a suitable epistemic operation could locate the instant of the epistemic time governed by "*H*, *G*, *P*, *F*" in the objective time $\{t\}$.

## 4. Presentism and Eternalism

In our system, a subset *E* of the well-formed-formulas of the calculus represents events. Our system has a denumerable infinity of individual constants $\{t\}$.[7] One can indicate with the symbol $E_i(t_i)$ a generic event at time $t_i$.[8] We establish that in an event,[9] only one individual constant of the group of time constants $\{t\}$ could appear. Let us leave implicit the other individual constants or functions of $E_i(t_i)$. "$E_i(t_i)$" means intuitively the event $E_i$ obtains at $t_i$.

The fundamental principle of presentism is:

(1) $E_i(t_i) \rightarrow \forall t_j\ (t_j \neq t_i \rightarrow \sim E_i(t_j))$

That is, if an event is presently real in *my* time, it is not real in any *objective* other time.[10] Consider that, as we will see in a moment, operators "*P*" and "*F*" do not refer to the $\{t\}$ series of time, else (1) would be incontestable, but to the time of the knowing subject.

On the contrary, the fundamental principle of eternalism is:

(2) $E_i(t_i) \rightarrow \forall t_j\ (t_j \neq t_i \rightarrow E_i(t_j))$

That is, all events exist independently of their position in *my* time.

[7] With this series of instants, one can approximate any instant of continuous time as s/he likes, diminishing the interval between two instants.

[8] We restrict ourselves to an instantaneous event for the sake of simplicity. "$E_i$" could be represented more formally as a conjunction of subject-predicates sentences, in each one of which "$t_i$" appears.

[9] The term "event" is a bit sloppy, since it refers both to a sentence and to the corresponding physical situation.

[10] With respect to the now fashionable taxonomy of presentism forms proposed by Fine (2006), this is a standard one, which recuses "neutrality". On the other hand, Pooley (2013) attempts to reconcile presentism and special relativity by denying neutrality, that is, proposing presentism without a global "now".

The two principles are in contradiction in $L_{AB}$ unless either there is no event or there is only one instant. Therefore, either presentism is true, and eternalism is false, or vice versa.[11]

## 5. Presentism, Eternalism and Special Relativity

Let us consider what happens in an accelerator like the Large Hadron Collider. Here the best scientific explanation is Quantum Field Theory (QFT). Spacetime in QFT is Minkowski spacetime. For many other physical systems, the best explanation is QFT, particularly for those in which the velocity of particles is sufficiently high, and gravity is not too high. QFT is not only the best explanation of what happens in our accelerators, but it holds as well inside stars if they are in a part of their life during which their density is not too high, and in astrophysical relativistic jets. Therefore, we assume that there is a set of systems $S_{\text{QFT}}$ for which QFT is partially true.[12] Now we can ask what happens to presentism and eternalism in the $S_{\text{QFT}}$ realm.

In order to discuss the relation between $S_{\text{QFT}}$ and $L_{AB}$, it is necessary to interpret the temporal operators of my epistemic time into the time of the systems. Remember that the time in $S_{\text{QFT}}$ is Minkowski (space)time.[13] Let us indicate the standard simultaneity hypersurfaces of Minkowski spacetime with $\{\mathrm{t}\}$. Our interpretation function "*I*" associates to each $t_i$ its correspondent $\mathrm{t_i}$ and to "*R*" a relation "<" such that "$t_iRt_j$ iff $\mathrm{t_i} < \mathrm{t_j}$". Moreover, let us indicate globally with "$\mathrm{E_i}$" the interpretation *I* of "$E_i$". Finally, let us introduce a set of instants $\{\tau\}$, among which a relation "$\prec$" holds. For the relation "$\prec$" no special property is presupposed. Note that $\{\mathrm{t}\}$ are the "instants" of the physical theory, whereas $\{\tau\}$ are those of my time. We must also assume that there is an empirical procedure to establish whether a member of $\{\tau\}$ is or not the same as a member of $\{\mathrm{t}\}$. Let us indicate the positive result of this procedure as "$\tau_i \equiv \mathrm{t_i}$". The relation "$\equiv$" is symmetric and transitive. An evaluation function *V* associates a subset T of $\{\mathrm{t}\}$ to each event. The simple and natural semantic rules we apply will be the following:

i. $E_i(t_i)$ is true for $\langle I, \{\mathrm{t}\}, \{\tau\}, \prec, V\rangle$ iff if there is a $\mathrm{t_i} \in \{\mathrm{t}\}$ such that $\mathrm{t_i}$ belongs to $V(E_{\mathrm{i}})$ then there is a $\mathrm{t_i} \in \{\mathrm{t}\}$ such that $\tau_i \equiv \mathrm{t_i}$
ii. $PE_i(t_{\mathrm{i}})$ is true for $\langle I, \{\mathrm{t}\}, \{\tau\}, \prec, V\rangle$ iff if there are $\mathrm{t_i}$ and $\mathrm{t_j}$ belonging to $\{\mathrm{t}\}$such that if $\mathrm{t_j} < \mathrm{t_i}$, then $\mathrm{t_j}$ belongs to $V(E_i)$, then there are $\mathrm{t_i}$ and $\mathrm{t_j} \in \{\mathrm{t}\}$ such that $\mathrm{t_i} \equiv \tau_i$, $\mathrm{t_j} \equiv \tau_j$, and $\tau_j \prec \tau_i$.
iii. $FE_i(t_{\mathrm{i}})$ is true for $\langle I, \{\mathrm{t}\}, \{\tau\}, \prec, V\rangle$ iff if there are $\mathrm{t_i}$ and $\mathrm{t_j}$ belonging to $\{\mathrm{t}\}$such that if $\mathrm{t_i} < \mathrm{t_j}$, then $\mathrm{t_j}$ belongs to $V(E_i)$, then there are $\mathrm{t_i}$ and $\mathrm{t_j} \in \{\mathrm{t}\}$ such that $\mathrm{t_i} \equiv \tau_i$, $\mathrm{t_j} \equiv \tau_j$, and $\tau_i \prec \tau_j$
iv. $HE_i(t_{\mathrm{i}})$ is true for $\langle I, \{\mathrm{t}\}, \{\tau\}, \prec, V\rangle$ iff if there is $\mathrm{t_i}$ belonging to $\{\mathrm{t}\}$such that $\mathrm{t_i} \equiv \tau_i$, and for each $\mathrm{t_j}$ belonging to $\{\mathrm{t}\}$such that $\mathrm{t_j} < \mathrm{t_i}$, $\mathrm{t_j}$ belongs to $V(E_i)$ then there is a $\mathrm{t_j}$ such that $\mathrm{t_j} \equiv \tau_j$, $\mathrm{t_j} \in \{\mathrm{t}\}$ and $\tau_j \prec \tau_i$

[11] In philosophical literature, there are many forms of presentism and eternalism. Here we consider only a sort of minimal core of these perspectives.
[12] Note that here I bypass the measurement problem in QFT altogether.
[13] Note that it is possible to interpret special relativity without giving such great importance to Minkowski spacetime; see, for instance, Brown (2005). On the other side, if one does not introduce a preferred reference frame—and Brown does not do this—special relativity remains incompatible with presentism.

v. $GE_i(t_i)$ is true for $\langle I, \{t\}, \{\tau\}, \prec, V\rangle$ iff if there is $t_i$ belonging to $\{t\}$such that $t_i \equiv \tau_i$, and for each $t_j$ belonging to $\{t\}$such that $t_i < t_j$, $t_j$ belongs to $V(E_i)$ then there is a $t_j$ such that $t_j \equiv \tau_j$, $t_j \in \{t\}$ and $\tau_i \prec \tau_j$

Note that, to make i.-v. false, the antecedent of the semantic condition must be true and the consequent false.

Let us take an event $E_1(t_1)$ and let us assume that "$E_1(t_1)$" is true in my present. Define the meta-semantical notion "to be true together" ($\bowtie$) between two sentences referring to different events, whose intuitive meaning is that both events are the case in my present. It is clear that the relation "$\bowtie$" must be an equivalence relation.[14] Moreover, we know that in Minkowski spacetime, it is possible to define only two equivalence relations between events (Putnam 1967), viz *identity* and the *universal relation*. This means that one must decide either in my present, all events occur, or only $E_1(t_1)$ is the case (Calosi 2014). Almost all philosophers of physics today, facing such a dichotomy, would choose the former option, that is eternalism.[15] Indeed, if one applies the rules i.-v., (1) and (2) become:

(1') if there is a $t_i \in \{t\}$ such that $t_i$ belongs to $V(E_i)$ and there is a $t_i \in \{t\}$ such that $\tau_i \equiv t_i$ then there is no $t_j \in \{t\}$, $t_j \neq t_i$, such that $E_i(t_j)$

(2') if there is a $t_i \in \{t\}$ such that $t_i$ belongs to $V(E_i)$ and there is a $t_i \in \{t\}$ such that $\tau_i \equiv t_i$ then for each $t_j \in \{t\}$, $t_j \neq t_i$, $E_i(t_j)$ holds.

First, note that (1') is not obviously true. Indeed, if there is a simultaneity hypersurface in Minkowski spacetime, which could be identified as my present, the same event could be true in other objective hypersurfaces, making the consequent false.

Clearly, if the antecedents of (1) and (2) are false, the definitions of presentism and eternalism do not apply. However, this falsity would mean it is impossible to find a physical instant corresponding to the subjective present. We assume instead that it is possible to find a physical instant corresponding to my present. Therefore, if the relation "$\bowtie$" is the universal one, clearly (1) is false and (2) is true, whereas if "$\bowtie$" is the identity relation, (1) is true and (2) is false. How to decide between these two possibilities? Here accepting at least a modest scientific realism is crucial. If one believes that Minkowski spacetime is real, s/he is compelled to choose "$\bowtie$" as the universal relation. However, this is not the only possibility. Indeed Čapek (1975) endorses the latter identity position, which saves presentism, maintaining that, after special relativity, it is no longer possible to speak of what happens in a place different from that of the observer. Presentism

[14] We do not consider here the possibility that "$\bowtie$" is not symmetric, as proposed by Stein (1991). Here we are discussing for the sake of simplicity only presentism and eternalism, not the so-called "growing block". Neither will we investigate the so-called non-standard forms of presentism: see Fine (2006). Lipman (2015) proposes a co-obtain relation that is neither reflexive nor transitive, which would save a fragmented form of presentism in Minkowski spacetime. I wonder who could accept this strange kind of artificial co-obtainment.
[15] See, for instance, Price (1996), Saunders (2002), and Callender (2017). Even Maudlin (2007, Chpt. 4), though he introduces an asymmetry in time on the tracks outlined by Earman 1974, maintains eternalism.

is safe but based on a strong verificationism that transforms spacetime into a sort of solipsistic network of egos.[16]

For this reason, we conclude that eternalism is a better option in the $S_{QFT}$ realm.

Norton (2015) repeats Dorato's (2006) argument against the meaningfulness of the eternalism-presentism debate. It seems pretty clear that the difference between the two theses is evident in our framework. Roughly speaking, eternalism is true if the sentence concerning a present event is true at each physical time. On the contrary, presentism is true if there is only one physical instant at which the sentence concerning the present event is true. These theses are meaningful, because there is a difference between the subjective time $\tau$ and the physical one t.

The only escape from the conclusion that in $S_{QFT}$ eternalism holds seems to endorse a form of agnosticism about the reality of Minkowski spacetime. In the next section, we are going to discuss this issue.

## 6. Scientific Realism

In the case of Minkowski spacetime, is this moderate realism justified? Note that the claim necessary to deduce the support for eternalism is not *universal* either in the sense that it holds for spacetime in general or for all theoretical terms implied by QFT. We are committed only to a sort of "model-theoretic realism", which holds only for domains of objects satisfying a given theory, and only for those entities also represented in the metaphysical language we are discussing.

In the neo-Quinean approach to ontology, we are committed to the reality of those entities over which our best scientific theories quantify (van Inwagen 2016). However, neo-Carnapians (Price 2009) contest both that Quine ever maintained such a position and the sensibleness of this ontological commitment. In this context, we are interested in the latter issue. In particular, if our best scientific theory on *S* quantifies over *x*, we cannot deny the existence of *x*, at least if we accept first-order predicate logic as the natural regimentation of our reasoning. Take the famous Quinean example (1948: 32): "When we say that some zoological species are cross-fertile, we are committing ourselves to recognise as entities the several species themselves, abstract though they be". This means "there exist some cross-fertile species"; therefore, if one would assert "species do not exist", s/he will contradict him/herself.

Nevertheless, consider that the impossibility of saying "species do not exist" is not the same as saying "species must exist". Indeed, in the epistemic regimentation of our belief, the excluded middle is not obvious. To be more precise, if "$K_a p$" means intuitively that "*a* knows *p*", we have four possible formulations of the excluded middle:

1. $K_a p \vee K_a {\sim} p$
2. $K_a p \vee {\sim} K_a p$
3. $K_a (p \vee {\sim} p)$
4. $K_a p \vee {\sim} K_a {\sim} p$

[16] Hinchliff (1998) attempts to reconcile special relativity theory and presentism, giving some credit to the idea that in Minkowski spacetime the present could be identified with the surface of my past light cone. This is quite a weird thesis since one considers present what happens billions of years ago. We do not consider the so-called neo-Lorentzian approach to special relativity theory; see Balashov and Janssen 2003.

In standard epistemic logic, 2. and 3. are reasonable but not 1. and 4. (van Ditmarsch et al. 2015: 2-3). Therefore, one cannot deduce $K_a p$ from $\sim K_a \sim p$; i.e., if I do not know that "species do not exist" I cannot infer that I know that there are species.

Despite this, it is clear that to be quantified over in our best scientific theories is a necessary condition for the existence of theoretical entities from an epistemological point of view. That is, if a non-observable entity does not appear in our best scientific theories, we have no empirical reason to believe in its existence.[17] Of course, in QFT, it holds that:

> there is a spacetime framework in which particles move, and the logico-mathematical structure of this framework is Minkowski geometry.

Therefore, this necessary condition holds in our case. Now the question is: which other conditions are necessary for existence?

It seems reasonable to request the validity of at least two other conditions before accepting the existence of a theoretical entity *x*:

I. The existence of *x* must not conflict with the reality of other entities we have good reasons to accept.

II. If the experimental psychology of perception shows that we perceive reality either in a way different from that proposed by the best explanation or we do not perceive the entity proposed, then there must be a good naturalistic explanation of these facts.[18]

A few considerations about I. and II are here in order.

If, on the basis of our model-theoretic scientific realism, we accept the reality of something in a context where the best scientific explanation is different with respect to that of the domain under discussion, this does not create incompatibility.[19] The typical incompatibility problem arises when one system is causally connected with another, and the reality attributions of both are conflicting. Take, for instance, Planck resonators introduced to explain black body radiation. If one ascribes reality to them and to the different levels of energy—not among Planck's commitments—one must maintain that there are true light quanta, as proposed by Einstein in his 1905 paper on the photoelectric effect (Norton 2006), and this is in contrast with the wavelike character of radiation.

Many scholars maintain that common experience is an important metaphysical source of knowledge.[20] This claim could be accepted only if it is filtered by an experimental investigation of our perceptual intuitions, else everyone could ascribe epistemological value to his/her personal experience. Condition II. vindicates this constraint. Condition II. could be deemed too strong since it could be that we have already understood something beyond our perceptual capacity, but either we have not or even we cannot have a good explanation of the relation between our perception and that reality. I am afraid I have to disagree. Until now, we have evidence that we only receive information about concrete objects through

[17] I am not familiar with good a priori arguments favouring the existence of concrete, non-observable entities. However, here we are not concerned with this point.

[18] Norton (2010) seems to apply a similar criterion when he refuses to accept that passage of time is an illusion, as proposed by the eternalist interpretation of relativity theory.

[19] We will return to the compatibility problems raised by the relation between a whole and the parts of which it is composed.

[20] See, for instance, Lewis 1973: 88 and Paul 2012.

our sense organs. If someone thinks that we could know something about concrete reality in another way, the burden of the proof falls on him.

To understand better condition II., take, for instance, ultraviolet rays; they are not only the best explanation of many phenomena, such as, for instance, solar burns, but, though not visible, we know pretty well why our eyes are not able to catch this radiation. Take another example, like electrons. They are too small to be perceived, but since the famous experiment by Thomson (1897), we have good indirect evidence of their existence. On the contrary, the epistemic situation of the further spatial dimensions necessary in string theory is quite different from that of the electron. The classical argument to justify the non-perceivability of extra-dimensions is that they are too small to be observed and even detected (Zwiebach 2009: 30ff.). This is a form of "begging the question". Extra-dimensions are introduced in string theory for reasonable theoretical motivations, but until now, they do not satisfy our existence conditions. Therefore, even if string theory will be empirically confirmed, it will remain solely a piece of mathematical machinery, unless the empirical confirmation does not bring a better understanding of the undetectability of further dimensions (Cinti and Sanchioni 2021).

Nevertheless, note that conditions I. and II., together with the Quinean criterion, do not constitute a necessary condition for ascribing reality but a quasi-sufficient one.[21]

Now we are equipped to face the problem of Minkowski spacetime reality. Remember that we are speaking of what happens when QFT is the best explanation; hence we are not considering gravitation. At the scale relevant in particle physics, we can assume the continuity of spacetime, and it is not necessary to give an account of curvature due to gravitation. Possibly we have physical reasons to believe that at Planck scale, spacetime could be not continuous, but this does not concern us. It is also clear why in our everyday experience, we do not perceive the relativistic effects due to the Minkowskian nature of spacetime. Indeed, the velocity of light is too high, and our perception threshold of time is circa 30 milliseconds. During this interval of time, light runs circa 10.000 km; therefore, in a certain sense, all that happens in a sphere with a radius of 10.000 km appears to us as present, since inside this sphere, we cannot distinguish a before and an after (Butterfield 1984). Moreover, many experimental consequences of Minkowski spacetime structure are confirmed, such as time dilations and relativity of simultaneity (Mattingly 2005).

To sum up, we have good reasons to accept the reality of Minkowski spacetime in the domain $S_{QFT}$. Therefore, we can deduce that in the same domain, eternalism holds.

## 7. Middle-Size Bodies and Presentism

Take, for instance, the motion of a soccer ball during a match. Its trajectory depends on the force the players' feet apply, terrestrial gravitational field, bumps on the ground, wind, and friction. This motion could be described reasonably well through classical mechanics of material point together with some correction taking friction into account. There are a lot of physical systems—and they are crucial

[21] "Quasi-sufficient" because it could happen that one quantifies over entities in a theory, maintaining at the meta-level that these entities are only helpful fictions.

for our everyday life—which satisfy Newtonian mechanics. Let us call the set of such systems $S_{CM}$.

Here someone could hold the position that the best explanation of what happens to the ball is not classical mechanics with its correction but special relativity theory. Indeed, though the soccer ball travels at a very low speed with respect to the velocity of light, we have no reason to deny the existence of this minimal effect, even if it is challenging to detect it. The velocity of the ball could be circa 30 m/s. The relativistic correction is due to a factor $v^2/c^2 = 10^{-14}$! The volume of the ball is $4\pi r^3/3$. Let r = 12 cm. Then the volume is circa 7000 $cm^3$. Now let us imagine adding to the ball a speck of dust smaller than 10 cube nanometers, a volume $10^{-14}$ times smaller than the ball. Is the reality of our system changed? In other words, if we embed the ball in a relativistic context, it is as if we put a speck of dust on it, and after this minimal physical change, we state that all metaphysical consequences of relativity must apply to this context. This inference does not seem reasonable.

Nonetheless, this argument deserves a deeper investigation. In section 6, we explained that we prefer a model-oriented scientific realism, despite the more common theory-oriented one. This means that it is not enough that a theory is well confirmed for establishing *in general* the reality of its theoretical entities. This is motivated also by the pessimistic meta-induction. We know that all our theories, even the best ones, are false. Indeed, sooner or later for each theory we will find situations in which it doesn't work. Would we deduce from this either empiricism or instrumentalism? Would we give up to our rational beliefs in the reality of theoretical terms in those physical systems where the theory still works well? I think this is to throw the baby with the dirt water. If a certain theory *T* is a good explanation of the system *S*, the fact that a system *S′* must be explained by the theory *T′* could be irrelevant. When this occurs, the metaphysical issues we deduce from theory *T* concerning *S* are not washed out by the new theory. Indeed, in general the relevance of the new theory *T′* for the system *S* is minimal. This is exactly what happens in the case of the soccer ball (*S*), classical mechanics (*T*) and relativity theory (*T′*). To sum up, the metaphysical relevance of Minkowski spacetime for the soccer ball must not be overvalued.

Coming back to our argument, remember that in classical mechanics, time is representable by $R^1$, and it is independent of space. Following the same procedure presented in section 5, we arrive again at the formulas (1') and (2'), which I repeat for readers' convenience:

(1') if there is a $t_i \in \{t\}$ such that $t_i$ belongs to $V(E_i)$ and there is a $t_i \in \{t\}$ such that $\tau_i \equiv t_i$ then there is no $t_j \in \{t\}$, $t_j \neq t_i$, such that $E_i(t_j)$

(2') if there is a $t_i \in \{t\}$ such that $t_i$ belongs to $V(E_i)$ and there is a $t_i \in \{t\}$ such that $\tau_i \equiv t_i$ then for each $t_j \in \{t\}$, $t_j \neq t_i$, $E_i(t_j)$ holds.

Now we assume $E_I(t_I)$; for instance, "the ball is at the centre of the soccer field on March 13th, 2022". After that, we can introduce the relation between events "$E_i(t_i)$ is simultaneous to $E_j(t_j)$" iff $i = j$. In Newtonian spacetime, this relation is an equivalence relation. As before, we introduce the relation "⋈". Now "⋈" can be not only the identity and the universal relation, but also *simultaneity*. This last possibility was not available in Minkowski spacetime, where simultaneity is not an equivalence relation. If one identifies "⋈" with simultaneity (1) is true and (2) is false. Moreover, in my epistemic present, there is not only the event $E_I(t_I)$—as in the case of QFT—but all events simultaneous to $t_I$.

Hence, we have at least two alternatives: if we identify "⋈" with the universal relation, eternalism is true, and presentism is false; on the contrary, if we identify "⋈" with the relation of simultaneity, presentism is true, and eternalism is false. Both metaphysics are compatible with the physical theory. The first argument favouring presentism is economy, that is (1) is quite more parsimonious from an ontological point of view than (2). Against this point, an eternalist could claim that if his/her metaphysics is true for the part—a particle of the soccer ball—it must also be true for the whole—the whole ball. We will return to this point later, but this metaphysical principle is not always true. Think, for instance, of the burning of a cigar: it is an irreversible process, whereas to our knowledge, every motion of each particle of the cigar is reversible.

A second argument favouring presentism[22] is that the perception of becoming is not an illusion from its perspective. Intuitively, with the term "becoming", I mean that reality seems to enter my consciousness again and again as something new. A thought experiment can help in understanding this point. Let us imagine that nothing changes in all possible stimulations of our sense organs. In this case, we probably would have even so the feeling of time passing, that is, of becoming (Brentano 1915: 108). Note that the perception of becoming is not only the fact that reality enters in succession in my consciousness, but also the fact that the perception of the present fades into the past and tends toward the future. This peculiarity of our perception, detected by Edmund Husserl (1991: §8), is dubbed "retentional model of temporal consciousness" by Dainton (2022). Indeed, presentism vindicates the reality of this perception, which, to my knowledge, does not have a good naturalistic explanation of being an illusion.

Norton (2010) argues that we do not have a good explanation of the fact that the passage of time is an illusion. First, many illusions have the characteristic that, in given circumstances, they disappear, whereas the illusion of the passing of time is very persistent. Second, we do not know a precise neurological mechanism to explain this illusion. For instance, we have the illusion that there are up and down in space, but we know that this sensation is caused by the action of gravity on the middle ear. No similar mechanism is known for the passing of time. Moreover, if the passage of time is an illusion, why can we never jump from one part of the alleged block universe to another?

A large amount of literature attempts to explain the illusion of the passing of time, to justify eternalism. Butterfield (1984) maintains that the specious present is an illusion since light, sound etc., need time to arrive to our brain. Therefore, if we perceived correctly, the present would be reduced to a spatiotemporal point. This could be true, but it does not explain the passage of time. This kind of argument is good only if we accept the reality of Minkowski spacetime, which means that we have to explain the illusion of simultaneity. However, here we must decide between eternalism and presentism *in a Euclidean framework*. The first, but not the second, denies the reality of becoming. Moreover, Butterfield's argument cannot explain this issue.

Moreover, neuropsychology explains that the slice of reality we perceive as present is specious, i.e., we perceive as simultaneous events that are temporally

[22] This argument does not favour only presentism, but all dynamic theories of time. Many thanks to an anonymous referee, who raised to me this point.

in succession when the distance between them is smaller than a certain threshold. Nevertheless, the very problem is something different: *why do we perceive events as coming into existence in a continuous succession and not as all real*? To explain this phenomenon, saying that we are moving along a worldline of the block universe is begging the question, because we have no independent empirical evidence of this fact.

Callender (2008) claims that "to be present" is not a real perceptual characteristic. Therefore, to say that only what is present is real, from the perceptual point of view, is meaningless. Perhaps, but we have a clear perception of the passage of time, that is, in perceiving an event, we also perceive in a peculiar way something that has just occurred. Therefore, even if the present perception is not absolute, it is at least relative in the just mentioned sense. Therefore there is something to explain.[23]

Le Poidevin (2006: 85-86)[24] attempts to explain the fact that we perceive only a limited temporal part of the block universe by appealing to the adaptative argument from natural selection, that the perception of all events would be inadequate for our memory and action. It seems to me that this is a "just so story" without a clear scientific justification. Moreover, the point of the perception of becoming is not only the coming in our perception of successive events, but also the fading of the present perception in the past and the gradual appearing of what is future. In other terms, Le Poidevin's analysis does not consider that, even if we do not perceive duration, the passing of the present in the past is *gradual*.

Hence, we can conclude that in $S_{\mathrm{CM}}$, presentism is in a mildly advantageous position. Nevertheless, note that the support for eternalism by special relativity theory is more robust than that of Newtonian spacetime for presentism. Better, in a Newtonian spacetime it is possible and perhaps reasonable to arrange a presentist metaphysics.

Before concluding the section, we must consider another objection. A ball is also subjected to the Earth's gravitational force. Must this force be described by Newtonian mechanics or by general relativity? Following scale considerations similar to the preceding one on special relativity, we can say that the deformation of spacetime due to the terrestrial gravitational field is irrelevant in this context. However, if we consider gravitational force as Newtonian, it becomes a sort of mysterious action at a distance. On the other hand, from an ontological point of view, even if we introduce general relativity, the small spacetime deformation due to the terrestrial field is insufficient to impose eternalism as, on the contrary, occurs for high-speed objects and special relativity. Therefore, here nothing supports eternalism, and general relativity can live together with Newtonian mechanics to explain the system's different aspects.

## 8. A Significant Objection

We have arrived at a first provisional conclusion:

> Inside $S_{\mathrm{QFT}}$, eternalism is supported, whereas, inside $\mathrm{S_{CM}}$, presentism is a viable possibility.

However, this statement violates two apparently reasonable principles:

[23] Ismael (2011) attempts to explain this illusion as a byproduct of our volitions. However, the problem of explaining our volitions as illusory processes stands.
[24] Thanks to an anonymous referee for the reference to Le Poidevin's argument.

I. The laws of physics holding for the parts should also hold for the whole.
II. The ontology of the parts should be compatible with the ontology of the whole.

An example clarifies these points. Take my car parked in the street. Classical mechanics well describes its motion. Therefore, the car belongs to $S_{CM}$. Hence for people in the car, presentism holds. However, my car is also composed of electrons, for which relativistic effects are significant. It is well known, for instance, that the spectra of atoms have a fine structure, which only relativistic correction of quantum mechanics can account for. Therefore, electrons in the car belong to $S_{QFT}$. It follows that eternalism holds for an hypothetical living being chasing an electron of my car.

In the example, both I. and II. are violated. Concerning I., let us consider, for instance, the law governing the sum of velocities of two objects. If body 1. travels with velocity $v_1$ in the opposite direction with respect to body 2., which travels with velocity $v_2$, the relative velocity between 1. and 2. in classical mechanics is $V_{CM} = v_1 + v_2$; however, in relativity theory it is: $V_{QFT} = (v_1 + v_2)/(1 + v_1v_2/c^2)$. Concerning II., recall how $S_{QFT}$ favours eternalism strongly, whereas $S_{CM}$ is more hospitable for presentism.

A reasonable answer to the violation of I. is possible through *correspondence* principles. They explain at least partially the apparent incompatibility of laws concerning the parts and the whole of the car. Indeed, quantum mechanics almost always becomes irrelevant for macroscopic objects, and relativistic corrections of fine structure spectra are insignificant for the car's motion. Let us suppose that for the part holds the equation, $z = f(x, y, h)$, where $z$, $y$ and $x$ are physical quantities, $f$ is a function and $h$ is a constant. Nevertheless, for the whole, $z = g(x, y)$ holds, where $g$ is another function. If $f(x, y, h) \approx g(x, y)$, when $x$ and $y$ refer to the whole,[25] there is not an actual contradiction. Take, for instance, the composition of velocities in classical mechanics and quantum field theory. In the case of my car, the energy of electrons needs relativistic correction, whereas the car's velocity does not. Moreover, if $v_1$ and $v_2$ are very small with respect to $c$, $V_{CM} \approx V_{QFT}$, that is, the composition of velocities in the part is almost equal to that in the whole. In other words, when a correspondence principle of this kind holds, it is possible to deduce the different laws of the whole from that holding for the parts.[26]

Consider also that the best explanation of a certain domain of objects is not true, but only *partially* true. Therefore, in general, inferences either from parts to whole of a system or vice versa are not wholly justified.

Much more problematic seems the ontological question: is it possible that the time of the part has a structure incompatible with that of the time of the whole?

Let us consider principle II. again:

II. The ontology of the parts must be *compatible* with the ontology of the whole.

What does the term "compatible" mean? The part could have peculiarities the whole does not have and vice versa. For instance, water in a glass in normal environment conditions is liquid and[27] without polarity, whereas a single molecule

[25] That is, the values of $x$ and $y$ make the presence of $h$ irrelevant.
[26] It could also happen that the laws holding for the parts are not sufficient for establishing the laws of the whole. The latter, in general, are compatible with the former, but something often must be added. See, for instance, Chibbaro et al. 2014.
[27] Here, "liquid" means that it does not resist shear forces and is incompressible.

of $H_2O$ is not liquid, and it has a mild polarity of δ+ on each hydrogen atom and 2δ- on the oxygen atom. It is also clear that the whole could have peculiarities co-impossible with those of the part—if referred to the same object—and vice versa. Take, for instance, the hydrogen atom: the whole is neutral, whereas its electron—a part of the atom—is negatively charged. It is even possible, in statistical mechanics, for instance, that the whole has very general peculiarities incompatible with those of the parts and vice versa. The evolution of the whole could be deterministic and irreversible, whereas that of the parts could be indeterministic and reversible.[28]

Perhaps, to understand better what the ontological (in)compatibility between a whole and its parts is an example could be helpful. Take for instance a transparent liquid and a drop of the same liquid, which is not transparent. This situation seems impossible. Someone could trace back this impossibility to a sort of law of experience: "the visual appearance of a surface is the same of all its parts". This is not true. If one looks at a white surface with a red spot enough time then one moves to a white surface, one will see a sort of green spot where the surface now is white. Otherwise, one could think that there is a sort of metaphysical impossibility, that is that if a certain property holds for a whole surface it must hold for each of the parts of the surface as well. This is not true as well, as shown by the example of transparency. For many materials, in region small enough the transparency changes. The reason why a drop of a transparent liquid *must* be transparent is that the drop is a part of the whole big enough to have the same reflection/absorption properties as the whole. Then the question becomes: how can we establish the strength of the "must" appearing in the preceding sentence? *Physical laws* establish that the molecular microstructure of a liquid cannot be relevant in the radiation/absorption properties of a so big system as a drop of liquid. Therefore, we arrive at the conclusion that the term "must" we used has only a nomological meaning and not a metaphysical one.

Let us consider another objection to our perspective.[29] All the examples of metaphysical incompatibility I proposed concern certain ontological features, but the contraposition between presentism and eternalism regards something more fundamental, that is *existence*. To see the strength of the paradoxicality implicit in the regional view of time, let us consider a car embedded in an A-time composed of particles embedded in B-time. At a certain instant *t* the car is scrapped. It seems that we can say that the particles organized in a car do exist in tenseless sense, whereas the car does exist only until time *t*; but, the argument goes on, the car and a set of particles organized as a car are the same thing; hence, one concludes that the car does and doesn't exist. This situation seems more counterintuitive than how it really is. Are we sure that if we consider the quantum-mechanical representation of the car, we can identify the singles particles of which it is constituted? Probably not, because, as we know, macroscopic bodies are superpositions of an enormous number of not identified particles. This means that a set of particles organized as a car is not a well-defined expression. There is the car as a

[28] One could object that according to statistical mechanics, the whole process is not irreversible in the strict sense, but that it is solely very improbable. Nevertheless, even if we accept the complete reduction of thermodynamics to statistical mechanics, there is a robust ontological conflict between something with almost null probability and something with a reasonable physical probability.

[29] I thank an anonymous referee for this criticism.

physical system, not an enormous number of particles organized as a car. The latter seems a not precise physical notion.

These examples push in the direction that incompatibility in principle II. should be intended in a nomological way. We conclude, therefore, that in principle II. the term "compatible" means nothing more than that we need a good scientific explanation of the difference between peculiarities of the whole and those of the parts. Therefore, in a certain sense, the ontological incompatibility can be reduced to the nomological one. Moreover, we have already seen that it is possible to tame the nomological incompatibility through adequate correspondence principles.

Sklar (2003) criticises a metaphysical deduction of regionality, which build on the undeniable fact that science uses different theories to explain diverse domains of objects. Nevertheless, in this context, we do not claim that there is not a unitary concept of time, but only that, given our best knowledge, time seems metaphysically different in diverse contexts. As Sklar himself admits, in the beginning, the burden of proof is on those who maintain the unity of the world.[30] The burden passes to those that endorse a general dappled view of reality only if the latter denies the possibility of a unitary scientific image of the world.[31]

Before concluding, we must face another important objection. Let us imagine that it would be possible to accelerate a spaceship to velocities significant with respect to that of light. The question is: at which velocity would people in the spaceship switch from a presentist world to an eternalist one? This thought experiment makes evident the paradoxicality implicit in a world with a regional character of spacetime. First, I have to emphasise that, in reality, it is challenging to find a macroscopic process moving at a velocity close to that of light; therefore, this question has a partially scholastic flavour. Nonetheless, during the explosion of a nuclear bomb, for instance, at first, the pressure could be so intense that the gases would move with so big a velocity that relativistic effects are relevant;[32] moreover, in the accretion disks of neutron stars and black holes, relativistic jets are produced. Therefore, macroscopic phenomena with relativistic velocities could be detected. There seems to be something arbitrary in deciding where the threshold between classical and relativistic physics is. In a certain sense, we have to say that if velocity increases gradually, presentism ontology becomes less and less true, while at the same time, eternalist ontology becomes more and more true. This conclusion appears very counterintuitive, because we are used to thinking that something either exists or does not exist, *tertium non datur*. The same dichotomy seems to hold for spacetime: either spacetime is Newtonian or it is Minkowskian. One who maintains the regional view of time that I am investigating here could answer that until now, we do not have a very good explanation of these macroscopic phenomena intermediate between classical and relativistic physics since we must say that they are explained by a first order classical term added to a second order relativistic term. Perhaps new physics and new philosophy will clarify the ontology of this weird process.

[30] This point is missed by Mumford (2000).

[31] Here one sees again the difference between my point of view and Cartwright's (1999): I do not endorse a dappled metaphysics; I only apply our scientific knowledge to build the most up-to-date scientific image of the world. On this point, Ruphy (2003) is quite clear.

[32] See Rindler 1983: 144ff. for other examples.

## 9. Concluding Remarks

On the basis of a posteriori conceptual analysis, we establish which metaphysical questions are important (Machery 2017). In particular, in this paper I have discussed presentism and eternalism, intended respectively as the statement that there is only what is present and that there is all what happens at any time.[33] We have seen that physical theories do not give an unequivocal answer to the question of which theory of time is true. Normally scholars deduce eternalism from special relativity theory, but this theory is not always the best explanation of physical systems. Where Newtonian spacetime is dominant, presentism seems a viable position. This regional image of time is different from the dappled one proposed by Cartwright (1999). Contrived nomological machines do not constitute scientific theories. Scientific theories aim to be universal and sometimes explain well an extensive set of systems, but special relativity theory is not completely universal. This theory is adequate above all in our accelerators and inside stars. Nevertheless, we live our everyday life in a Newtonian spacetime. Moreover, to our knowledge, the metric of spacetime on a very large scale—FLRW metric—allows the definition of a sort of privileged foliation in which the cosmic fluid is at rest. For this reason, one could suppose that time on a cosmological scale is something different from that claimed by eternalism. Perhaps the cosmological time is something more similar to what presentism outlines.[34]

In this paper, time has also been a case study for the a posteriori metaphysical method I propose.[35] In empirical science, conflicting images live together at different scales and in diverse realms. If we approach metaphysics from an empiricist perspective, we must be ready to accept that these conflicting representations must coexist even in our more general worldview.[36]

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[33] It would be of great interest to know not only which is the opinion of different groups of people on the question of presentism and eternalism, but also which metaphysical questions concerning time are important for scientists, philosophers, and laypeople.
[34] Nevertheless, see Wüthrich 2012.
[35] See Corti and Fano 2020. As Zimmerman (2011) emphasised, the fate of presentism and eternalism is connected to the evolution of our best scientific theories concerning space and time.
[36] This work was supported by the Italian Ministry of Education, University and Research through the PRIN 2017 project "The Manifest Image and the Scientific Image" prot. 2017ZNWW7F_004. Thanks to one anonymous referee, Claudio Calosi, Giovanni Macchia, Ernesto Graziani, John Norton, Francesco Orilia and all the Fellows of Pittsburgh Center for Philosophy of Science, Spring 2018, for reading this paper's provisional versions and proposing many valuable comments. Many thanks also to all companions of the PRIN 2017 project, *The Manifest Image and the Scientific Image*.

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