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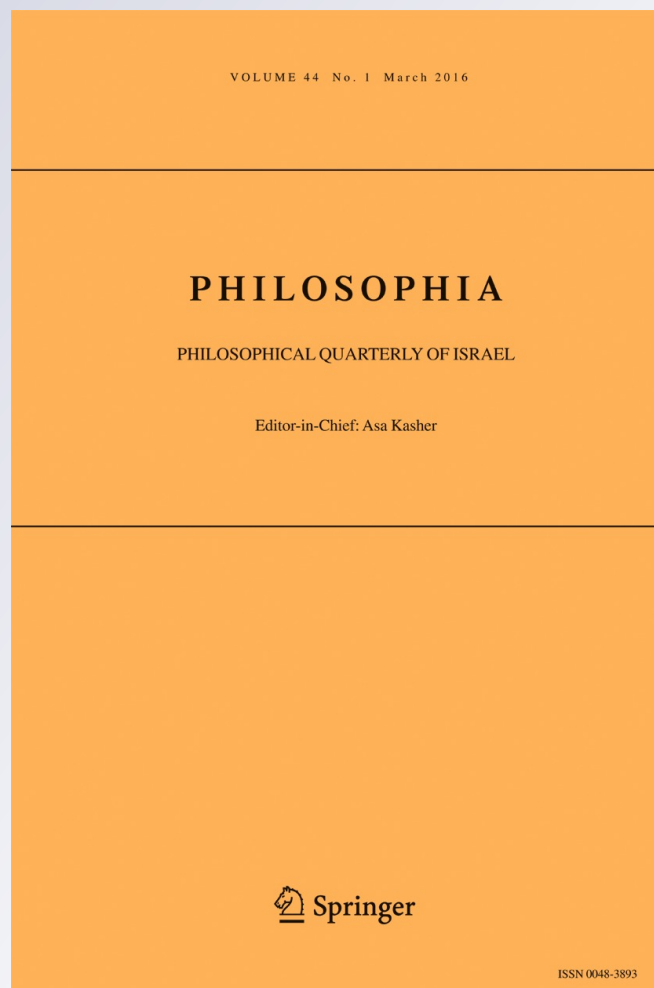
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Chronometric Explanations

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Abstract In this paper I present a problem for the conventionalist regarding temporal metrics, and I defend an objectivist position on the ground of its explanatory force. Roughly, the conventionalist has it that there is no fact of the matter with respect to the truth or falsity of judgments of the kind “event e_1 lasted as long as event e_2 ”, while the objectivist thinks that they are grounded in objective features of space-time. I argue that, by positing grounds for judgments of relative temporal length, the objectivist gains an explanatory force that the conventionalist position lacks.

Keywords Conventionalism · Temporal metric · Explanation

How Should the Debate Between the Conventionalist and the Objectivist Regarding Temporal Metrics be Understood?

Although conventionalism and objectivism regarding temporal metrics are two opposing metaphysical views, the debate between them hinges dialectically on a well-known epistemic problem concerning our capacity to know events. Events seem to have at least two types of temporal determination. Firstly, pairs of events are either related by succession (the earlier/later relation), or they overlap to some extent (with inclusion being a particular case). These determinations constitute the topological aspect of the temporal dimension. Secondly, events have durations, and event e_1 can last as long as event e_2 , or there can be a certain ratio p/q between the two events. These determinations constitute the metric aspect of the temporal dimension.¹

¹Note that the otherwise interesting philosophical debate on whether the relation between the structure of the order of the purely temporal elements “containing” the events and the structure determined by the temporal relations between events is identity — viz. the relationist vs. substantivist debate — will not concern us.

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Mapping the topological aspect of time onto a mathematical formalism which can be used to represent it (in a way that is informative) is not epistemologically problematic. Our perceptual judgments of succession, precedence and simultaneity are often reliable.² When a certain external factor (such as the velocity of sound in air) impinges on them, we have theories (which we deem to be good for independent reasons) that allow us to explain the apparent mismatches and tell us how to correct them. The same goes for judgments based on evidence gathered through the use of instruments. But when we come to metric aspects, and ask ourselves how we can know whether two events last the same amount of time, or that the first lasted a certain ratio p/q with regard to the second, things pretty soon get murky. In order to encode metrical (and not only topological) information, our mathematical formalism should represent temporal length properties of events. The mapping of temporal length properties of events (usually to intervals of rationals) requires us to be able to measure the temporal lengths of events in some temporal unit. In certain particular circumstances, partial metric information can be detected by direct comparison between events. For instance, if two events begin and end at the same moment, we will have evidence that they have the same temporal length; if the length of one event is entirely contained in the length of another event, we will have evidence that the first is shorter than the second. But when events are successive to one another, we need a physical system that produces a succession of events of the same temporal length, namely a clock, in order to compare their lengths. As long as we have a clock C “ticking” — namely, producing a succession of events c_1, c_2, \dots reproducing the temporal unit we are adopting — the beginning of any event e will take place while the beginning of some event c_n in the succession created by the clock occurs, and the same goes for the end of e . In order to measure the length of e we need to count the ticks of the clock, namely the number of events c_n in the succession produced by the clock while the e was going on. This procedure allows us to gather observable evidence for claims that a certain event e_1 has lasted q/p as long as event e_2 — or that an event has temporal length n time units, where the time unit is the temporal length of each of the event c_n produced by the clock).

The problem with this procedure is that it works on the assumption that the events that the clock produces in succession all have the same temporal length; but it seems impossible to warrant this assumption. The only way we have to provide evidence for two events having the same temporal length is by using a clock. Thus, evidence to confirm or disconfirm the hypothesis that a clock is regular, namely that the events it produces are isochronic, can be provided only through a further clock, which in turn can work as a reliable source of evidence only on the assumption that it is regular. Bad news: we are caught either in an infinite regress or in a circle. How can we move on? The disagreement between the objectivist and the conventionalist lies in the choice of strategy to move out of the epistemological impasse. And although the puzzle is epistemic, each strategy is based on a characteristic metaphysical stance.³

² Of course, it is a consequence of STR that such mappings are always relative to a reference system — for instance, the one centred on the instrument — assumed to be at rest or in inertial motion. Relativistic considerations are immaterial to the problem that I am discussing in what follows (although the objectivist position that I eventually defend can be easily extended to a relativistic environment).

³ Adolf Grünbaum, a proponent of conventionalism who does not generally show much sympathy for metaphysical debates, seems to agree: “clearly [...] the thesis of the conventionality of congruence [i.e. of temporal metrics] is, in the first instance, a claim concerning structural properties of physical space and time [...]” (Grünbaum 1963: 26)

The objectivist maintains that the ground for the truth or falsity of our ordinary and scientific claims about the relative temporal length of events (i.e. that an event lasts as long as another, or p/q as much as another) are facts about the ratio between the temporal lengths of events. Such ratios are genuine (although relational) properties of events, that they possess objectively, namely independently of any choice of an instrument of measurement.⁴ If we call the facts concerning these ratios “chronometric”, the objectivist thesis is that there are objective chronometric facts. Although there cannot be observational evidence for chronometric facts, given independent criteria of selection of a physical system like a reliable clock (i.e., a clock producing a succession of isochronic events), we can gather indirect evidence for the fact that event e_1 lasted p/q as long as event e_2 , by the direct evidence we have of the epistemically unproblematic relations between the beginning and ending of e_1 and e_2 (respectively) and the events c_1, c_2, \dots produced by the clock.

The conventionalist adopts the same procedure to measure temporal lengths, but she maintains that temporal length ratios are not genuine properties of events. Rather, they are “disguised” relations to the events produced by the clock that we chose as measuring instrument — namely to the convention we have adopted as congruence standard. The conventionalist thesis is that chronometric facts are “conventional” in this sense. Given that there are no non-conventional chronometric facts, there will be in general nothing that grounds the truth or falsity of absolute judgments of the relative length of events. The only judgments of relative temporal length that are assured to be true or false are those explicitly or implicitly relativized to a given clock. Such judgments are grounded in facts about the (epistemically unproblematic) relations between the (beginnings and endings of the) events in question and the events produced by the conventionally chosen clock. Note that the properties accepted by the objectivist but denied by the conventionalist (ratios between temporal lengths of events) are relational properties too — i.e., relations “in disguise”. Indeed, the difference between the two positions might be described in terms of the different type of relations they posit: dyadic relations for the objectivist (relations between two temporal events) and triadic for the conventionalist (relations between two events and a -conventional-clock). However, the more interesting aspect of the different relations they posit does not lie in their different adicity. Rather, it lies in the fact that the objectivist posits relations that are not, in principle, observable (ratios between temporal lengths of successive events), while the conventionalist maintains that our talk about such unobservable relations is disguised talk about relations that are in principle observable (those concerning the epistemically unproblematic relations between the “ticks” of the clock and the beginnings and endings of the events that we are comparing).

⁴ A slightly stronger version of objectivism may have it that temporal length properties of events — their covering a certain “amount of time” — are genuine properties. This stronger version entails the weaker version. I confine my discussion to the weaker version here, because the stronger version raises problems about dense and continuous structure and objective metrical properties, which are beside the point for the problem that I want to discuss (See Newton-Smith 1980: 166). Again, relativistic considerations are bracketed here. Besides, it may have occurred to the attentive reader that an analogous skeptical scenario holds for spatial length measurements with physical rulers. I do not need here to enter the difficult issue on whether there are interesting *epistemic* differences between the spatial and the temporal case. However, although I will ignore the spatial case altogether, the objectivist position that I defend at the end suggests that from a *metaphysical* standpoint the two cases are analogous (given special relativity).

Objectivism seems to respond better to our pre-theoretic intuitions: we do normally talk and think as if relative temporal length properties were objective matters of fact. Conventionalism seems far less intuitive, especially if we think of the consequences that it has for our judgments of relative temporal length. As long as the physical system that we choose as a clock can be mapped through a linear transformation to another system, relativizing to one clock rather than to another will lead to the same judgments of relative temporal length. However, the conventionalist thinks that physical systems that do not map through linear transformations into each other can also be used as legitimate clocks. It follows that choosing a clock C_1 rather than (a non-linearly related) clock C_2 can make a difference for our judgments of relative temporal length of events. Two events that have the same temporal lengths according to clock C_1 may not have the same temporal lengths according to clock C_2 , and in general the ratio between the temporal lengths of two events may vary depending on the convention that we adopt. Thus, hereafter I will use the expressions (clock) $C_1 \dots C_n$ as labels for class of linearly related clocks. In the next section, I argue that conventionalism is not only counterintuitive, but runs into a serious philosophical puzzle.

The Bomb Disposal Expert Puzzle

Imagine that a bomb with a timer is found in a building, and a bomb disposal expert is immediately called. The expert arrives, and once she has carefully observed the bomb, she correctly comes to believe that it is a device entirely similar to one she has disposed of yesterday, during a drill, in two minutes sharp. She looks at the timer, which shows “2 min and 10 s”, and thinks.

(B) If it takes me as long as it took me yesterday to dispose of this bomb, I'll make it

If the expert has no reason to doubt her present skills, or that the device works normally, it seems correct to say that she is justified in believing (B). Now, how can the objectivist and the conventionalist account for the expert's belief being justified?

According to the objectivist, the success of the expert's actions depends on her ability to make the process of disposal of the bomb take as long as in yesterday's drill. If the expert survives, this will be explained by the fact that the process of disposal of the bomb took as long as yesterday's drill (or less). In general, one is justified in believing a conditional of the form (B-gen) below, when A expresses the condition of success of bringing about B. More precisely, the justification of the conditional is transferred from the justification in believing that one can do A, and that the occurrence of A explains the success of bringing about B.

(B-gen) If I do A, then B will occur.

Now, since the expert has evidence from past experience that she is in a position to make the two events last the same time, and that such a fact will result in her life being saved, she will be justified in believing (B). There are of course further facts, besides those concerning the temporal relations between the two events, that enter the

explanation of the success of the expert's actions — for instance, facts concerning the interaction between the clock mechanism of the bomb and the explosive. However, what is crucial is that, according to the objectivist, facts concerning the relation between the two events and any particular instrument of measurement of time are irrelevant to explaining why the expert will be successful if she acts in a timely manner.

Contrariwise, according to the conventionalist, whether the process of disposal of the bomb will take as long as yesterday's drill depends on the choice of a chronometric convention. Assume that according to a certain clock C_1 the process of disposal will take as long as yesterday's drill, whereas according to a different clock C_2 , it will take longer. If that is the case, the success of the expert's actions cannot depend on her ability in making the two events last the same time. What the conventionalist can say is that the success of the expert's action depends on her ability to see to it that the process of disposal will take as long as yesterday's drill according to clock C_1 . But if the expert were justified in believing that, then whether or not she manages to save her life would depend on the choice of a particular chronometric convention, and not merely on her performance (other things being equal). If we reject this conclusion, as intuitively it seems everyone should do, then the expert is not justified in believing (B). But this is wrong, since surely evidence from past experience puts her in a position to be justified in believing (B). That is the predicament for the conventionalist. Let us see now where she might look for a solution.

Newton-Smith's Moderate Conventionalism

Conventionalism with respect to temporal metrics had been defended in quite radical forms by Hans Reichenbach and Adolf Grünbaum. In its radical form, conventionalism has it that whether two successive events have the same temporal length or not is a matter of definition. We define “being isochronic” by adopting a clock, namely by stipulating that a certain physical system that produces a succession of events is the congruence standard for temporal lengths. In the 1980s, Newton-Smith argued (1980: 162) that appealing to definitions is infelicitous here, and he advanced a characterization of conventionalism in terms of lack of truth-conditions for absolute judgments of relative temporal duration: there is generally no matter of fact with respect to the truth or falsity of absolute judgments of relative temporal duration. I propose a slightly different formulation of conventionalism, in positive terms. The core conventionalist thesis is that judgments of relative temporal duration are grounded in facts concerning the epistemically unproblematic relations between the events at issue and the succession of events produced by a given clock. Given that clocks that are non-linearly related to each other can yield different verdicts with respect to the relative temporal duration of the same events, judgments of temporal duration that are not relativized to a clock will generally lack a determinate truth-value. (Note that together with the assumption that there is more than one non-linearly related clock, my formulation entails Newton-Smith's, although not vice versa).

Now, the “old school” conventionalists are not radical because they formulate their core thesis appealing to definitions; rather, they are radical because “all definitions are equally admissible” (Reichenbach 1950: 116), namely any physical system that produces successive events is a legitimate congruence standard. Someone who does not

endorse objectivism and the existence of facts about relative temporal duration, but also does not maintain that all clocks are admissible as congruence standards, is a moderate conventionalist. According to the moderate conventionalist, some absolute judgments of temporal duration are false — those that would be vindicated only by the adoption of a non-admissible clock, while others lack a truth-value — those that are true according to certain admissible clocks and false according to other admissible clocks.

But what are the “bad” clocks, the ones that it is not admissible to adopt as a congruence standard, according to the moderate conventionalist? Newton-Smith, who defends a form of moderate conventionalism, starts by eliminating the ones that diverge too widely from our intuitive judgments of isochrony:

“The [...] thesis [...] that no judgments of relative temporal congruence have truth-conditions is absurd. For if I adopt some deviant clock which gives the Ice Age, the time between my last two heartbeats and a performance of Wagner’s Ring the same duration, I am just wrong”. (1980: 163)

Furthermore, we should adopt reproducible physical systems that “tick together” (namely, they preserve mutual congruence), at least when the systems reproduced do not find themselves in physical conditions that are excessively different.⁵ Among the physical systems that are reasonable clock systems (namely, they generally preserve mutual congruence), we should select only the ones that can be used to arrive at a viable total physical theory. Indeed, we want clocks that preserve mutual congruence, because that is a minimal condition for a measurement instrument of time to be used to discover adequate physical theories. Once we have selected a successful physical theory T (namely one that is confirmed by its predictions to a satisfactory degree), T can be used to refine our criterion of selection: the better clocks are the ones that better approximate the prediction of T. (Besides, we can use T to correct the measurement of the clocks when they are in physical conditions that disrupt congruence).

As Newton-Smith rightly notes, the factors relevant for selecting the instrument of measurement of time are not a point of disagreement between the conventionalist and the objectivist. The disagreement concerns “the status to be accorded to the factors” (1980: 158). According to the objectivist, they are a source of evidence that the system is indeed tracking isochronic intervals; according to the conventionalist, they indicate “the greater simplicity that will be obtained by stipulating that that physical system generates isochronic events”. (1980: 158).

A Super-Valuationist Formulation of Moderate Conventionalism

In order to see how moderate conventionalism could be exploited to solve the bomb disposal expert puzzle, I will formulate it in super-valuationist terms.⁶ Given a set of ordered couples of all admissible clocks together with their related total physical theory

⁵ It is very important to note that preservation of mutual congruence among cognate clocks is not observational evidence for congruence between the events produced in succession by each clock. Even if we had billions of clocks ticking in unison, we cannot rule out the possibility that the intervals produced in succession by each clock are not isochronic. See (Le poidevin 2007: 115).

⁶ On super-valuationism, see Varzi 2007.

$C = \{ \langle C_1, T_1 \rangle, \langle C_2, T_2 \rangle, \dots \}$, and the set of all atomic relative length judgments $L = \{ \langle p_1, p_2, \dots \rangle \}$, we can construct a super-valuationist semantics for all judgments in L as follows. If a judgment p in L is true or false according to all admissible clocks in C (corrected by the related physical theory if needed), then it is super-true or super-false, i.e., true or false simpliciter. If p is true according to certain admissible clocks, but false according to others, then it is neither true nor false, i.e., it is indeterminate. As we have seen, according to the moderate conventionalist there are at least some judgments about relative durations that are absolutely false. Indeed, since no reasonable clock would vindicate completely crazy judgments, such as that the Ice Age lasted the same time as Britney Spears's last concert, they will all turn out false.

What about absolutely true judgments regarding relative temporal length according to the moderate conventionalist? Surely, it should not be a problem to admit negations of crazy judgments as absolutely true: according to any reasonable clock it is true that it is not the case that the Ice Age lasted the same time as Britney Spears's last concert. Also, judgments that have the form of any classical logical validity — such as “either e_1 has the same length of e_2 or not” — are true simpliciter according to the super-valuationist semantics.⁷ All such cases, though, are non-atomic, and thus do not concern the judgments in L . The interesting question is whether the moderate conventionalist can accept atomic relative length judgments. It is not clear why we should rule out this possibility. Thus, I will assume that at least some judgments in L are super-true.⁸

Such an assumption is plausible if we allow in L approximate judgments — such as the judgment that event e_1 roughly lasted as long as event e_2 . Intuitively, if we do not require a high standard of precision for a certain judgment about relative temporal length, it may well turn out that any reasonable clock will deliver the same verdict. Thus, I will assume that at least some approximate judgments of temporal length are either super-true or super-false. Finally, when the indetermination of a judgment p_1 is due only to a comparatively small number of admissible clocks, can we consider the evidence that we may have for p_1 as good enough for being justified in believing it? Here the issue is trickier, but I think that in so far as evidence for justification is still defeasible evidence, we should answer positively. We can call this thesis the *thesis of tolerance of evidence with respect to large cases of positive verdicts*.

Newton-Smith does not discuss these issues (nor does he formulate his position in super-valuationist terms), but he does consider the possibility that there be only one admissible clock with a related total physical theory. In such a situation, there will be interesting cases of absolutely true atomic judgments of relative temporal length — and trivially so, since all judgments of relative temporal length would be either absolutely true or absolutely false. What grounds the truth or falsity of judgments in L are not objective facts about the ratio between the temporal lengths of events, but nonetheless there will be a ground for all of them, provided by the relation between the events in questions and the “ticks” of the only admissible clock.

⁷ A general feature of supervaluationist semantics is that theorem-hood is preserved, thus if the underlying logics is classic, any classically valid sentence is true in any supervaluation.

⁸ Of course, if it is true that, intuitively, there are super-false atomic judgements in L , a different choice of primitive would have given us immediately super-true judgments in L . What I am claiming here is that even if we admit only “natural” primitives in L (i.e., those that respect our intuitions with respect to crazy claims such as “My last heartbeat lasted as much as the Ice Age”), it is not unreasonable to maintain that we have super-true atomic statements.

It is important here to note a consequence of the difference between Newton-Smith's formulation of conventionalism and my own. According to Newton-Smith's characterization, it is crucial for conventionalism (both radical and moderate) that there should be a variety of admissible clocks such that they diverge in their verdicts of relative length. Thus, according to Newton-Smith's characterization of conventionalism, it follows that if there is only one admissible clock, conventionalism is false. However, it is not false because there are facts of relative temporal length in the world; rather it is false because there is only one type of admissible conventional facts about relative temporal length (i.e., facts concerning the relation between the events at issue and the events produced by the only admissible clock). It follows that there is a fact of the matter with respect to the truth or falsity of judgments of relative temporal length. Thus, objectivism (as he defines it) is true. To the contrary, according to my characterization, even if there is only one admissible clock, conventionalism does not need to be false. I will call the combination of conventionalism (as I characterize it) and the tenet that there is only one admissible clock "pseudo-objectivism". If pseudo-objectivism is true, although there are no facts of relative temporal length (and thus objectivism — as I define it — is false), any judgment of relative temporal length has a determinate truth value. This is so because there is only one admissible clock (with an associated total physical theory), and facts about the epistemically unproblematic relations between the succession of events produced by the preferred clock and the events at issue ground the truth or falsity of any judgment of relative temporal length. Yet, the pseudo-objectivist is a conventionalist (according to my characterization of conventionalism), since if it is true, judgments of relative length are still grounded in relations between an admissible clock and the events at issue, rather than on the ratio between the temporal lengths of the events at issue.

The Moderate Conventionalist's Solution to the Puzzle

Let us go back to the bomb disposal expert puzzle now. Can the pseudo-objectivist explain why the expert is justified in believing (B)?

(B) If it takes me as long as it took me yesterday to dispose of this bomb, I'll make it

It seems she can. Remember that the justification of the expert crucially hinges on evidence concerning the conditions of success of her actions, and on her being in a position to see to it that those conditions obtain. The conditions of success of her actions express what has to be the case for her to survive, namely they express the facts that would explain why she survived. The case of the expert is not substantially different from many other ordinary ones, in which someone is in a position to make it the case that *p*, because they can bring about the fact that *q*, whose obtaining would explain how *p* is the case (together with background conditions and a physical theory). In many such cases we can be justified, in virtue of our knowledge of physics and of past experience, in believing that if we bring about that *p*, then *q* will obtain. For instance, suppose there is a fish in a tank and we can regulate the pH of the water in which it lives. If we have evidence that the fish survives only in waters with a pH

within certain values, and that the regulation system is working normally, we are justified in believing that if we keep the pH of the water within those boundaries, the fish will stay alive.

Now, according to the pseudo-objectivist, there is only one admissible total physical theory with a related clock. If the expert had past experience with clocks sufficiently similar to the standard one, she is justified in believing that if the judgment of isochrony concerning the past drill and her future performance is true, then she will survive. She might have a belief that does not correctly characterize the relevant facts, because she might have in mind alleged facts of relative temporal length, rather than relational facts between the events at issue and the ticking of the preferred clock, but if she performs correctly, her belief will be true and she has evidence for that.

If such an account is viable to the pseudo-objectivist, then probably something analogous could also apply to a moderate conventionalist. Even if the expert had only experience with the clocks associated with a particular physical theory, in so far as a large number of (non-linearly related) clocks with the associated physical theory does not contradict its verdict, the expert will have evidential support for her belief (B). If the antecedent in (B) were a claim about the length of a temporal interval, of course, there could not be more than one (non-linearly related) clock that does not contradict it. However, “as long as” in (B) is more naturally construed as expressing the *maximal* length that the activity of disposing of the device could have, if the expert makes it. If so, several (non-linearly related) clocks could confirm the claim (all those according to which the expert’s deed lasts *less* than yesterday’s drill). Thus, unless we set the standard for justification exceedingly high, it is reasonable to assume that both that and the thesis of tolerance of evidence with respect to large cases of positive verdicts will hold. Therefore, this evidential support will suffice for justification. The account is even stronger if the conventionalist argues that (B) is an approximate judgment (as it seems plausible to maintain). If this is the case, then the evidence that the expert has gathered from past interactions with one type of measuring device would suffice to warrant the conclusion that (B) is true. Moreover, the expert could claim to have evidence for her belief, even if we were to understand “as long as” in (B) strictly speaking – viz., as expressing the length of a temporal interval, rather than a maximal length. I grant that the moderate conventionalist’s story has some plausibility. However, it fails in one crucial respect — or so I will argue in the next section.

Chronometric Explanations

According to Newton-Smith, the tenability of conventionalism rests on an empirical thesis and on a philosophical thesis. The empirical thesis is the underdetermination of time by the date:

(UM) “It is possible to produce a family of clocks which are pairwise non-linearly related. [...] Each clock has an associated total physical theory. No experiment or observation can decide between these pair of clocks and theories.” (1980: 162)

The philosophical thesis is the essential accessibility of facts:

(TEAC) “[...T]here is no reason to assume that there is a matter of fact at stake if [...] a hypothesis is empirically undecidable even by the totality of all possible observation and experiments [...]” (1980: 163)

Although Newton-Smith shows sympathy towards (UM), he acknowledges that it would be a Titanic enterprise to actually confirm it, given the current status of physics. However, he thinks that (TEAC) can be defended with philosophical arguments. The core of his conclusions is in the following quote:

“It is not clear what could possibly count as a reason for thinking that there is a matter of fact (a matter of inaccessible fact) at stake here [i.e. when a hypothesis is empirically undecidable even by the totality of all possible observation and experiments]. For there is nothing that would be *explained* by the supposition that there are such facts.” (1980: 235, italics mine).

In the above passage Newton-Smith is defending TEAC in general, and he uses as an example the debate on whether time is topologically closed or open. Now, whatever the status of that debate, I want to argue that with respect to the debate between the conventionalist and the objectivist the situation is different: by positing facts about relative length, the objectivist’s position gains *explanatory power* over the conventionalist’s.

In his 2007 book, Robin Lepoidevin has argued that a certain kind of explanation, which he calls *chronometric explanation*, has a legitimate position in science and ordinary practice, and it presupposes objectivism. Here is his characterization:

“Chronometric explanation appeals to the temporal location and extent of things, or to the rate of change. Often it will occur in the context of a causal explanation. Thus, a certain effect may be explained, not simply by the existence of an antecedent cause, but by the location of that cause in time, or by the interval between that cause and another item, or by the rate at which some antecedent change proceeded. Here are some examples of causal explanations that include chronometric explanations:

(a) Why did the firework explode at t ?

Because it was lit five seconds before t

(b) Why did electricity flow around the system?

Because the two buttons were pressed simultaneously, thus closing the circuit

(c) Why are the two traces on the Campbell-Stokes recorder the same length?

Because the two intervals of sunshine that caused the trace were equal in duration”⁹

⁹ (Le poidevin 2007: 117), see also (Le poidevin 2007: 101–3). Lepoidevin compares chronometric explanations to the ‘geometric explanations’ introduced by (Nerlich 1994) as a kind of non-causal explanations.

Now, we have seen that observation cannot decide between the conventionalist and the objectivist positions. This is not surprising, since — as I have argued — conventionalism and objectivism are two metaphysical tenets concerning the fundamental constitution of reality. Again, according to the objectivist, there are facts about the ratio between the temporal lengths of successive events, which are hence inaccessible; whereas according to the conventionalist, no such facts are to be found in the world, there are only accessible facts concerning the relation between the beginning and the ending of events and the succession of events produced by a chosen clock. However, it is not a trivial claim that when philosophical theses are at stake, only observation and experiments should count as evidence for choosing between them, and that theoretical virtues should be regarded as mere pragmatic factors of theory choice. In particular, explanatory power is a central theoretical virtue with respect to philosophical positions that have consequences for the interpretation of scientific theories, as surely conventionalism and objectivism with respect to temporal metrics are. Thus, if objectivism turns out to be more explanatory than conventionalism, this fact should be regarded as *defeasible* evidence in favor of the former.¹⁰

With this notion of chronometric explanation in mind, let us see whether the bomb disposal expert puzzle can be exploited in an argument in favor of objectivism and against conventionalism. We have assumed that the expert knows what she has to do to achieve her goal, since she has no reason to doubt her abilities on that day, and she is justified in believing (B). The kind of account of the justification of the expert that I have sketched in §V for the moderate conventionalist is *prima facie* plausible. However, as I have stressed, the expert is justified in believing (B) in so far as she has justification in believing in an explanation of the success of her actions. The objectivist explanation essentially involves not only causal facts, but also facts about the relative temporal lengths of the drill of the day before and of today's performance in disposing of the bomb. Thus, this explanation — being a chronometric explanation — is not something the conventionalist can resort to.

The conventionalist can appeal only to the relation between the ticks of the standard clock *C* and the moments in which her action of disposing of the bomb begins and ends. Facts with respect to the standard clock, confidence in her abilities, and the general physical theory connected with the standard clock warrant the belief that if her action today is congruent with her action during yesterday's drill, she will be safe. However, even a moderate conventionalist maintains that there can be non-linearly related clocks that are acceptable congruence standards. Let us consider one such non-standard clock C_1 , according to which it is false that events that last the same number of ticks as the standard clock *C* are congruent. Now, if what explains the success of the expert's actions is the relation between a given admissible clock and the moments of beginning and ending of her actions, then reference to the standard clock *C* is essential to the explanation. If we referred to C_1 , the explanation would fail. With respect to C_1 , the success of the expert is explained by her performance having lasted p/q as long as the drill of the day before (where $p \neq q$). But that is in conflict with the expert's being

¹⁰ Incidentally, if the boundaries between scientific theories and philosophical ones are not clear cut, as it is also reasonable to believe, theoretical considerations can also play a role in evaluating incompatible scientific theses. An analogous thesis is defended at length by (Psillos 2009).

justified in believing (B) on the grounds of her past experience with C. Thus, the moderate conventionalist has to face a tension between the tenet that the expert is justified in believing (B), which — as we have seen — entails that we disregard non-linearly related clocks that differ in verdicts from the standard one, and the tenet that explanations of the success of the expert actions is essentially linked to the standard clock C, which follows from the thesis of conventionalism itself.

The pseudo-objectivist is in a better position, because according to her, there are no other acceptable clocks than the one that we have discovered to be the only acceptable one. Of course, unless the pseudo-objectivist takes the laws of physics to be metaphysically necessary, one or more non-linearly related clocks could have turned out to be acceptable. But in the counterfactual situation in which a different clock turned out to be the acceptable standard, the pseudo-objectivist can reasonably maintain that the laws of physics would also have been different (or the boundary conditions maybe). Thus, it is not clear that the expert would have been justified in believing that she will be safe. Yet, for the pseudo-conventionalist as well the appeal to the standard clock is essential to explain the success of the expert's action, whereas justification in believing (B) requires, at least in principle, tolerance with respect to non-standard clocks.

The advantage of objectivism over conventionalism, thus, is that within the objectivist's framework, in situations like the one of the expert, the explanation concerning the success of an agent's actions and the explanation concerning her being justified in believing in her conditional success go hand in hand, as it seems it should. Maybe the conventionalist can insist that facts concerning the epistemically accessible relations between the standard clock and the expert's past actions can account for the conditions of success of her action. But that belief seems to be the outcome of a confusion. It is probably true that the relations that the expert has experienced in the past between similar events and the verdict of the standard clock have contributed to form her belief that she will be safe if she acts in certain ways with respect to the bomb. But that such relations can explain the genesis of her belief in (B) does not entail that they must enter an explanation of the *success* of her actions. Finally, the case of the bomb disposal expert makes clear that the impossibility of recurring to chronometric explanations is a serious explanatory drawback for the conventionalist.

Conclusions

Facts concerning comparison between events produced by a chosen clock and the events we are focusing on cannot provide an explanatory ground for the outcome of our actions, when these are based on the justified belief that if we manage to do something in a timely manner, then we will achieve a certain goal. If using different clocks leads to different truths about relative temporal lengths, we lose any explanatory link between the condition of obtaining of a timely action and its consequences. This seems to be a general explanatory deficit of conventionalism. If so, we have theoretical reasons to prefer objectivism over conventionalism — in so far as explanatory power is a theoretical virtue against which we should gauge our metaphysical endorsements.

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