Mauro Dorato

On Various Senses of "Conventional" and Their Interrelation in the Philosophy of Physics: Simultaneity as a Case Study

My aim in this note[1] is to disambiguate various senses of 'conventional' that in the philosophy of physics have been frequently conflated. As a case study, I will refer to the well-known issue of the conventionality of simultaneity in the special theory of relativity, since it is particularly in this context that the above mentioned confusion is present.

My plan is to start by sketching Reichenbach's original treatment of the problem (section 1). In section 2, I will try to locate Reichenbach's problem within a much more general philosophical framework, essentially proposed by the American philosopher Wilfrid Sellars almost fifty years ago.[2] I regard this second section as particularly important, and not only as a general introduction to our topic: contemporary philosophy of physics is affected by a dangerous temptation of excessive specialization, and by an attitude that considers technicalities as ends in themselves. *Qua* philosophers, we ought to understand, as Sellars put it, "how things (in the widest possible sense of the word) hang together (in the widest possible sense of the word)".[3] In section 3, I will then distinguish among *five* different senses of "conventional", and will then study their logical relationship *vis à vis* the problem of establishing in which of these senses the relation of simultaneity could be regarded as conventional.

Not only will I press the point that, as noted by Dieks in his paper, much of the current philosophical debate on conventionality lacks contact with the issues Reichenbach's analysis was meant to address to start with.[4] Following Friedman's

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1 This note originated as a comment to Dennis Dieks's presentation *The philosophy of physics in perspective*, held in Vienna in December 2008 for the meeting of the European Science Foundation. I would like to thank first and foremost Dennis Dieks, and then the audience, for the comments I received to my comments.

2 Wilfrid Sellars, "Philosophy and the Scientific Image of Man", in Robert Colodny (Ed.), *Frontiers of Science and Philosophy*, Pittsburgh: University of Pittsburgh Press, 1962, pp. 35-78.

3 Ibid.

4 See the beginning sentence of his contribution to this volume: "The history of the philosophy of physics has been shaped by a complicated and fascinating interplay between physics, philosophical ideas and external factors. This history is not only an intriguing subject for study in its own right: historical considerations can also shed light on the content of doctrines put forward by philosophers of physics and are relevant for the appraisal of such doctrines."

outlook toward the history of logical positivism,[5] I will also argue that, without taking into due account the original problem inspired by Kant's philosophy − and consisting in trying to separate what in our scientific theories is "due to us" from what is contributed by the external world − the debate on the conventionality of simultaneity loses much of its interest. This concession, however, should not make us blind to the fact that the special theory of relativity has epistemically driven, verificationist foundations, inspired by the work of Mach and especially David Hume, a fact that has been very important for the subsequent history of both physics and philosophy. As to the more circumscribed question of the conventionality of simultaneity *per se*, we will see how, in an important sense of 'conventional', the relational character of "being simultaneous with" implies by itself that simultaneity *is* conventional, despite Malament's celebrated result,[6] while in another sense, simultaneity appears to be non-conventional.

1 Reichenbach's original formulation of the problem

After Reichenbach's groundbreaking *The Philosophy of Space and Time*,[7] the problem of the conventionality of simultaneity is traditionally regarded as the ~~problem~~ of establishing whether simultaneity, besides being non-controversially *relatively* to a given inertial worldline, is also *conventional*, or non-unique, even after an arbitrary inertial worldline has been picked.

As is well-known, the original problem that Einstein had to solve in 1905 was that of synchronizing two distant clocks ~~being~~ at rest in the same inertial frame. Adopting some terminology that has been invented only later, here is Einstein's solution. Emit a light signal at point e on the inertial worldline O toward another, parallel inertial worldline O': parallelism indicates, of course, that O and O' are in the same inertial frame.[8] Suppose that the light signal is reflected by a mirror at point f on O' and is received again after some time at point r on O. The problem of synchronizing the two clocks that trace out the two inertial worldlines is equivalent to the question of determining which event t_f along O is simultaneous to the epistemically inaccessible reflection event f on O'.

In order to gain some generality in Einstein's simple thought-experiment, Reichenbach introduced a real number ε, $0 < \varepsilon < 1$, such that

$$t_f = \varepsilon(t_r - t_e)$$

5 M. Friedman, *Reconsidering Logical Positivism*, Cambridge: Cambridge University Press, 1999.

6 David Malament, "The Conventionality of Simultaneity", in *Noûs* 11, 1977, pp. 293-300.

7 Hans Reichenbach, *The Philosophy of Space and Time*, transl. by Maria Reichenbach and John Freund, New York: Dover, 1958, pp.123-129.

8 ~~Here I am helping myself with some later terminology.~~

Now Reichenbach's question about the conventionality of simultaneity can be formulated with precision. Can we assume that the reflection event *f* on *O'* has occurred exactly at

$$t_f = (t_r - t_e)/2,$$

on *O*, as Einstein had originally assumed, and therefore fix the value $\varepsilon = ½$? Or, on the contrary, is the choice of one among the non-denumerable infinity of values of $\varepsilon \neq ½$ comprised between 0 and 1 absolutely unconstrained by any fact, and therefore *conventional*? In the former hypothesis, the speed of light on the two legs of the journey (from *O* to *O'* and back) is assumed to be the same (*isotropy* of the propagation of light). In the latter hypothesis, light has two different speeds on the two legs of the journey, in such a way, however, that the only measurable quantity on the part of *O*, the total two-way time, is always the same.

Reichenbach's original claim is that the choice of $\varepsilon = ½$ *is* unconstrained, or conventional, *due to the impossibility of measuring the one-way speed of light*. In order to measure the one-way speed of light, in fact, according to Reichenbach we would already need a synchronized clock on *O'*, but the whole "radar procedure" that Einstein proposed was meant to synchronize the two clocks to begin with. So the conventionality of simultaneity, for Reichenbach, is a consequence of the impossibility to attribute isotropy to light without falling into the *vicious circle* of using a criterion of simultaneity to determine the one-way speed of light and using this one-way speed in order to establish a criterion of simultaneity.

Reichenbach's argument has spurred various criticisms that have often relied on different senses of "conventional": in order to look back at the whole debate one more time, these senses need to be disentangled with care. Before doing so, however, some more general remarks are appropriate.

2 The ambiguity of 'conventional', and Sellar's conflict between the manifest and the scientific image

> The terms "convention" and "conventional" are flagrantly and intricately ambiguous. On the one hand, the conventional is the ordinary, the usual, the traditional, the orthodox as against the novel, the deviant, the unexpected, the heterodox. On the other hand, the conventional is the artificial, the invented, the optional, as against the natural, the fundamental, the mandatory.[9]

While this quotation obviously refers to the *social* and *epistemic* sense of convention, one that does not seem directly connected to our topic, it nevertheless helps me to make explicit the general philosophical perspective from which I want to tackle Reichenbach's original problem.

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9 Nelson Goodman, "Just the Facts, Ma'am!", in Michael Krausz (Ed.), *Relativism: Interpretation and Confrontation*. Notre Dame: University of Notre Dame Press, p. 80.

In a first sense of 'convention', Goodman writes, 'conventional' seems to refer to what is the result of a widely shared, but not necessarily intentional, *agreement*, something that can be regarded as part and parcel of *common sense*. In this sense, we claim for instance that, before the revolutionary view proposed by Copernicus, the shared belief in a static Earth was part of orthodoxy, or simply of our 'conventional knowledge'.

On the other hand, and following the ancient sophists, Goodman contrasts 'conventional' also with what is 'natural'; in this second sense, it was also natural − i.e. non-conventional and mandatory − for us all to believe in the immobility of the Earth. Such a belief seems in fact to be entrenched in the so-called *folk* or *naïve physics*, whose universal and innate hold on our brains so many experiments in the cognitive science have now confirmed. From this viewpoint, scientific knowledge artificially, non-naturally and 'conventionally' goes against some of our 'natural', naïve physical beliefs, as when it convinces us that, for instance, the Earth moves along its orbit at the average speed of approximately 30 km/sec.

The conflict between Goodman's two senses of 'conventional' could then be reformulated by claiming that part of what is traditionally and *conventionally* believed by human beings (in Goodman's first sense of "convention") is so believed because of *natural, non-conventional "forces" that have been shaping our brains during our biological evolution*. Consequently, the whole scientific enterprise could be regarded as an invention of our culture based on our natural capacities, an invention that, however, had to go against (at least) *some* of our natural beliefs, like the centrality and speciality of human beings in nature, the existence of a cosmic now, the fact that moved bodies require movers, our pervasive tendency to project the notion of purpose onto the natural world, and so on.

It then seems natural to claim, along with Sellars, that one of the main aims of the philosophy of physics is to inquire into the *compatibility* of the physical image of the world (the physical image of time, space, matter, identity, etc.) with the "manifest image", which is the world of our experience, as it has been explicated by philosophers and phenomenologists of the past, and investigated empirically by neuropsychologists and cognitive scientists today. In a word, if I am right in claiming that conventional beliefs (in Goodman's first sense of 'convention') are part of the manifest image, and that they are naturally, non-conventionally believed by common sense (in Goodman's second sense of 'convention') because of evolutionary reasons, the difference between these two senses of 'convention' is *Sellars' conflict between the manifest and the scientific image of the world*.

The importance of Sellars' conflict in this paper is two-fold. Firstly, we will see one of its manifestations in the thicket of questions surrounding the conventionality of simultaneity, in particular *a propos* of our natural, naïve physical belief in the existence of a cosmic present, which found its expression in the Newtonian, *absolute* character of the relation of simultaneity. Secondly, focussing on Sellars' conflict is also particularly important in judging the importance of the a priori in the growth of scientific knowledge, *at least to the extent that many a priori presup-*

positions of science come from the manifest image of the world. How changeable is this a priori *vis à vis* the evolution of scientific theories?

3 Various senses of conventional in the philosophy of physics

The following list is not to be regarded as exhaustive,[10] but simply as a first guide to further, more detailed work.

1) 'Conventional' is whatever is opposed to synthetic or factual, that is, something that can be said of a proposition that is either analytically true, or simply devoid of any truth-value; *this is a semantic sense of 'conventional'*;
2) 'Conventional' can be regarded as what is *constitutive* of our theory (Reichenbach's *constitutive a priori,* to be contrasted with the *a priori* regarded as 'universally valid', or 'apodictic'); 'conventional' here corresponds to the formal element of knowledge in the kantian sense, something that in the construction of a scientific theory is exclusively 'due to us';
3) 'Conventional' can be regarded as what *is non-reducible/definable in terms of a ~~causal~~ relation*: this sense involves the *causal theory of time*, and is the target of Malament's 1977 much discussed theorem on the non-conventionality of simultaneity;[11]
4) 'Conventional as more changeable', or less entrenched *epistemically* (opposed to 'analytic' in Quine's sense) because not present in direct experience. This sense is discussed by Reichenbach in his famous treatise on space and time and by Dennis Dieks in the paper contained in this volume (section 3); it is definitely an *epistemic* sense of conventional;
5) 'Conventional' can be regarded as what is referred to a choice that is supposed to *fix a gauge*. While I will not comment in a detailed way on this last sense, it is important to list it together with the others, as in some approaches the choice of a synchronization for non-inertial frames is equivalent to gauge fixing.[12]

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10 A first attempt of separating different senses of conventional is due to my former teacher Robert Rynasiewicz: see his abstract in "Varieties of Conventionality", in Jacek Cachro and Katarzyna Kijania-Placek (Eds.), *Volume of Abstracts, ~~International Union of History and Philosophy of Science, and~~ 11th International Congress of Logic, Methodology and Philosophy of Science*. Cracow: Kopiorama. 1999, p. 329. My list does not overlap much with his, however, and after his oral presentation, Rynasiewicz never wrote a paper.

11 See note 6.

12 David Alba, Luca Lusanna, "Generalized Radar 4-Coordinates and Equal- Time Cauchy Surfaces for Arbitrary Accelerated Observers", in *International Journal for Modern Physics*, D16, 2007, pp. 1149-1186. See also David Alba and Luca Lusanna, "Charged Particles and the Electro-Magnetic Field in Non-Inertial Frames of Minkowski Spacetime," *arXiv: ~~0812.3057.~~*

3.1 The semantic sense of conventional: conventional as the non-synthetic

In one clear sense of the word, possibly the most central one, 'conventional' is opposed to whatever is factual or synthetic. There are two ways for a sentence to be non-synthetic: it can be devoid of any truth value, or it can be analytically true. Let me start by exemplifying the sense of convention that we are after in this section by beginning with the former alternative. After the special theory of relativity, and the discovery of the relativity of simultaneity, we know that there is no fact of the matter that could be invoked to answer the question:

Q = what is happening *right now* in Andromeda?

simply because we know that in the special theory of relativity *there is no cosmic present*: in this theory, the now does not extend in space at all (it is pointlike), or extends in space at most *locally*, in a sense of local that is in any case different from that ruling in quantum physics.[13]

The answer to question Q is conventional in this first, semantic sense, since it depends on an arbitrary choice of a reference frame or of an inertial worldline. Consequently, the sentence "event *e* on Andromeda is simultaneous with an event here-now", in the post-Newtonian universes lacks a definite truth value; being an incomplete sentence (it lacks a relational term), *it is neither true nor false* or even *meaningless*.

As an instance of a sentence that is not synthetically true but still 'conventionally true' because analytically true, think of the conventionalist reading of the axioms of the geometry. In 1902, Poincaré thought of such axioms as *disguised definitions*: as such, the axioms of geometry could not be regarded as a reflection of empirical facts nor, given the multiplicity of geometries, as synthetic a priori judgments.

> The *axioms of geometry therefore are neither synthetic* a priori *judgments nor experimental facts*. They are *conventions*; our choice among all possible conventions is *guided* by experimental facts; but it remains *free* and is limited only by the necessity of avoiding all contradiction.[14]

According to Poincaré, axioms are "true" at best in the sense in which definitions like "bachelors are unmarried men" are (necessarily) "true". In another sense, however, *qua* definitions, they are neither true nor false, exactly like sentences that have no truth-maker coming from the world of facts. A definition can be useful and apt for our goals or not, but not really true or false.

Could we claim that after we fix an inertial worldline O passing through our "here-now", the answer to the above question Q is a matter of mere definition? This harder question will be tackled in the remainder of the paper.

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13 Dennis, Dieks, "Becoming, relativity and locality", in Dennis Dieks (Ed.) *The ontology of spacetime*, Amsterdam: Elsevier, 2006, pp.157-176.

14 Henri, Poincaré, *Science and Hypothesis*, in *The Foundations of Science*. Trans. George Halsted. New York: The Science Press, 1902/1905, p. 65.

3.2 The conventional as the constitutive a priori

According to Einstein's original treatment, establishing whether "event *e* on Andromeda and an event here-now are simultaneous" necessarily requires a *Festsetzung* (a stipulation), as Einstein put it in 1905.[15] That is, given the epistemic inaccessibility of event *e* on Andromeda from our here-now and conversely (see the fourth sense of conventional) even within a single inertial frame, in order to answer any question about distant events relatively to a chosen inertial frame we need some operational/conceptual convention, like the radar method illustrated above.

To the extent that Einstein's radar convention transforms meaningless questions into empirical questions, the convention itself is also '*constitutive*' of the special theory of relativity, in Reichenbach's peculiar sense of the *constitutive a priori*.[16] And this explains the transition from the sense of conventional discussed in 3.1 to the currently discussed sense.

In a nutshell, the main idea of identifying the conventional element in a scientific theory with its constitutive element(s) is this: *not all scientific concepts in a theory are epistemically on a par*, *since conventional truths about some of them* (simultaneity in our case) *make empirical questions possible in Kant's sense*. Since without a convention of some sort (radar method), we could not even ask questions like *Q* above, the radar method and the resulting concept of simultaneity *ground* the ~~rest of the~~ theory.

Note that this also corresponds to Friedman's doctrine of the *relativized a priori*: Michael Friedman, following the early Reichenbach, and various other logical positivists, separates from the original kantian meaning of the a priori regarded as something pertaining to a judgment that is universally valid and unrevisable, the concept of an priori that is constitutive of a scientific theory.[17] As Reichenbach had it, such a "constitutive a priori" may change; it is therefore revisable ~~in~~ scientific changes, and is therefore *not* universally valid. Its flexibility is compatible with the fact that what is constitutive a priori for one theory can be abandoned in the later conceptualization of a new theoretical framework.

Why do I refer to such constitutive a priori elements of our scientific knowledge as conventions? Here I follow Moritz Schlick's oft-quoted letter to Reichenbach, one that was very important to convince the latter that he had to abandon his previous kantian language. Schlick writes:

> it is the main point of this letter that I cannot see what is the real difference between your a priori statements and conventions … The decisive place where you describe the character

15 Albert Einstein, "On the Electrodynamics of Moving Bodies", in Albert Einstein et al., *The Principle of Relativity*, New York: Dover, 1952, pp. 37-71.

16 Hans Reichenbach, *The Theory of Relativity and A Priori Knowledge*. Berkeley: University of California Press, 1965.

17 Michael Friedman, *Dynamics of Reason: The 1999 Kant Lectures at Stanford University*, Stanford: CLSI Publication, 2001.

of your a priori correspondence principles seem to me nothing short of accomplished definitions of the concept of convention.[18]

Even though Reichenbach in his later writings implicitly kept on believing in the importance of *some* constitutive a priori element in the foundations of scientific knowledge,[19] it is in any case highly significant that *after* this crucial letter and his exchange with Schlick, he will make reference to Kant more to criticize him than to vindicate or revise aspects of his thought. As a consequence, after this letter Reichenbach *will coherently abandon any form of kantian-sounding language*. This had a pragmatic motivation: the neopositivists had to make a carrier in the German University after the First World War, in a cultural environment that was dominated by neokantiants, by heirs of classical German idealism, and by phenomenologists like Husserl and their students like Heidegger. Before moving to the third sense of 'conventional', I would like to add four ~~additional~~ remarks ~~that are meant to add some more completeness to this section~~.

First of all, while not all constitutive a priori elements in our scientific theories have to be regarded as conventions, in our case the ~~foundational, constitutive role of Einstein's constitutive a priori *convention* about the isotropy of the velocity of light is undeniable~~.

Secondly, as Reichenbach himself makes clear, the choice of a coordinate system in the theory of relativity is underdetermined by all possible facts. Accordingly, in his *Relativity Theory and Knowledge a priori*, he insists that the invariance with respect to (Lorentz) transformations represents the objective, factual content of reality, while the structure of what in 1920 he still calls 'reason' (the source of the whole a priori structure of a theory) is expressed by the arbitrariness of the admissible coordinate systems … 'the subjective form that makes our description possible'. So the choice of a coordinate system is conventional (because subjective and therefore a priori), and yet indispensible for the description of the physical world. In this related ~~by~~ slightly distinct sense of constitutive a priori, for Reichenbach the choice of a coordinate system is constitutive of the theory ('it makes our description of the world possible') because we are spatiotemporally located beings, ~~and~~ *must* describe the world from somewhere and somewhen. ~~Its~~ a priori character depends entirely on the arbitrariness of the choice of a reference frame:

> That the concept of object has an origin in reason can be revealed only by the fact that in it there are contained elements for which no choice is prescribed and that are independent of the nature of reality … The contribution of reason is not expressed in the fact that in the

18 Quoted from Alberto Coffa, *To the Vienna Station*, Cambridge: Cambridge University Press, 1993, pp. 201-2.

19 For an illustration of this claim, see Massimo Ferrari, *Categorie e a priori*, Bologna: Il Mulino, 2003.

coordination system there are invariant elements, but rather in the fact that in it there are arbitrary elements.[20]

Thirdly, note that what is constitutive of science need not be *also* constitutive of our experience of the world in Kant's sense (an aspect that neokantians tend to forget even today). In fact, there is a *prima facie conflict* between the special theory of relativity and our experience of time (see above): the latter strongly suggests a natural belief in a cosmic, absolute present, which is part and parcel of the manifest image of time, a belief that the former explicitly denies by insisting on the relativity of simultaneity. This remark creates some tension in Kant's philosophy, to the extent that in his thought the conditions of possibility of our experience are regarded also the conditions of possibility of scientific theories.

Finally, note how the first and the second sense of conventional are deeply related: the presence of conventional elements in science in the second, constitutive sense entails the view that scientific theories are "a free creation of the human mind" (as Einstein often put it), and that they are *not* simply "deducible from facts", but *depend on us*. In other words, scientific models and theories are human artefacts: those conventions that are constitutively *a priori* are, in analogy to the formal element of Kant's theory of knowledge, due to us, and therefore not extractable from the world of facts, which is the realm of those invariant transformations preserving the structure of spacetime.

It is therefore quite crucial to note that when we discuss the problem of the conventionality of the metric, or of the relation of simultaneity in a mere "technical setting", *we ought not to forget the struggles of the early neopositivists to confront themselves with Kant's thought, and in particular with the role of the constitutive a priori in science.*

3.3 Conventional as "non-definable in terms of a physical (causal) relation"

Malament's famous 1977 result concerns the unique definability of Einstein $\varepsilon = 1/2$ simultaneity relation in terms of a time-symmetric relation of causal connectibility, and therefore in terms of the invariant structure of Minkowski spacetime. Suppose, along with the defenders of the causal theory of time, that a spatiotemporal relation x is conventional iff x is not definable or reducible in terms of a physical/causal relation. Then, Malament proves that *to the extent* that the causal theory of time ought to be endorsed (in 1977 he did not explicitly defend it, but presented his philosophical claim in a *conditional* form), his unique definability result − already implicitly present in a work by Alfred Robb[21] − rules out the claim that the relation of simultaneity is conventional.

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20 Hans Reichenbach, *The Theory of Relativity and a priori Knowledge*, ibid, my translation, p. 138.

21 Alfred, Robb, *A Theory of Time and Space*. Cambridge: Cambridge University Press, 1914.

Note that this third sense of conventional seem to be totally alien to Reichenbach's original (kantian) philosophical worries about the "constitutive a priori". In this hypothesis, such a third sense (Malament's definability) would be totally *irrelevant* for the second sense (constitutivity), so that we should not confuse them under the heading "conventionality of simultaneity".

On the other hand, we could try to defend the view that causation is a constitutive a priori element of the special theory, in the sense that the objectivity and invariance of the partial temporal order available in the theory depends on the objectivity and invariance of the causal order. Of course, to the extent that causation can be regarded as a relation that is imposed by us onto the physical phenomena in the sense of a kantian category, we could as well consider it as element that is "due to us". But this claim would need additional argument that cannot be presented in the limited space of this paper.

All I can note in support of this claim here is the following: since in Robb's *axiomatization* of the special theory of relativity, the relation of 'being after' enjoys a foundational role, the reducibility of this relation to causation would give also the causal theory of time a "constitutive" role, since the causal relation would become the true and "primitive" building block of the theory.

This hypothesis, however, is highly controversial, since we still do not agree on what causation is. For instance, if we accepted a Humean, reductionist account of causation as mere regularity, regularities certainly don't depend on us, so that causation, while possibly constitutive of the theory in the axiomatic sense, could not be regarded as being *a priori*. An analogous conclusion would hold if we adopted a theory of causation involving a realist attitude toward potencies or causal powers.[22]

The relevance between the third sense and the first is not very easy to establish either. On the one hand, Malament's result seems certainly related to the first sense of conventional, at least to the extent that what is non-conventional *qua* definable in terms of a causal/physical relation also appears to be non-conventional *qua* factual. After all, a physical/causal relation between events represents a physical fact, albeit relational. On the other hand, if one insisted in holding that the only "facts" in SR are the invariant (worldline-independent) facts, then the relativity of simultaneity would automatically imply its conventionality.

Therefore, due to the ambiguity about the notion of fact in the special theory of relativity, and the related difficulty of establishing whether relational facts also count as fact in that theory, the thesis that Malament's result implies that simultaneity is non-conventional in the first sense remains controversial, even *after* an inertial worldline is given.

Here is another way of looking at this question, and appreciate its complexity. Consider an event a on an inertial worldline O: is it still meaningless to ask

22 For a defence of the importance of causal powers in making laws true, I refer to M. Dorato *The Software of the Universe*, Ashgate, 2005, and A. Bird, *Nature's Metaphysics*, Oxford University Press, Oxford, 2007.

whether an event *e* in Andromeda is occurring simultaneously with *a* on *O*, *relative* to *O*?

As is well-known, this question has been subject to various discussions. On the one hand, Reichenbach and Grünbaum insisted on the claim that, since we cannot measure the one-way velocity of light, we cannot deem the answer to the question as being based on matters of fact. We still need the conventional assumption that light has the same speed in all directions. So, even *after* we assign a worldline *O*, relatively to *O* simultaneity is conventional.

On the other hand, many philosophers after 1977 have taken Malament's result as having solved this problem once and for all. The relation of "being orthogonal to *O*", said of a straight intersecting point $a \in O$ identifies uniquely a simultaneity relation. This relation, being definable in terms of the automorphisms of the structure of Minkowski spacetime, preserves that structure. If no other simultaneity relations can preserve the structure, giving up Einstein's $\varepsilon = 1/2$ choice would amount to giving up the whole structure of Minkowski spacetime.[23] Furthermore, a relation like "is simultaneous with $a \in O$ *relative* to *O*" would seem to be objective and factual, *qua invariant* for all possible observers.

Debs and Redhead have recently claimed that, in a sense, *both* of these positions sketched above turn out to be correct.[24] Pick a worldline, and then ask whether two points selected by Einstein's standard synchrony are objectively simultaneous relative to that worldline: the answer must be in the positive, for the reasons just given. However, the correctness of this answer crucially depends on a previous *choice*, *that of eliminating Lorentz boosts from the full group of automorphisms of Minkowski spacetime*.[25] Debs and Redhead conclude that conventionalism is still with us for at least two reasons:

1) the choice of adopting a restricted set of symmetries (rather than the full set) as an invariance criterion for the objectivity of a relation is, in some sense, in itself conventional (not dictated by facts);

2) once we decide to *include* Lorentz boosts in the full group, then conventionalism seems again to be correct, because a boost will tilt the hyperplane of simultaneity orthogonal to the original worldline and will not preserve it.

Unfortunately, this irenic claim seems to forget that the choice between leaving Lorentz boost out of the automorphisms group or not is not so "free". If the question is to decide whether simultaneity if conventional even after having fixed an inertial worldline, as Reichenbach had originally posed the question, then Debs and Redhead should conclude that Malament is right, because Lorentz boost *must* be left out of the full group of automorphisms. Of course, "the choice of whether to use the line of simultaneity defined by *O*, *O'*, or any one of any infinite number

23 This argument is defended in M. Friedman, *Foundations of Spacetime Theories*, Princeton University Press, 1983.

24 Talal A. Debs, Michael L.G. Redhead, *Objectivity, Invariance, and Convention*, Harvard: Harvard University Press, 2007, p.95.

25 *Ibid*, p. 97.

of inertial worldlines"[26] is fully conventional. However, this is a consequence of the relativity of simultaneity, and unless we are convinced that there is no difference between the relativity and the conventionality of simultaneity, we should stick with a distinction between the two notions. In a word, if the debate on the conventionality of simultaneity is about the uniqueness of an ε-value, *once a given worldline has been conventionally fixed*, the full Poincaré group is not a live option.

3.4 The Conventional as the epistemically "more changeable"

This epistemic sense of conventional has been clearly defined by Dieks in his paper:[27] he seems to imply that distant simultaneity is a non-local concept and that, as such, it is less firmly anchored in direct experience; therefore more open to change, or more "conventional". Concepts used in direct, local observations are in practice unrevisable "although in principle all our concepts may eventually change under the influence of new empirical findings, in practice some of them are virtually immune to such revision".[28]

Here one could raise a point that involves the meaning of *direct, local observation*. Distant simultaneity is not *directly* observable of course, if 'direct' means '*local*', but in order to decide what counts as locally and directly observable we always need a theory, namely the special theory of relativity and classical electromagnetism. *What Dieks seems to neglect is that it is always a scientific theory that decides for us what is directly, locally observable and what isn't*. Consequently, if for scientific reasons we could admit an instantaneous transmission of light, then our "direct experience of time" (in a slightly enlarged sense of "experience") would include a cosmic now. And note that as part of our manifest image of time, *we* firmly believe that there exists a cosmic present, and that simultaneity is absolute, and this seems part of our direct experience of the world. However, what seems global is instead only local, since by looking at a star in the night sky, we wrongly believe that we directly observe the light emitted by it *at present*, but we observe only light emitted light years ago. This remark is linked to the fact that, against Dieks' opinion, I think that science may dispose even of concepts that appear the result of our *direct* and most entrenched experience of the world, for the simple reason that "local observation" is a theory-laden concept. Interestingly, conventional in this sense is fully synonymous with Quine's sense of synthetic, given that the latter means more revisable, because impinging on the periphery of the whole networks of beliefs in which our scientific knowledge consists.

In any case, it is because of the theory derived, non-directly accessible character of the simultaneity relation between two distant events that in order to judge such two events as simultaneous we need some additional operational procedure.

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26 *Ibid*., p. 87.

27 See the paper in this volume, section 3.

28 See Dieks's ~~section 3 of his~~ paper in this volume

The procedure in question must translate the unobservability of the distant simultaneity of two events into a locally discernible coincidence of point-events (two distant light signals intersecting two mirrors posed in front of us). The lack of direct accessibility is the major reason for assuming that questions like *Q* lack factual content.

Therefore, conventional in this fourth sense ~~explains~~ conventional in the first sense: there is no matter of facts making a certain assertion about the simultaneity of two lightlike separated events as true or false, simply because the two events in question do not, and cannot in principle, fall within the limits of a single perception. On the other hand, it is the lack of direct epistemic access between distant events that Einstein (and Poincaré before him) has exploited to introduce some sort of a constitutive a priori convention (the second sense of the word) in the theory. As we have seen, this convention is capable of transforming a meaningless question like *Q* into an empirical question.

Analogously, the fact that the whole region outside the light cone centered in a point *p* of Minkowski spacetime is causally non-connectible with respect to *p* (the elsewhere region relative to *p*) gave philosophers additional motivations to defend the causal theory of time, already defended by Kant. The epistemic non-accessibility of distant simultaneity (its conventionality in the fourth sense) finds an explanation in the lack of a physical connection between different regions of spacetime (third sense of conventional given by the causal theory of time). If there cannot exist in principle physical signals connecting with *p* points in the elsewhere region relative to point *p*, then any sort of temporal relationship that we may fancy to introduce between spacelike related events (simultaneity included) is going to be conventional in both the third and fourth sense of the word. The only invariant temporal order is given by the causal connectibility relation, which is left invariant by the full group of automorphisms of the Minkowski spacetime. So the connection between sense three and four of conventional is certainly not unimportant.

In sum, the importance of this fourth sense of convention can hardly be exaggerated, a fact confirming that special relativity is *an epistemically based theory*. Also the point-coincidence argument, that Einstein defended later in the context of the general theory of relativity in order to avoid the dire consequences derived from the hole argument, is based on the claim that the directly observable relations are the foundational elements of any spacetime theory. This means that while I agree with Dieks that the centrality of Mach's (and Hume's) influence upon Einstein and the neopositivists needs to be re-examined with care, I think he will agree with me that it is certainly difficult to deny that the special theory of relativity has empiricist, epistemically-driven foundations.

3.5 The conventional as deriving from gauge-fixing, i.e. determining simultaneity for non inertial observers

In a recent essay, Lusanna begins by remarking that

> real observers are never inertial and for them Einstein's convention for the synchronization of clocks is not able to identify globally defined simultaneity 3- surfaces, which could also be used as Cauchy surfaces for Maxwell equations.[29]

As Lusanna clarifies, what is required in this case is

> a 3+1 splitting of Minkowski space-time, namely a foliation … whose leaves … [are] both a Cauchy surface for the description of physical systems and an instantaneous (in general Riemannian) 3-space of simultaneity implied by a clock synchronization convention different from Einstein's one.[30]

After a technical discussion involving the Hamiltonian constraint approach to the problem, Lusanna clarifies that all the admissible 3+1 splittings, namely all the admissible procedures for clock synchronization, and all the admissible non-inertial frames centered on time-like observers, are *gauge equivalent*.

The question that is quite interesting and novel for our problem is the following: in Lusanna's approach to establishing simultaneity for non inertial frames, the gauge fixing is linked to the *conventional* choice of an *extended physical laboratory*. The spatio-temporal phenomena as they are viewed from non-inertial frames are therefore coordinate-dependent, in the same sense in which they are coordinate dependent when we choose inertial frames. In this more general approach invoked by Lusanna, however, the inertial frames centered on inertial observers become a special case of gauge fixing. In particular:

> For each configuration of an isolated system there is a special 3+1 splitting associated to it: the foliation with space-like hyper-planes orthogonal to the conserved time-like 4-momentum of the isolated system.

Conclusion

In sum, I have tried to show that we cannot tackle the problem of the conventionality of simultaneity as if it were solvable merely with technical means: the above

29 Lusanna, Luca, "General covariance and its implications for Einstein's space-times", talk at the Meeting *La Relativita' dal 1905 al 2005: passato, presente e futuro* organized by SIGRAV and SISM, Department of Mathematics of University of Torino, June 1, 2005, p.3.

30 Ibid, p. 4.

illustrated conflation of various senses of ‘conventional’ can be avoided only by giving both historical and conceptual considerations their due.

On the one hand, as already pointed out by Friedman, we ought not to forget the deep involvement with Kant’s philosophy both of Reichenbach and of the other members of the Vienna circle. This involvement entails that the question of the conventionality of simultaneity was for them simply a case study used to test the validity of the framework proposed by the *Critique of Pure Reason* after the new revolutionary results introduced by the two theories of relativity.

On the other hand, the historical importance of empiricist methods for the foundations and discovery of the special theory of relativity − and the relativity of simultaneity in particular − can hardly be denied. Not only is this illustrated by the fourth sense of conventional presented above, but also by important evidence provided by Einstein himself on the role of Mach and Hume’s thought on the origin the 1905 theory.[31] In a letter sent by Einstein to Schlick at the end of 1915, we read:

> Your exposition is also quite right that positivism suggested relativity theory, without requiring it. Also you have correctly seen that this line of thought was of great influence on my efforts and indeed E. Mach and *still much more* Hume, whose treatise on understanding I studied with eagerness and admiration shortly before finding relativity theory. *Very possibly, I wouldn’t have come to the solution without those philosophical studie*s.[32] [my emphasis]

However, Dieks will hardly disagree with me on this point. It is worthwhile to recall that while Einstein later disowned it – by claiming that a good joke should not be repeated − an appeal to the verificationist/operationalist foundations of Einstein’s critique of the concept of simultaneity will be of immense historical importance. This applies not only to the history of scientific philosophy (think of its influence on Wittgenstein’s thought, or the Vienna circle etc.), but − considering the enormous influence that it had in Heisenberg’s and Bohr’s thought, and in the many physicists that still follow them − also to the interpretation of quantum mechanics.

Department of Philosophy
University of Rome 3
Viale Ostiense 234
00144, Rome
Italy
dorato@uniroma3.it

31 See J. Norton, „How Hume and Mach Helped Einstein Find Special Relativity,“ prepared for M. Dickson and M. Domski, eds., *Synthesis and the Growth of Knowledge: Essays at the Intersection of History, Philosophy, Science, and Mathematics.* Open Court, forthcoming.

32 A. Einstein, Letter to Schlick, December 14, 1915, *Papers*, A, Vol. 8A, Doc.165, A.