Spacetime Functionalism

Henrik Sherling

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I will argue that, in light of spacetime functionalism[1] and the "ought implies can" principle[2], we do not need a constructive theory of special relativity (SR), for the simple reason that we cannot hope to find one.

I shall confine my argument to the consequences of my two assumptions, rather than their defense. My conclusion may thus best be viewed as a reductio: *either* spacetime functionalism holds and ought implies can, *or* we need a constructive theory — but not both.

In broad strokes, my argument will proceed as follows. First, I will define my terms. In order to make my case, I will need to introduce some non-standard terminology. Second, I will outline two possible constructive explanations of SR and show why they cannot succeed. Finally, I will show that it follows from my terms and this failure that we ought not prefer a constructive theory of special relativity.

I will begin with the definitions.[3] *Principle explanations* begin, aptly, with principles that are not themselves deduced or induced from anything more *fundamental*[4] But from these principles we deduce predictions about the world and its phenomena. The principles are successful to the extent that their predictions fit the world. A good *principle theory* is composed of consistent principles that predict a range of connected phenomena. And so it is the business of principle theories to provide principle explanations.

Thermodynamics is an example of a very good principle theory. Its principles entail that your latte will never spontaneously separate into smooth layers of milk and coffee. And this is exactly what we expect, because lattes do not in fact spontaneously separate. Moreover, thermodynamics can tie this phenomenon to other seemingly distinct phenomena, such as apparent absence of perpetual motion machines — the second law of thermodynamics[5] precludes their existence, just as it precludes the spontaneous separation of milk from coffee.

But there is a sense in which thermodynamics leaves us with an *explanatory gap* (Felline 2011, 998): it does not explain *why* its principles are true in the first place. They may be superb predictive tools, but their origins are mysterious. Everyone agrees that the second law of thermodynamics, for instance, is *true* — but we want to know *why* it is true. And that is why so many physicists have tried to ground it in the more fundamental principles of statistical mechanics (Albert 2000; Chapter 2-3).

And this search to explain the principles themselves — to bridge the explanatory gap — is often interpreted as a search for *constructive explanation*. Very roughly, a

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1 See Knox (2017) for a defense.
2 See Stern (2004) for an overview.
3 I adopt Felline's (2011) interpretation of Balashov and Jansen (2003) here.
4 I will not need to define fundamentality. I will only require that it is irreflexive.
5 Which states that the entropy of an isolated system never decreases over time.

constructive explanation is the completion of a principle explanation — it explains the principles from which it deduces its predictions. But this is plainly *too* rough for our purposes, so I will need to properly pin down what exactly a constructive theory amounts to.

Einstein's original distinction (Einstein 1919) between principle and constructive theories might, as Felline (2011) points out, have been merely methodological. But Brown (2005) and Balashov & Jansen (2003) certainly make much more of it: they implicitly imbue it with *normative force*. They believe that we *ought* to prefer constructive explanations because they *explain more* than principle explanations. Call this the *norm of construction*: we *ought* to find constructive explanations of our physical theories. Thus, when I define down constructive theories more precisely, I also need to capture this norm.

I will follow Felline's (2011, 994-995) suggestion that constructive explanations are *ontic* explanations.[6] Thus, they attempt to explain by reduction to the fundamental constituents and relations of our ontology. If matter and causation were fundamental, then ontic explanations reduce everything else to matter and causation. This is, very roughly, what statistical mechanics attempts to do for thermodynamic phenomena — it provides an ontic explanation.

Of course, before an ontic explanation can get off the ground, we need to figure out what actually counts as fundamental — and matter and causation are unlikely to succeed.[7] But there is no need to do so for the present purposes, as my argument does not rest on it. Instead I want to call attention to a general feature of ontic explanations: they are *exclusive*.

Here is how I will define exclusivity: A exclusively explains B just in case A explains B and nothing is both more fundamental than A *and* explains B. Thus, the principles of thermodynamics might *explain* why lattes don't spontaneously separate — but the presence of a more fundamental explanation, in this case statistical mechanics, means that the principles of thermodynamics do not *exclusively explain* it.

Consider a theory or explanation exclusive just in case it exclusively explains its predictions. It follows by definition that an explanation is ontic only if it is exclusive. And if we equate (as I have) constructive and ontic explanations, it further follows that an explanation is constructive only if it is exclusive.

I think exclusivity is key to the aforementioned normativity. Consider the *norm of exclusion* to say that we *ought* to find exclusive explanations of our physical theories. It should be plain that the norm of exclusion captures the *intuition* behind constructive explanations. It demands not just that we partially illuminate, but that we

6 A term she attributes to Salmon (1984). Brown (2005, Chapter 8.2) seems to endorse this definition.

7 This topic is too large for this essay. See Price (1997) for clues.

enlighten entirely — that we do not stop until everything has been explained in terms of the most fundamental.

And notice that the norm of construction *entails* the norm of exclusion[8]: if we *ought* to find constructive explanations of our physical theories, then we *ought* to find exclusive explanations of our physical theories. By a simple modus tollens it follows that a rejection of the norm of exclusion entails a rejection of the norm of construction.

Now suppose that ought implies can. Thus, if we *cannot* find an exclusive explanation, then we *ought not* find one. And so all that remains is to show that we cannot find an exclusive explanation of SR, and it will follow that we ought not find a constructive explanation.

In his own 1905 paper, Einstein set out two principles: that the laws of physics are the same for all inertially moving observers (Galilean Relativity), and that the speed of light in vacuum is constant (the Light Postulate). From these two principles he deduced some crazy consequences: we will observe objects in relative inertial motion to contract in their direction of motion, and observe their clocks as ticking more slowly than ours. And these phenomena are not merely theoretical: two synchronizes watches will diverge if we send one on a roundtrip to Mars in at a really high speed (this is called the twin paradox).

Einstein's theory of SR offered a principle explanation of these phenomena, as he himself saw (Einstein 1919), because he never got around to explaining the principles themselves. Is it possible to find an exclusive explanation of its principles?

There are two schools of thought, which I will term Lorentzian[9] and Minkowskian[10], that more of less agree that we can, but differ in *how* they think it should be done.

Lorentzians argue like this. First, (supposed fundamental fact) time dilation and length contraction are real phenomena. Second, (supposed fundamental fact) some finite set of dynamical laws will hold true for our world. Third, (assumption) this set of laws will be Lorentz covariant[11]. Fourth, (corollary) spacetime has a Minkowski geo-

[8] As I have set it up, the entailment only goes one way — but this is all I need for my conclusion. A two-way entailment would be a stronger thesis and I do not see a need to defend it here.

[9] Adopted from Brown (2005) and Brown and Pooley (2001).

[10] Adopted from Balashov and Jansen (2003) and Maudlin (2012).

[11] The Lorentz covariance of the laws of physics requires that said laws will maintain their mathematical form under coordinate transformations. This means, very informally, that any inertial observer will observe any separate inertial observer in relative motion to be experiencing physical laws of the same form but with some varying parameters, and other invariant parameters. In short, Lorentz covariance uses symmetries of our physical laws to define inertial structure.

metry[12]. Finally, it follows that Galilean Relativity and the Light Postulate must be true.[13] If we can show that Lorentz covariance is fundamental *in some sense of the word*, we have the beginnings of an exclusive explanation of SR.

But Minkowskians inverts the assumption and corollary. Third, (assumption) spacetime has a Minkowski geometry. Fourth, (corollary) this set of laws will be Lorentz covariant. If we can show that Minkowski geometry is fundamental *in some sense of the word*, it seems that we have the beginnings of *another* exclusive explanation of SR.

But neither of them has any hope of being more fundamental than the other, *no matter how we define fundamentality.* To show why, I need to introduce the concept of *spacetime functionalism* (Knox 2017). It is the view that all there is to spacetime is the functional role it plays in a theory. Knox's view is that the functional role of spacetime, in SR, is to assign an inertial structure[14] — and so anything that defines the inertial structure *is* spacetime.

It follows that there cannot be an answer as to whether Lorentzianism is more fundamental than Minkowskianism, or vice versa. In virtue of defining the inertial structure, Lorentz covariance entails Minkowski structure. In virtue of defining the inertial structure, Minkowski structure entails Lorentz covariance. And since there is nothing more to spacetime than inertial structure, we may infer the converse entailment as well: the inertial structure of SR entails Lorentz covariance and Minkowski structure. Thus, we have mutual analytic equivalence between the two.

And so one could not possibly be more fundamental than the other, no matter how we define fundamentality. Because fundamentality is at a minimum irreflexive: nothing can be more fundamental than itself. Thus, Lorentz covariance cannot be more fundamental than Minkowski geometry, for it would then have to be more fundamental than itself — a plain impossibility.

I should mention that it is open, in principle, for the joint explanation to constitute an exclusive explanation of SR. This would have as its third premise the conjunction of Lorentz covariance and Minkowski geometry. But given that conjunctions are logically reducible to their conjuncts, I do not see any coherent way of defining fundamentality that could admit of this as an exclusive explanation — each conjunct would

12 The Minkowski structure defines the geometry of spacetime. It tells us that inertial observers will have straight worldlines in four-dimensional spacetime geometry, and that we can define an invariant spacetime interval (ds^2 = (cdt)^2 − dx^2 − dy^2 − dz^2) that all intertial observers will measure to be the same. In short, it uses symmetries of geometry to define inertial structure.

13 Due to a lack of space I have left the argument formally invalid. See Brown and Pooley (2001) and Knox (2017) details.

14 In general the role is to define *local inertial structure*: (roughly speaking) how an object will move through spacetime in the absence of external forces.

necessarily be more fundamental than the conjunction itself.[15]

And so it seems, given spacetime functionalism, that it is not possible to find an exclusive explanation of SR. Therefore, since ought implies can, we ought not find such an exclusive explanation. And since we ought to find a constructive explanation only if we ought to find an exclusive explanation, it follows by modus tollens that we ought not find a constructive explanation of SR. That is, we do not need a constructive explanation of SR, because it does not exist.

It is, of course, open to the reader to reject my conclusion at the cost of rejecting *either* spacetime functionalism *or* that ought implies can. But if the reader is sympathetic to both, they must reject the need for a constructive theory of SR. And they must, like me, consider it quite strange to ask what such a theory might look like — much like a square circle, I assume.

[15] Due to the aforementioned mutual entailment, the same holds for a disjunction of the two.