The paper aims to revisit Reichenbach's interpretation of special relativity, making two different but interrelated claims: (I) Reichenbach's interpretation is best characterized non as a conventionalist interpretation, as is usually argued, but rather an early form of the dynamical interpretation; (II) Reichenbach offers a more robust version of the dynamical interpretation than contemporary accounts. On this basis, the paper argues that Reichenbach's approach provides the conceptual resources to (I) strengthen the dynamical approach against common criticisms from defenders of the geometrical approach, (II) put one's finger on the true weak point of both approaches. Unlike the dynamical approach, special relativity does not require a *specific* theory of matter to explain ether drift experiments; rather, it demands that *any* such theory be Lorentz invariant. Unlike the geometrical approach, Minkowski 's formalism helps test this requirement but lacks explanatory power. The paper concludes that, following Lange, special relativity provides an 'explanation by constraint.'

Reichenbach and the Prehistory of the Dynamical Approach to Special Relativity

Keywords: Hans Reichenbach • Lenght Contraction • Special Relativity • Dynamical Relativity • explanation

Introduction

Harvey **Brown2005**'s (**Brown2005**) book **Brown2005** is widely credited with reshaping the debate on the foundations of space-time theory over the past two decades. Brown argues that special relativity as it stands is incomplete: phenomena like length contraction must ultimately receive a *dynamical explanation* in a fundamental theory of the material structure of rods. Defenders of the traditional view, such as Michel **Janssen2009<empty citation>**, object that special relativity was already completed by Minkowski, who provided a theory of the mathematical structure of spacetime: length contraction receives a *geometrical explanation* from the fact that the world tube of the rod is intersected differently by the hyperplane of simultaneity. Regardless of one's position, it is clear that the discussion surrounding the role of rods and clocks in relativity theory has undergone a fundamental transformation. For a long time, the debate—rooted in logical empiricism—framed the role of rods and clocks in relativity theory in terms of *confirmation*, as a dispute between empiricism and conventionalism. Since Brown's work, the center of gravity has shifted toward the problem of *explanation* of the behavior of rods and clocks, recasting the discussion as a conflict between dynamical and geometrical approaches.

This paper aims to uncover an overlooked chapter in the pre-history of the dynamical approach. It argues that it was the logical empiricist Hans Reichenbach who, already in the 1920s, first to draw the attention to the problem of 'explanation' in spacetime theories. Reichenbach denied the explanatory power to Minkowski spacetime, and insisted that special relativity requires the behavior of rods and clocks to be explained by a specific, though still unknown, theory of matter. The paper seeks to draw renewed attention to this aspect of Reichenbach's interpretation of relativity, which has been largely overlooked.[1] In particular, this paper advances two distinct but interrelated claims:

(a) *historical claim*: Reichenbach's axiomatization of special relativity was not a variant of the conventionalist interpretation paradigmatically articulated by Moritz **Schlick1915<empty citation>**, as is usually argued, but an early variant of the dynamical interpretation.

(a) *systematic claim*: through a careful analysis of both the notion of 'contraction' and the notion of 'explanation,' Reichenbach presents, in many respects, a more

[1] (**Gruenbaum1955Gruenbaum1963a**).

robust version of the dynamical interpretation of special relativity than the contemporary ones.

Building on these two claims, the paper maintains that Reichenbach's work provides the conceptual tools (I) to steel man the dynamical approach against the most common objections; (II) to expose the crack in what seems to be its strongest armor In contrast to the dynamical approach, special relativity does not need to explain the failure of ether drift experiments by *finding* a *specific* Lorentz invariant theory of matter; rather, relativity explains such negative results by *requiring* that *any* possible theory of matter *must* be Lorentz invariant. Minkowski's mathematical apparatus allows one to check directly whether available laws comply with this requirement, but, contrary to the geometrical approach, does not provide any further explanatory contribution. The paper wraps up by arguing that, if one wants to cast the contribution of special relativity relativity in explanatory terms, it is better to speak of an *explanation by constraint*, as suggested by Marc **Lange2016<empty citation>**.

1 The Schlick-Reichenbach Correspondence and Reichenbach's Cautious Conventionalism

Reichenbach's habilitation thesis, **Reichenbach1920a** (**Reichenbach1920a**), appeared in print during the famous 86th meeting of the *Gesellschaft deutscher Naturforscher und Ärzte* in Bad Nauheim (19–25 September), marking the beginning of a politically charged backlash against modern physics in Germany (**Weyl1920**). Schlick, who did not attend the meeting, received the booklet in those days (Schlick to Reichenbach, Sep. 25, 1920; **HR**). Writing to Einstein, he praised it, but complained about Reichenbach's 'Kantian' critique of conventionalism (Schlick to Einstein, Sep. 23, 1920; **CPAE**). Schlick articulated his stance corresponding with Reichenbach himself in the ensuing months (**Oberdan2009**).

In the book, Reichenbach shared with **Schlick1918<empty citation>** the idea that physical knowledge is, ultimately 'coordination' (*Zuordnung*), the process of relating an axiomatically defined mathematical structure to concrete empirical reality (**Padovani2009**). However, Reichenbach attempted to give this insight a 'Kantian' twist. According to Reichenbach, in a physical theory, besides the 'axioms of connections' (*Verknüpfungsaxiome*) encoding the mathematical structure of a theory, one needs a special class of physical principles, the 'axioms of coordination' (*Zuordnungsaxiome*), to ensure the univocal coordination of that structure to reality. For the young Reichenbach, the latter axioms are *a priori* because they are 'constitutive' of the object of a physical theory. However, they are not apodeictic or valid for all time.

Writing to Reichenbach, Schlick objected that, at closer inspection, Reichenbach's coordinating principles where nothing but arbitrary 'conventions' in the sense of Poincaré (Schlick to Reichenbach, Nov. 26, 1920; **HR**). Reichenbach initially opposed some resistance. If the coordinating principles were fully arbitrary, he feared, they would be empirically meaningless. In Poincaré's conventionalism, Reichenbach missed a constraint in "the arbitrariness of the principles [...], if the principles are combined"; Therefore, he concluded "I cannot accept the term 'convention'" (Reichenbach to Schlick, Nov. 26, 1920; **HR**). Schlick replied it would, of course, be unfair to assume that he was unaware of this fact (Schlick to Reichenbach, Dec. 11, 1920; **HR**). Indeed, in January **Schlick1921<empty citation>** mentioned favorably Reichenbach's book in an article for the *Kant-Studien*, but rehearsed in public what he had already explained in private correspondence.

Still, Reichenbach did not seem to have been fully turned on the conventionalist side at this point. Einstein's famous January lecture on 'geometry and experience'—published in March in the Proceedings of the Berlin Academy (**Einstein1921**)—might have been instrumental to bring Reichenbach closer to Schlick's position. Not only did Einstein mentions Schlick's work approvingly, but he also declared that Poincaré was *sub specie aeterni* correct in claiming that so that in principle only geometry plus physics could be compared by experience. In reviewing the book version of Einstein's lecture Schlick could interpret this claim as a confirmation of the form of 'holistic conventionalism' (**Schlick1921a**) that he had attributed to Poincaré and, then, extended to Helmholtz in his edition of the latter's epistemological writings (**Helmholtz1921**). As Reichenbach recognized in his review, one of the merit of the Schlick-edition was to have shown that "Poincaré did not express conventionalism more clearly" than Helmholtz already did (**Reichenbach1921b**).

By September 1921, Reichenbach wrote to Schlick that he considered their difference in opinion as resolved (Reichenbach to Schlick, Sep. 17, 1921; **SN**). He hoped to finally meet Schlick in person in Jena at the meeting of the *Gesellschaft Deutscher Naturforscher und Ärzte*, where he was going to present his project for an axiomatization of special relativity that he had developed in the previous months (Reichenbach to Schlick, Sep. 17, 1921; **SN**). Indeed, when he sent to Schlick the published version of the report (that was published in December), Reichenbach emphasized that his axiomatization "obviously provides a confirmation of conventionalism". However, he also qualified his remark by insisting that "reveals those facts that also conventionalism cannot interpret" (Reichenbach to Schlick, Jan. 18, 1922; **SN**). Reichenbach clarified his position more thoroughly in a long review paper on the philosophical interpretations of relativity, completed around March 1922 (Freundlich to Einstein, Mar. 24, 1922; **CPAE** Einstein to Reichenbach, Mar. 27, 1922; **CPAE**).

By sketching his own interpretation, Reichenbach emphasizes once again that he prefers to *avoid* the term 'conventionalism,' for the following reasons: (1) it does not express, the important Kantian intuition that the non-empirical principles are 'constitutive' for the concept of the object; (2) it overemphasizes the arbitrary nature of the principles of knowledge, while downplaying the fact that their combination is no longer arbitrary (**Reichenbach1922a**). Reichenbach was willing to admit with Schlick that Poincaré would probably acknowledge this point. Nevertheless, Reichenbach still insists that the problem is "not only uncovering the arbitrary principles of knowledge but also determining the entirety of [their] permissible combinations" (**Reichenbach1922a**) Reichenbach presents his axiomatization as the solution to this problem. In particular, he emphasizes that latter was organized around two distinctions:

- *axioms* vs. *definitions*. In this context, 'axiom' means, unlike in mathematics, an observable fact, that has already been experimentally proven or provisionally assumed as an hypothesis. Opposed to the axioms are the 'definitions,' which contain rules for how certain empirical realities are to be assigned to specific mathematical concepts. In particular, according to Reichenbach, Einstein discovered that determining whether two spatially separated events are simultaneous depends on a convention regarding the ratio ϵ of the one-way speeds of light in the round-trip journey between the two events. Since we cannot measure the one-way speed without already having defined simultaneity, Einstein's convention $\epsilon = \frac{1}{2}$ is not ‘more correct’ than any other. The separability of the ‘conventional’ elements of scientific theories (definitions) from the empirical ones (axioms) shows that Poincaréan accommodation empirical findings through changes in conventions is strongly constrained. E.g. the definition the conventions of simultaneity must be ‘univocal’ (independent of prehistory), and this a ‘fact’ (**Reichenbach1922b**)

– *light axioms* vs. *matter axioms.* Light axioms assert only the properties of electromagnetic signals, and matter axioms the properties of material rigid measuring rods and natural clocks. Reichenbach claimed be able to show that a *light geometry* alone can serve as the basis for the measurement of space and time. Whereas in Einstein s original theory of relativity light served merely to determine simultaneity, in Reichenbach’s axiomatization light may be used for all measurements of time intervals and space distances (that can be measured by the time needed for a light signal to travel a certain segment). The advantage of light geometry is that it avoids the definition of the ‘metric’ through material entities such as rigid bodies and clocks; these entities are complexed atomic system, whose behavior presupposes the knowledge of physical laws. In Reichenbach’s axiomatization, the *matter geometry* based on the behavior of rods and clocks are introduced only after the development of the light-geometry in the form of a series of ‘matter axioms.’