MASTER OF ARTS DISSERTATION

Spreading Time Through Space: An Analysis of the Conventionality of Intra-Frame Simultaneity

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ABSTRACT

§1. It is shown that the simultaneity of distant events is taken for granted by some major thinkers, most notably Leibniz and Newton, preceding Einstein. However, in 1905, the STR's examination, and subsequent reconstruction, of this assumption, engendered two types of simultaneity: intra-frame and inter-frame. The former is the focus of this investigation and deals with the simultaneity of distant, yet relatively stationary, events. The latter involves the simultaneity of distant, yet relatively moving, events. Einstein glossed over the former, briefly claiming that distant clocks are synchronized according to a definition. Reichenbach interpreted this as illustrating that the STR supports a conventionalist reading. The synchronization of distant clocks within the same inertial frame is only possible according to a convention. This is known as the conventionality of simultaneity, not to be confused with the relativity of simultaneity which deals with the setting of clocks in different inertial frames. Grünbaum follows Reichenbach's view and argues further that inter-frame relativity of simultaneity must be understood on the basis of intra-frame conventionality of simultaneity.

Whether or not intra-frame simultaneity is conventional is a small, but nonetheless crucial, part of the twentieth-century's corpus of space-time philosophy. Because this literature's breadth is so large, an organizing framework is offered. Grünbaum is then situated in this framework. It is argued that he occupies a middle position between the two major approaches to the philosophy of space-time. This framework and subsequent placement organizes the examination of simultaneity which ensues. Namely, it illustrates that if Grünbaum's position collapses, space-time philosophy does not have a middle ground. It is shown that whether or not Grünbaum's position stands depends on his view of intra-frame simultaneity. Consequently, Grünbaum's defence of the conventionality of simultaneity is the main concern of this investigation.

§2. Reichenbach's a priori, inter-theoretical conventionalism is clearly separated from Grünbaum's a posteriori, intra-theoretical conventionalism. This is done because the two thinkers are often misleadingly equated. They are linked simply because a particular argument, which connects conventionality and light signals, is shared. The moral of this chapter is not only that shared conclusions do not entail shared premises, but more importantly, shared arguments do not entail shared approaches.

The shared argument Grünbaum first uses to demonstrate the conventionality of simultaneity is explicated in detail. By laying the argument out clearly, it will be clear just how Grünbaum modifies his conventionalism when faced by Ellis and Bowman (hereafter, E&B.)

§3. Bridgman, who is the intellectual antecedent of E&B, is briefly examined. E&B's arguments against the conventionality of simultaneity are then considered. They argue that such conventionality violates transitivity when viewed from one inertial frame. They argue that it violates relativity and linearity principles when viewed from more than one inertial frame. Finally, they argue that slow-clock synchrony enables distant clocks to be set uniquely (the setting corresponding to standard signal synchrony). Thus, the conventionality thesis is trivial and should be rejected.

Grünbaum responds by elucidating implicit conventions in all of E&B's arguments. However, in this defence of simultaneity, Grünbaum modifies his earlier view. No longer is it solely based on the limiting speed of light signals; it also incorporates the thesis that the space-time manifold is metrically amorphous. Grünbaum has moved further away from Reichenbach.

Ellis alone responds to Grünbaum charging that latter misunderstood the paper. Ellis ultimately concludes that the difference between himself and Grünbaum rests on the initial positions assumed in the philosophy of science: realism versus conventionalism. In his effort to strengthen the former against the latter, Ellis makes some unfounded charges against Grünbaum.

It is concluded that Grünbaum can defend himself against the charges of Ellis and Bowman.

§4. The latest of Friedman's external attacks on the thesis of the amorphous manifold are considered. They are neither accepted nor rejected, but are ultimately found to be inconclusive. Consequently, Grünbaum's view is at least still plausible.

The main conclusion of the investigation, namely the call for the end of simultaneity experiments, based on chapter three, is further supported.

An internal critique, that of Malament, is then considered. However, this attack, although claiming to be built on Grünbaum's premises, incorporates conventions. Yet, Malament's concerns are shown to force Grünbaum to modify his own position still further.

The examination of Malament's argument leads into a discussion of the relationships between the strengths of assumed primitives, methodological prin iples and possible worlds. These are shown to ultimately involve global and unverifiable propositions. It is argued that decisions in such areas depend upon the theory which is already accepted.

Finally, the results of this entire investigation on the original organizing framework and Grünbaum's position in it are summarized, and some reflections on the philosophy of space-time are offered.

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Abbreviations Used In The Text:

A.D.	:	Action-at-a-distance
ϵ	:	Set inclusion
$\varepsilon=\frac{1}{2}$	:	Standard Signal Synchrony (isotropic light speeds)
$\varepsilon\neq\frac{1}{2}$	:	Non-standard Signal Synchrony (anisotropic)
E&B	:	Ellis and Bowman
GTR	:	The General Theory of Relativity
STR	:	The Special Theory of Relativity
v	:	Velocity (bold print represents vector notation)

CHAPTER ONE: INTRODUCTION

§1.1 Simultaneity: Historical Sketch

R.G. Collingwood noticed that the propositions which we include as facets of belief function as answers to questions. This is not terribly illuminating since it is but another way of saying that our investigation of the world, that is, our asking of questions, gives rise to beliefs. What is interesting, however, as well as relevant to this study, is that these questions themselves always have presuppositions.[1] Eventually, if we keep examining the questions we ask, we reach what Collingwood called an "absolute presupposition."

One question we could pose to Aristotle, Newton and Leibniz, as well as Kant, and always receive the same answer would be: "it is two o'clock here, what time is it over there?" In each case the answer would be: "the same."[2] But if we asked our thinkers what time itself is, a variety of views would be offered. Thus two questions, both dealing with time, receive quite different responses. The point here, and I will further illustrate it with a brief overview of some thinkers, is that they all have a presupposition of global time, or simultaneity. This presupposition is a common thread running throughout the historical fabric of

[1] R.G. Collingwood, *An Autobiography* (London: Oxford University Press, 1967).

[2] This is taking the existence of time zones into account.

expressed views.[3]

As early as Heraclitus the view of time as singular emerged. All events are ordered within this single time. "Time is a child at play, playing draughts; a child's is the kingdom."[4] According to Heraclitus, time is a name for God. There is but one deity, a single order of events to the cosmos. It would be senseless to speak of different orders at all let alone wonder whether two events could be indeterminate with respect to their temporal order.

Aristotle expresses his view of time less poetically. He agrees that there is a single time and explicitly assumes global simultaneity. Time, Aristotle argues, is a measure of motion. Its uniqueness, as well as universality, is expressed by regarding it as a measure of motion in general. He simply tells us that "there is the same time everywhere at once."[5]

There is a tense relationship between time and the world. Aristotle accepts as a basis that "time is neither movement nor independent of movement."[6] Time is both in and out of the world. In essence, it has both a worldly (dependent) and other-worldly (independent) component.

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[3] I say "a common thread" rather than "*the* common thread" since continuity is also common to the history of thoughts on time.

[4] Edward Hussey, *The Pre-Socratics* (New York: Charles Scribner's Sons, 1972) 49.

[5] Aristotle, "Physics", Book IV., 220^b, 1-10, *The Complete Works of Aristotle*, ed. Jonathan Barnes (Princeton: Princeton University Press, 1984) Vol. 2, 373.

[6] Aristotle, "The Physics," Book IV., 219^a, 1. For more information on Aristotle's view of time, *cf.*, Bas C. van Fraassen, *An Introduction to the Philosophy of Time and Space* (New York: Columbia University Press, 1985) 11-20.

The development and eventual emancipation from Aristotle's view of time was a slow process which passed through several centuries. This process came to a head under the mutual influence of philosophical and scientific thought in the sixteenth and seventeenth centuries. This interplay engendered a re-examination of time which led to the fracture of Aristotle's tense relationship between time and the world. However, new views are constructed from particular selections and modifications of the old. Issac Newton emerges as a key thinker in the re-construction of time.

Indeed, Newton did not emerge out of a vacuum, for he appropriates Aristotle's other-worldly component of time. Furthermore, Newton's views on the structure of time are coloured by his physics mentor Issac Barrow and by his theological mentor Henry More.[7] However, because of Newton's enormous influence, he is representative of the early modern reconstruction of temporal theory. To illustrate this reconstruction, Newton writes:

> **Absolute, true, and mathematical time, of itself, and from its own nature, flows equably without relation to anything external...[8]**

In the Principia there is no explanation of what time is: for that,

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[7] For more on Newton's conceptual development, *cf.*, Frank E. Manuel, *A Portrait of Issac Newton* (Cambridge: The Belknap Press of Harvard University Press, 1968). Also *cf.*, Max Jammer's *Concepts of Space* (New York: Harper and Brothers, 1960). For example, in Jammer's text, a dialogue of More's is discussed which contains the prototype of Newton's bucket experiment. Newton's dynamical explanation of this experiment lead him to postulate absolute space and so engenders this particular dispute (since there were many) with Leibniz. This debate over the dynamics of rotational motion is considered crucial to the relationalist-absolutist issue even today, *cf.* John Earman, *World Enough and Space-Time* (Cambridge: The MIT Press, 1989).

[8] Issac Newton, *Sir Issac Newton's Mathematical Principles of Natural Philosophy and His System of the World*, orig. tr. A. Motte (1729), tr. revised by Florian Cajori (Berkeley and Los Angeles: University of California Press, 1966) Vol. 1, 18.

"De Gravitatione" must be consulted.[9] Although fascinating, the views expressed in "De Gravitatione" are not of particular relevance to us since they pertain to the substance of time, whereas the focus of this historical sketch is the structure of time. Newton completely removes time from the world; in other words, he asserts its autonomy by saying that time itself flows, and thus is not a measure of anything.[10] But it is important to notice that Newton still regards time as unitary and, since Newtonian space-time is $E^3 \times \mathbb{R}$,[11] simultaneity remains intact.[12] (When any point in space is assigned a specific time value, all other points are assigned that same value.)

Unlike Newton's selection from Aristotle, Leibniz appropriates Aristotle's connection of time to the physical world. Although Leibniz modifies this connection into a causal nexus, it nonetheless retains the golden thread of simultaneity:

> Time is the universal order of non-contemporaneous things. It is thus the universal

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[9] Newton, "De Gravitatione," *Unpublished Scientific Papers of Issac Newton*, eds. A.R. Hall and M.B. Hall (Cambridge: Cambridge University Press, 1962).

[10] That is, time is not to be thought of as predicated upon a deeper substratum like a wave upon an ocean.

[11] Here E^3 stands for an Euclidean three-space while $\mathbb{R}$ denotes Euclidean one-space or the real number line. The x stands for the Cartesian product.

[12] There is nothing mysterious about the shift from speaking of Newtonian space and time to speaking of Newtonian space-time. All that is involved here is the recognition that to uniquely specify a point we need three spatial coordinates and one temporal. It is important to note that the invariants are the same in either way of talking and thus nothing has changed. For more information on this *cf.* Hans Reichenbach, *The Philosophy of Space and Time* (New York: Dover Publications, 1958) 109-113. Also, Michael Friedman, *Foundations of Space-Time Theories* (Princeton: Princeton University Press, 1983) 34. What I have said above is about the only thing upon which these two thinkers agree.

order of change in which we ignore the specific kind of changes that have occurred.[13]

It is to Leibniz' credit that he was the first major thinker to have attempted to explain (not question) simultaneity. Leibniz defined contemporaneous, or simultaneous, events to be those which are not, and could not be, causally connected.[14] For Leibniz, simultaneity is an equivalence relation which partitions the universe's events into equivalence classes. The abstract order of these classes is time. In other words, temporal order is predicated on causal order. Nevertheless, Leibniz harbours no doubt that there is absolute simultaneity; hence, he joins Aristotle and Newton in simply presuming its truth.[15] This presumption nicely illustrates a basic structure of discourse: in order for people to argue about a topic, something must be held in common --and in the Leibniz-Clarke debate this "something" was simultaneity. It was never questioned by either side.

The next major thinker who attempts to combine these views (although he clearly did not resurrect Aristotelianism), is Kant. Unquestionably, it is Kant to whom Einstein refers when he says that philosophers hinder the progress of scientific thinking when

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[13] G.W.F. von Leibniz, "Metaphysical Foundations of Mathematics," in *Leibniz: Selections*, ed. P.P. Wiener (New York: Charles Scribner's Sons, 1951) 202.

[14] G.W.F. Leibniz, "Metaphysical Foundations of Mathematics," 201-202.

[15] Although the later Leibniz came to regard space and time as ideal continua devoid of any internal partitions (anticipating Riemann's view of the non-intrinsical nature of the metric), he never abandoned his notion of a global time and so would not have jettisoned simultaneity. For more information on the later Leibniz cf., G.A. Hartz and C.A. Cover, "Space and Time in the Leibnizian Metaphysic," *Nous*, Vol. 22, #4, 493-519. For more information on Leibniz' causal theory of time and its difficulties cf., John Winnie, "The Causal Theory of Space-Time," *Minnesota Studies in the Philosophy of Science*, Vol 8, Section 2, *Foundations of Space-Time Theories*.

they wrest concepts from under mental control, that is, the empirical domain, and place the mind under conceptual control. This reversal of roles is achieved by boosting concepts to "the intangible heights of the a priori."[16] Kant tries to provide metaphysical and epistemological grounds for Newtonian physics. Furthermore, he thinks that Newtonian mechanics serves as a type of concrete model of his own transcendental philosophy.[17] Thus, in particular, the Newtonian view of time is not a contingent empirical truth, but a transcendental ideal one. On the one hand, as with Leibniz, time is no longer something in addition to the world. Yet on the other, as with Newton, time is absolute; it is not to be reduced to any other type of order. Time is under the rubric, "pure intuition," and is "the formal a priori condition of all appearances whatsoever."[18] For Kant, time, even more than space, is the foundation of the possibility of experience. In the final analysis, simultaneity is firmly entrenched in thought since it is now regarded as a necessary component in the construction of a coherent world picture.[19]

Because of the impressive empirical success of Newtonianism

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[16] Albert Einstein, *The Meaning of Relativity*, (Princeton: Princeton University Press, 1988) 5th edition, 2.

[17] Immanuel Kant, *The Metaphysical Foundations of Natural Science*, tr. J. Ellington (New York: Bobbs-Merill, 1970) 23.

[18] Kant, *Critique of Pure Reason*, tr. Norman Kemp Smith (New York: St. Martin's Press, 1965) 77.

[19] For more detail on Kant's view of simultaneity *cf.*, Kant's *Critique* as well as H.J. Paxton, *Kant's Metaphysic of Experience* (London: George Allen and Unwin Ltd., 1964) Vol 2, 294-329. Also, van Fraassen's *An Introduction to the Philosophy of Time and Space*, 44-52.

and the enduring philosophical ascendence of Kantianism, simultaneity became a silent structure in the dreams of our dogmatic slumbers. Even Riemann, who anticipated Einstein in many ways with respect to the nature of space and geometry, never so much as even mentions the problem of time.[20] The questioning of the oneness of time, of simultaneity, does not emerge until the late nineteenth century in the work of H.A. Lorentz. While trying to extend the principle of relativity to electromagnetic phenomena via the contraction hypothesis, he noticed that an unusual assumption was needed: "a new time must be used in a system which is moving uniformly."[21] This new time he calls "local time." But Lorentz does not abandon his belief in an absolute or global time.

§1.2 Simultaneity: Albert Einstein

From the preceding section it is easy to see why Einstein writes that the "axiom of the absolute character of time, viz., of simultaneity, unrecognizably was anchored in the subconscious."[22] But Einstein, as Putnam rightly notes, never regarded small-scale simultaneity as problematic. Objects close together or moving at small relative speeds are still describable in everyday terms. As Putnam writes: "(i)n short, when Einstein asserted that we have to

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[20] *cf*, Riemann's dissertation "On the Hypotheses which Lie at the Foundations of Geometry," tr. H.S. White, *A Source Book in Mathematics*, ed. D.E. Smith (New York: McGraw Hill Book Co. Inc., 1973).

[21] Max Born, *Einstein's Theory of Relativity* (New York: Dover Publications, 1962) 222.

[22] A. Einstein "Autobiographical Notes," *Albert Einstein: Philosopher-Scientist*, ed., P. Schlipp (New York: Tudor Publishing Co., 1949) 53.

define simultaneity and not assert it, what he meant was that we have to repair an inconsistent notion, not throw it away altogether."[23]

When the absolute nature of time was presupposed, there was no difference between the times ascribed to "stationary" and arbitrarily "moving" frames of reference.[24] However, the situation becomes more complicated with the STR since the distinction between intra-frame and inter-frame simultaneity now arises. This investigation is concerned with simply the notion of intra-frame simultaneity.

Einstein begins his 1905 paper by laying down a simple definition of time.[25] When time plays a role in our judgments, these judgments always involve the notion of simultaneity. Einstein tries to prevent our subjective awareness of time from blocking theoretical access to it. The spirit of his approach is Copernican: we must separate our theories from our direct experiences. The test of the former is how well they explain the latter.

"Time," Einstein says, is to be substituted with "the position of the small hand of my watch."[26] That is, talk of time can be replaced with descriptions of the small hand's position. This

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[23] Hilary Putnam, "An Examination of Grünbaum's Philosophy of Geometry," in *Mathematics, Matter and Method* (Cambridge: Cambridge University Press, 1979) Vol.1, 2nd edition, 115.

[24] The term "frame" simply means a "coordinate system." For more information *cf.*, Reichenbach and Friedman in their respective texts previously cited in footnote 10.

[25] The full title of the paper is "On the Electrodynamics of Moving Bodies," *The Principle of Relativity* (Toronto: General Publishing Company, 1952).

[26] Einstein, "On the Electrodynamics of Moving Bodies," 38.

definition of time is not problematic as long as the events are spatially close. To talk of the time of an event which is distant from a clock engenders questions.

To begin, we may now ask: "what is a clock?" By definition, a clock is an instrument which measures duration, or the quantity of time elapsed. Employing an operationalist formulation allows the escape from begging any questions about the metaphysics of time as well as the complicated problems of the phenomenology of time. In essence, a clock counts periods. Periods are recognized by the return of a system to a previous state. For example, the period of a pendulum is simply the time taken for the bob to return to a given position. If the bob can return n times while an event happens, we say the event is n units long. In the case of the watch, the small hand keeps track of the number of periods for us and thus spares us the trouble of counting them. This concept of counting periods is not the only way to keep time, but at least it is not reducible to spatial comparisons.[27] Counting periodic processes is the method of modern time-keeping which employs atomic clocks.

However, from the above definition of time, we have only time in the neighbourhood of a watch. Unfortunately, the "immediate neighbourhood of a watch" is a vague predicate which Einstein does not explain but assumes as a primitive. Indeed, he tells us quickly in a footnote that the inexactitude lurking in the simultaneity of

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[27] For more on clocks *cf.* Reichenbach's *Philosophy of Space and Time*, 114-115 and van Fraassen's *An Introduction to the Philosophy of Time and Space*, 156-157.

nearly coincident points "can only be removed by an abstraction."[28] This parochial consideration allows him to move on. Hence we have only time at A and time at B but no common time for A and B. However, Einstein's next assertion, again seemingly innocuous, sparks a huge debate over the interpretation of relativity theory. He says that this common time "cannot be defined at all unless we establish by definition that the time required by light to travel from A to B equals the time it requires to travel from B to A."[29]

It is important to notice that this does not involve different inertial frames, but simply spatial separation. Suppose we send a signal from A at time t_{A1} and B receives it, according to B's clock at t_{B2}. Suppose further that B reflects this signal back to A which receives it at t_{A3}. The definition now says that:

$$t_{B2} - t_{A1} = t_{A3} - t_{B2} \qquad (1)$$

If we rearrange (1) we can write the time t_{B2} in terms of the average of the times read off A's clock:

$$t_{B2} = \tfrac{1}{2} [t_{A3} + t_{A1}] \qquad (2)$$

We have then the following question: if (1) is simply a definition, does it follow that calculating B's time is also simply a definition? If so, simultaneity of distant events is simply a choice since we could calculate B's time in a different way by replacing the constant in (2) with another number.

The above encapsulates the issue of intra-frame simultaneity.

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[28] **Einstein, "On the Electrodynamics of Moving Bodies," 39.**

[29] **Einstein, "On the Electrodynamics of Moving Bodies," 40.**

(In intra-frame simultaneity, relations of simultaneity between clocks at rest within one inertial frame are examined. In inter-frame simultaneity, relations of simultaneity between clocks at rest with respect to different inertial frames are examined. The clocks in the latter are in relative, uniform, motion.) To agree that the constant above is simply chosen is to embrace conventionalism. This is the position of Reichenbach and Grünbaum. Other philosophers argue that it is not a case of simply choosing; rather, there are good physical reasons for determining B's time via equation (2). The question of simultaneity and the interpretation of it has engendered different interpretations of the theory of relativity along relationalist and absolutist lines. Consequently, this question needs to be investigated carefully and should not be dismissed on the basis of its apparent simplicity.

Grünbaum is of primary interest in this study. The next task is to illustrate one way of organizing the absolutist-relationalist debate and where he should be located.

§1.3 The Absolutist-Relationalist Debate: The Twentieth Century

The absolutist-relationalist debate is difficult to characterize. Not only do the mathematical developments of the nineteenth century and the emergence of a possible physical realization of these mathematical structures in the twentieth open the doors to a variety of positions hitherto unknown, but historically perplexing questions of philosophy are also involved. To say that the debate over space and time concerns whether they are real or not immediately engenders the difficult metaphysical question of "what is real?" Circumventing this question by using the parochial boundaries of everyday language, we can say that Newton is a realist and Leibniz is not. This simply means that, for Newton, space and time are part of the ontological furniture of the world; they are just as real as the bodies which are within them. Alternatively, Leibniz argues that talk of space and time is simply elliptical for talk of relations between bodies. All space-time talk can be reduced to the latter. Furthermore, it can be argued that Einstein would be under the banner of Leibniz since in Einstein's writings a wish for just such a reduction can be found.[30]

On the other hand, the debate can be organized, following Arthur Fine, as one dealing with the approach to space and time.[31] The absolutist view is characterized by regarding the entire question of space and time as within the boundaries of physics. Geometry and physics are intertwined. Essentially, this is a Duhemian view. Newton and Leibniz are still opposed, but now Einstein goes over to the absolutist camp. Einstein regarded physics as a general investigation of our world and so would

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[30] For an interesting re-examination with respect to realist issues in the Newton-Leibniz debate in order to determine what they did --and did not-- agree upon, *cf.*, Earman, "Was Leibniz a Relationalist?" *Studies in Metaphysics*, eds. P. Fench and H. Wettstein, *Midwest Studies in Philosophy*, Vol 4 (Minneapolis: University of Minnesota Press, 1979). For Einstein's Leibnizian views *cf.* "Relativity and the Problem of Space" *Ideas and Opinions of Einstein* (New York: Crown Publishers, Inc.,1959) 375-376.

[31] Arthur Fine, "Reflections on a Relational Theory of Space," *Space, Time and Geometry*, ed. P. Suppes, (Dordrecht: Reidel, 1973) 235-237.

include geometry within its domain. The relationalist view is that there is a domain of questions dealing with space and time separate from that of physics.

Fine's organization in general is advantageous for it can avoid having to first answer the probably unanswerable questions of metaphysics. But in particular it suffers from a defect. Fine's framework would place Reichenbach in the absolutist camp along with someone like Friedman who flatly rejects Reichenbach's conventionalism. Reichenbach argues forcefully that our investigation into space and time must proceed solely through science.[32] Hence, I suggest a modification of Fine's organization. In light of what has happened and is happening in the space-time debate, it is profitable to look at approaches in mereological terms. What is going to determine the structure of space-time, the very large or the very small? How does the whole relate to the parts? This whole-part issue will be shown to apply to primitives and methodological principles in the final chapter.

From Riemann comes the view that action-at-a-distance (hereafter: a.d.) must be eradicated from geometry. Historically, a.d. is entrenched in geometry by Euclid's view that we can assume distant congruency of lengths. In addition, translation of lengths is not problematic since they are preserved under transport. Furthermore, it is assumed that the lengths of straight lines can be immediately given. Prior to Riemann, it was assumed that only

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[32] cf. Reichenbach, "The Philosophical Significance of Relativity," *Albert Einstein: Philosopher-Scientist*, 310.

curved segments need be integrated over in order to ascribe them a length. Riemann asserted that all questions of length must begin with the infinitesimal domain. In fact, all investigations in geometry must begin in the infinitesimal domain. In essence, what was regarded to hold without question over finite transport (for example, length), is now restricted to hold only for infinitesimal transport.

Taking such considerations seriously, I modify Fine's framework as follows: the space-time debate is to be organised in terms of inductive and deductive approaches. Both approaches agree that comparisons made between distant lengths is a non-trivial issue. However, they part company when it comes to dealing with this issue.

The deductive view eliminates a.d. by assuming a space-time manifold, defining relations on this manifold between infinitesimally near points, and then using integration techniques to express relations between finitely separated points on the manifold. A theory is then found to fit this mathematical structure. The theory is then engaged in empirical tests. It is important to note that this is not automatically a realist position with respect to the manifold. We may simply regard the mathematical structure as a useful instrument and nothing more.[33]

Starting with observable quantities, such as clocks and rods,

[33] For more information on this approach, *cf.* James L. Anderson, *Principles of Relativity Physics* (New York and London: Academic Press, 1967) 127-128. Anderson explicitly says that the question of the independent existence of space-time does not interest him. Indeed, many physicists operate in such a fashion. Roger Penrose is another example.

measurements are made, and then a theory to accommodate these measurements is constructed. This is the essence of the inductive approach. To eliminate a.d., one assumes that any distortions occurring in the transported clocks and rods are products of a universal force, in other words, a force which affects all objects in the same manner. It cannot be determined by clocks and rods and so can be set to zero. This is not automatically an anti-realist position. As we shall see in the next chapter, much rides on the interpretation of these universal forces.

Weyl and Reichenbach are the founders of the absolutist/deductive and relationalist/inductive camps respectively. Modifications within each camp have ensued, but the main point here is that soon after relativity theory appeared, two main lines of its interpretation, as well as the approach to the problems of space and time in general, were presented.

Einstein seems to start off in the inductive camp, but in later years moves to the other.[34] Unfortunately, Einstein often expressed himself in conflicting terms and thus it is very difficult to say what he honestly thought. Consequently, Holton quite rightly says that, because of his vacillations, all thinkers can "find some part of Einstein's work to nail to his mast as a battle flag against the others."[35]

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[34] For an excellent discussion of Einstein's epistemological and ontological views and the difficulty of interpreting them *cf.*, Robert Neidorf, "Is Einstein a Positivist?" in *Philosophy of Science*, 30, 1963.

[35] G. Holton, "On the Origins of Special Relativity," *American Journal of Physics*, Vol 28, 1960, 627.

Weyl's resistance to using clocks and rods to determine space-time structure stems from his view that these are complex systems of which our knowledge is quite minimal. Although they may indicate or adjust to fields, they should not be used to define them.

Weyl argued that space-time was a real entity. Although his views on the metric are obscure, he is clearly anti-conventionalist with respect to the affine manifold.[36] Weyl knew that every manifold was alternatively connectable; nonetheless, he insisted that some manifolds selected a particular connection from the logically possible set.[37] In the manifold of nature, the affine manifold, or, as Weyl calls it, "the guiding field," since it is a series of inertial trajectories on the space-time manifold, is something physically real. Furthermore, he does argue that it is ontologically distinct from the mass-distribution:

> The guiding field is (very slightly) disturbed by matter, just as the surface of a lake is disturbed by steamships cruising on it; it will go over into the undisturbed state described by the special theory of relativity when all matter disappears, as the surface of a lake becomes a smooth homogeneous plane when the ships ride at anchor.[38]

He also wanted to remove all traces of Euclideanism from geometry, or, "comparison-at-a-distance," whether we are comparing parallelism or congruence. Weyl argued that path independence of congruence was only applicable to the infinitesimal domain.

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[36] H. Weyl, *Space-Time-Matter*, tr. H.L. Brose (New York: Dover, 1952) 4th edition, 221.

[37] For more on Weyl *cf.*, J.A. Coffa, "Elective Affinities: Weyl and Reichenbach," *Hans Reichenbach: Logical Empiricist*, ed. Wesley Salmon (Dordrecht: Holland, 1979). Also *cf.*, Weyl, *Space-Time-Matter*.

[38] Weyl, *Philosophy of Mathematics and Natural Science*, tr. Olaf Helmer (Princeton: Princeton University Press, 1949) 106.

Riemann's work, which follows Weyl's general principle of "gaining knowledge of the external world from the behaviour of its infinitesimal parts,"[39] nonetheless does not follow it thoroughly, for it only goes "half-way towards attaining the ideal of a purely infinitesimal geometry."[40] Weyl argues that there is no a priori reason to assume that lengths (or anything for that matter) are preserved under transport. He argues that influences under transport "can be found only by starting from the physical laws that hold, i.e. from the principle of action."[41] This principle holds only in the infinitesimal domain.

Weyl's struggle to remove Euclideanism from geometry may have been successful, but the Pythagorean theorem remains at the heart of infinitesimal geometry. This is because the metric of the infinitesimal domain is assumed to be given by the Pythagorean relationship. Riemann sheared Euclid off the hydra of Greek mathematics and Weyl sealed the neck ensuring a victory in this battle. However, they may have lost the war since the head of Pythagoras rears up in the infinitesimally small.

Reichenbach, on the other hand, was a conventionalist both with respect to the metric and the affine connection. It can be argued that his conventionalism ran through his views of topology

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[39] Weyl, *Space-Time-Matter*, 92.

[40] Weyl, *Space-Time-Matter*, 102.

[41] Weyl, *Space-Time-Matter*, 309.

as well since he held that it, too, was not absolute.[42] For Reichenbach, statements about a manifold only take on truth values after a coordinate definition has been given.[43] Hence, what counts as a parallel displacement on a manifold will be determined by these definitions. Consequently, so too will the affine structure. In effect, Mother Nature does not choose her geodesics, we do.

The problems of rods and clocks are not problems at all. Universal forces, those that produce the same distortions under transport regardless of the material composition of the moved object, are not detectable by any means. Thus, by a verificationist epistemology, hypothesizing them is meaningless and can simply be set to zero. Therefore, Reichenbach would say that "comparison-at-a-distance" is not anything with empirical content; it does not need an explanation, simply a definition. According to Reichenbach, Weyl's infinitesimal approach puts the cart before the horse.

Grünbaum fits into the Weyl-Reichenbach dichotomy as follows: like Weyl, he speaks of the existence of the space-time continuum as a collection of points. Furthermore, he argues against conventionalism as applied to the continuity of this entity. Continuity for Grünbaum has an empirical status. Suppose we argue

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[42] In section 12 of *The Philosophy of Space and Time* he writes that "we assume a topology that leads to normal causal laws. Only in this way does the question about the topology become a well-constituted question." (80) Causal anomalies, according to Reichenbach, would be detected inductively at the experiential level of the physicist.

[43] As a matter of fact this is the key thing that we have learned from relativity according to Reichenbach. Consider, as he writes in section 4 of *The Philosophy of Space and Time*, "(t)he philosophical significance of the theory of relativity consists in the fact that it has demonstrated the necessity for metrical coordinative definitions where empirical relations had previously been assumed." (15)

against him claiming there are no empirical grounds for choosing a geometry which postulates continuous intervals as opposed to one which posits non-continuous ones. Rather, the acceptance of the former over the latter follows from arithmetic considerations only. Topology has no special status.

Grünbaum does consider this type of argument and agrees that on the basis of measuring rods we cannot ascertain the continuity of space. However, he argues that continuity should be regarded as a "broadly inductive physical framework-principle of physical geometry."[44] To help support his view of the non-conventionality of topology he employs what he calls the "acid test of conventionality." This test determines whether or not a given property may be abandoned and yet a theory with the same empirical fit may still be constructed:

> **Upon applying this test, what do we find? No mathematically discontinuous alternative set of theories have been shown to be as viable as those which are based on the continuum by demonstrating that these two kinds of theories must be, *in principle*, empirically indistinguishable from one another.[45]**

Grünbaum admits that absence of evidence is not evidence of absence; therefore, the fact that, at the present time, there is not a viable non-continuous alternative does not entail that there is not one at all. Consequently, it remains possible -despite Grünbaum, Weyl[46] and Einstein's[47] opinion of atomistic time as

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[44] Adolph Grünbaum, *Philosophical Problems of Space and Time* (Dordrecht: Reidel, 1973) 2nd edition revised and expanded, 335.

[45] Grünbaum, *Philosophical Problems of Space and Time*, 335-336.

[46] Weyl, *Philosophy of Mathematics and Natural Science*, 43

unintelligible- that just such a view may be constructed.[48]

The continuity of the manifold is a necessary condition of the metric's absence in Grünbaum's views on space and time. Therefore, he is also like Weyl in that the infinitesimal structure does explain finite results. However, to go beyond asserting the topological property of continuity to space-time is where Grünbaum and Weyl part company. Grünbaum agrees with Reichenbach that the affine structure, as well as the metric, is conventional. But the affinity between Grünbaum and Reichenbach lies in some of their conclusions, not premises. Because Grünbaum does have ontological considerations in his arrival at the conventionality of congruence, he is susceptible to empirical results.

§1.4 The Problem: Grünbaum's Situation

The debate over the conventionality of the metric of space-time is a large one. What I wish to examine here is a smaller, but, as we shall see, closely connected matter: the debate over the conventionality of simultaneity. I will show how this debate ties into the larger one. Furthermore, I will examine this debate within the context of special relativity.

Grünbaum maintains that the STR rests on a relationalist view of space and time. Prior to the construction of a coordinate

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[47] Einstein, *The Meaning of Relativity*, 165-166.

[48] Taking the risk of being drawn down Feynman's drain when asking "how can the world be like that?" on the basis of quantum mechanics, the results of the Stern-Gerlach experiment do suggest that space may be quantized. For more on this experiment *cf.*, R.I.G. Hughes, *The Structure and Interpretation of Quantum Mechanics* (Cambridge: Harvard University Press, 1989) 1-8.

system, it is the physical objects and events which are used to define points and instants. From this definition, one can construct a system within which other objects and events can be located. The more important issue I will examine here is Grünbaum's view of time. He says that the STR also rests on the existence of temporal relations between non-coinciding objects being a function of some physical relation between these events. Consequently, if there is no physical relation between two events, they are not connectable. Hence nothing should be said about their temporal order. Grünbaum writes:

> In brief, Einstein's innovation is that the physical relatedness which makes for the very existence of the temporal order has a structure that precludes the existence of objectively and uniquely obtaining relations of metrical simultaneity. Thus, the failure of our measuring operations to disclose relations of absolute simultaneity is only the epistemic consequence of the fact that these relations do not exist.[49]

Clearly, if a method could be devised which establishes simultaneity between two distant events then not only would Grünbaum's conventionalism fail but his limited realism that endorses only a topological structure would be jeopardized as well. If distant simultaneity were known, a method to establish congruences of distant intervals could be constructed. Finally, if conventionality of intra-frame simultaneity fails, Grünbaum's view of inter-frame simultaneity collapses as well. Consider Grünbaum's connection of the two types of simultaneity:

> The resulting conventionality of metrical simultaneity does furnish the logical framework within which the *relativity* of simultaneity as between relatively moving

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[49] Grünbaum "Reply to Hilary Putnam's 'An Examination of Grünbaum's Philosophy of Geometry,'" *Geometry and Chronometry in Philosophical Perspective* (Minneapolis: University of Minnesota Press, 1968) 93.

inertial system can first be understood.[50]

Ellis and Bowman argue that they have such a method, the synchronization of clocks by slow-clock synchrony. They argue that their method can reduce the conventionality of simultaneity to a trivial result.

The outline of my project is as follows: chapter two will begin with the separation of Reichenbach's verificationist conventionalism from Grünbaum's bridled conventionalism. This distinction is important since the two views are often spoken about interchangeably, and this conflation is very misleading. The chapter will conclude with an explication of Grünbaum's early position on simultaneity which provides background for illustrating how his view shifts in later discussions.

Chapter three commences with an explication of what Ellis and Bowman call slow-clock synchrony and how it supposedly refutes (or at least trivializes) the conventionality of simultaneity thesis. Then there will be an examination of Grünbaum's response. Finally, Ellis' reply will be considered. I will argue that Grünbaum can defend himself against Ellis and Bowman. But, as we shall see in detail, this defence relies intimately on his view of the metrically amorphous nature of the space-time manifold as well as fundamental epistemological attitudes towards explanation.

The final chapter will begin with some possible extrinsic attacks on Grünbaum. In particular, I will examine some objections

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50 Grünbaum, "Reply to Hilary Putnam's 'An Examination of Grünbaum's Philosophy of Geometry,'" 93.

to his view of the metric. In essence, I will argue that the status of the metric is still an unresolved issue. Then I will offer what I think to be the main conclusion we should draw with respect to simultaneity experiments. This conclusion is the moral of §3 and further support will be offered. This will lead me into examining a very different, that is, an intrinsic, type of attack on the conventionality thesis led by David Malament. The unearthing of the metaphysical presuppositions of Malament's argument will help support my view of simultaneity experiments by showing the intimate connection between primitives, methodological principles and the possible worlds entailed by accepted theories. In addition, I will examine how Malament's argument affects Grünbaum and what the latter would have to do to defend his position. The ultimate point of this entire investigation into simultaneity is to reveal that the positions taken with respect to such a simple topic as intra-frame simultaneity lead very quickly, and very deeply, into metaphysics and epistemology of science.

CHAPTER TWO: CONVENTIONALISM AND SIMULTANEITY

§2.1 Conventionalism: Reichenbach and Grünbaum[1]

From Augustine's eventual converging of the city of man with the city of God, through Vico's view of repetitive patterns, and on to the emergence of the Hegelian Absolute, the search for a pattern in history dominates the thought of many Western philosophers. We can find a pattern of relationships between philosophy and science that plays itself out in Kant-Newton and Reichenbach-Einstein. As outlined earlier, Kant, in a sense, regarded Newton's mechanics as a realization of the critical philosophy. Reichenbach, too, regarded Einstein's theories as a type of model of his epistemological discoveries.[2]

While Kant transformed Newton's space and time into pure a priori intuitions, Reichenbach thought that Einstein's space-time illustrated the a priori character of coordinate definitions.[3] Like Kant, Reichenbach argues that there are a priori conditions of the possibility of science. Unlike Kant, Reichenbach's a priori conditions are not previously fixed but are arbitrarily chosen. However, once chosen, they become the rigid framework upon which incoming data is organized. Reichenbach's attack on a priorism is not against it per se, but against Kant's a priori view of

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[1] This particular section develops ideas in Laurent A. Beauregard's article, "Reichenbach and Conventionalism," *Hans Reichenbach: Logical Empiricist*, 305-320.

[2] *cf.* Reichenbach, "The Philosophical Significance of Relativity," 295, where he refers to relativity theory as the model case of his theory of equivalent descriptions.

[3] Reichenbach, *Philosophy of Space and Time*, 176-177.

Euclidean geometry and causality, since possible experiences which would entail contradictions between these categories can be constructed. Hence, they cannot both be a priori. Nothing bears this property unless we say so. But, the fact remains that according to Reichenbach we must choose certain principles and so build a framework which is then treated as a priori. This framework is immune to empirical refutation.[4] This privileged status is because the conventionalism of Reichenbach (which differs from Grünbaum's) arises out of logical considerations.

Berkeley tells us that esse est percipi, and Reichenbach would essentially agree; however, this so-called agreement needs to be qualified. In his work on quantum theory, Reichenbach argues that whatever unobserved objects do is unknown to us.[5] Whether they exist as usual, lapse into nothingness, or mutate in various ways, is something we are logically prohibited from knowing. Consequently, we must employ what Reichenbach called an "extensional rule." In this case the rule says that "unobserved objects behave as observed ones." Reichenbach agrees with Berkeley that it is not necessary to postulate external objects, but emphatically disagrees with the latter's attempt to locate all within the mind. Furthermore, for Reichenbach, it is most probably -but not necessarily- business as usual with unobserved objects.

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[4] For more detail on the similarities and differences between Kant and Reichenbach cf., Friedman's *Foundations of Space-Time Theories*, chapter 1.

[5] Reichenbach, *Philosophic Foundations of Quantum Mechanics* (Berkeley and Los Angeles: University of California Press, 1948) section 5.

Thus, how we talk of these unobserved objects is the product of a convention.

Analogously, Reichenbach adopts conventionalism with respect to spatial and temporal talk. Is the standard metre in Paris really a metre? This question cannot be answered by more refined measuring techniques since the bar in the vault is arbitrarily defined as the metre. There is no ontological property "...is a metre." Does the length of a rod change in transport? Again, no measuring techniques will tell us. If our measuring rods change over distance as well, all we know is that a rod at position P_1 has length X and it has length X at P_2. We cannot infer anything further so we <u>define</u> the length of the rod at both positions to be the same. In the domain of space and time the conventionalism stems from the fact that it is logically impossible either to compare distant lengths or different periods.[6] The same approach applies to measuring lengths of moving bodies as well as defining when something is at rest.[7]

We may argue that this problem of measurement is an empirical impossibility since it is physically impossible to compare the separated rods at once. But the point still stands: performing more and more technically sophisticated experiments does not circumvent these concerns. Some will simply argue that these are trivial concerns and it really does not matter whether or not they can be circumvented. This we shall see more of in §3.

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[6] **Reichenbach, *Philosophy of Space and Time*, 29 (for lengths) and 116 (for periods).**

[7] **Reichenbach, *Philosophy of Space and Time*, 219.**

The conventionality of simultaneity arises for Reichenbach via the same type of issue, that is, logical impossibility of verification. Consider the heart of his argument with respect to intra-frame simultaneity:

> **To determine the simultaneity of distant events we need to know a velocity, and to measure a velocity we require knowledge of the simultaneity of distant events. The occurrence of this circularity proves that simultaneity is not a matter of knowledge, but of a coordinative definition, since the logical circle shows that a knowledge of simultaneity is impossible in principle.[8]**

The impossibility of comparison-at-a-distance, whether in space or in time, is the life-blood of Reichenbachian conventionalism. Because this is a logical problem, he thinks, nothing more need be said. Relativity theory merely illustrates this epistemological result by providing instantiations of conventionalism in action. Consequently, it comes as no surprise that Reichenbach frequently insists that his epistemological results stand even if relativity theory falls.[9] Thus, there is an even stronger sense to Reichenbach's a priori than Kant's since Reichenbach's model could collapse without crippling his epistemology. It is extremely doubtful whether Newtonian physics could tilt at windmills without severely damaging Kant's epistemology.[10]

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[8] **Reichenbach, *The Philosophy of Space and Time*, 126-127.**

[9] ***cf.* Reichenbach, *The Philosophy of Space and Time*, 15, 133, 176, 177. Also, Reichenbach insists that the problems of space and time are not unique. Conventionalism is a universal characteristic of all human knowledge. (288)**

[10] **Kant's forms of pure intuition have only Euclidean content. Furthermore, Kant regards mathematics without an application as meaningless. Were Newton's Euclidean model to collapse, we would be unable to construct a meaningful representation of the world. On the other hand, Reichenbach's necessary coordinate definitions have no content whatsoever. Were Einstein's**

Grünbaum wants to avoid verificationism.[11] He does not subscribe to general conventionalism, but only conventionalism within a theory. In essence, Grünbaum endorses less holism than Reichenbach; each theory must be investigated on its own as to if, and where, the fact-convention line should be drawn. Consequently, he rejects both the thesis that the fact-convention line can never be drawn, and the thesis that the line is ubiquitous within human knowledge. Grünbaum considers both theses as far too general.

The problem of comparison-at-a-distance also arises for Grünbaum. However, he wishes to explain it by a physical theory rather than simply leaving it as a logical problem. Conventions for distant spatial and temporal measurements are needed because space-time is asserted to be a smooth continuous manifold. Continuous manifolds, according to the early, cloudy intuitions of Riemann and the later, more clarified thoughts of Cantor, possess no intrinsic metric. (Cantor distinguished between dense, non-denumerable manifolds and dense, denumerable manifolds whereas Riemann did not.) Two separated intervals are ascribed lengths only by the introduction of an external metric. This is because the cardinalities of the continuum-slices are the same, thus, whether or not they are to be called "the same length" is a convention. The

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Riemannian model to collapse, we would still be able to construct a meaningful representation of the world.

[11] **Grünbaum, speaking in Thomistic parlance, regards verificationism as a conflation of the order of knowing with the order of being. For his attack on verificationism, *cf.*, "Operationalism and Relativity," *The Validation of Scientific Theories*, ed. Phillip G. Frank (Boston: The Beacon Press, 1956) 84-94.**

conclusions, then, are the same as Reichenbach's, but clearly the approach is not.

Grünbaum tries to clean up Reichenbach's metaphors.[12] In The Philosophy of Space and Time, Reichenbach spoke of distortions in the length of transported rods by universal forces. Grünbaum says that we should not impose a literal interpretation on these forces since all talk of length alteration is predicated on the existence of an intrinsic metric, which as we have seen, Grünbaum rejects. If we say that a rod at space-time location A is of length X, what are we really saying? According to Grünbaum, we are saying that according to our imposed metric, the distance between the endpoints of A is X. To speak of the rod's length distorting under transport due to universal forces should be interpreted as simply replacing one imposed metric for another.[13] There is no "objective length" to the rod in the first place; hence, there is no "objective change in length" under transport. Consequently, we should not think of a real physical force inducing distortions in objects.

In general, to focus the split between the two thinkers, consider Grünbaum's remarks:

> **_With respect to particular physical theories_, I asserted in earlier writings the conventional status of congruence in space, time and space-time, and of simultaneity. It has been mistakenly thought that these particular claims of mine can be construed as mere instance --pertaining to the particular theoretical terms "spatially congruent", "temporally congruent", "spatio-temporally congruent", and "distantly simultaneous"--**

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[12] "Clean up" itself is metaphorical for "shift from verificationist lines." As we shall see, Grünbaum wants to give an ontological grounding for why Reichenbach should be read as saying universal forces are metaphors. This may ultimately be a more philosophically satisfying way to read Reichenbach, since it divests him of problems with verificationism; however,I doubt that Reichenbach himself intended his work to be read in this way.

[13] Grünbaum, *Philosophical Problems of Space and Time*, 84-85.

> of a quite *general* thesis which *some* philosophers have asserted alike for any and *every* theoretical term and for *every* physical theory. [But] ...I would *deny* the conventionality of the corresponding ascriptions of congruence and simultaneity, *if certain other* physical theories were held to be true.[14]

Consequently, if alternative non-continuous mathematical representations could be developed, conventionalism with respect to separated intervals would break down. Furthermore, if relativity theory fails in particular, so too does the conventionality of simultaneity. Conventionalism is not a general thesis. If, for the sake of illustration, Einstein were wrong and Newton right, simultaneity would not be conventional for Grünbaum whereas it still would be for Reichenbach.[15]

The conflation of Reichenbach and Grünbaum rests on inferring from their common conclusion back to a common argument. This is a false inference as we have seen. Interestingly, Grünbaum himself appears to make this inference, since he regards his approach as being within a "Reichenbachian tradition."[16] This is no problem as long as the distinction articulated above, as well as in §1.3 is kept in mind.

A more detailed investigation of the similarities and differences between these two thinkers is not necessary to this project. The primary point is to firmly establish the difference

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[14] Grünbaum, *Philosophical Problems of Space and Time*, 451.

[15] §3.3.2.1 shall illustrate this remark in detail.

[16] Grünbaum, *Philosophical Problems of Space and Time*, 561. Also *cf.*, 557 where he refers to Reichenbach's views as arising out of "intrinsic facts." It is difficult to know what exactly this means, but it is false if Grünbaum means "properties of a continuous manifold," since I (as well as Beauregard), have not found any place where Reichenbach speaks in this fashion.

between Reichenbach's a priori, inter-theoretical conventionalism, and Grünbaum's a posteriori, intra-theoretical conventionalism. I will now focus on Grünbaum's view of intra-frame simultaneity.

§2.2 Simultaneity: Adolph Grünbaum

In order to set the stage for the discussion in the next chapter, it is necessary to present Grünbaum's view of intra-frame simultaneity as he constructs it in the original edition of Philosophical Problems of Space and Time. This articulation of his views will illustrate what presuppositions he has with respect to simultaneity and what he does when they come under attack by E&B.

The views to be examined in this section are: the constitution of time relations by physical relations; the absoluteness of topological simultaneity; and the conventionality of metric simultaneity. The limited restriction on the definition of simultaneity by topological considerations is the heart of Grünbaum's "bridled conventionalism." This conventionalism arises out of ontological considerations, not logical ones.

Recall that in §1.2 we noted Einstein as saying that we have defined a time only for A and one for B but are lacking a common time. How then do we achieve this common time? Again, recall that Einstein regarded this common time as merely the result of a definition. But as van Fraassen rightly points out, definitions are not created ex nihilo, for even a stipulative definition may have factual presuppositions.[17]

Grünbaum argues that the STR, in opposition to Newtonian mechanics, assumes a relationalist conception of space and time. For prior to the construction of any type of coordinate system in which to speak of space and time, it is physical things and events which define points and instants. These points and instants can then "constitute the spatial and temporal loci of other physical objects and events."[18] Secondly, events are ordered according to the "obtaining of some physical relations between them."[19] But, what are these physical relations? This is the starting point of the whole debate over simultaneity, which will be made clear presently.

If every pair of events, Grünbaum says, is unambiguously ordered, then there would be an absolute temporal ordering. Select any two points, L and M, then specify an event at L, say L_E. There would be one and only one event M_E simultaneous with L_E and this would be acknowledged by all possible observers. But, is there any physical basis for this simultaneity? If we could use transported clocks to establish distant simultaneity then there would be no problem. However, in an Einsteinian universe clocks are not well-behaved under transport. The STR argues that moving clocks experience dilation, hence, clocks synchronized at L and moved

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[17] van Fraassen, *An Introduction to the Philosophy of Time and Space*, 75-76.

[18] Grünbaum, *Philosophical Problems of Space and Time*, 345.

[19] Grünbaum, *Philosophical Problems of Space and Time*, 346.

along various paths and velocities to M will no longer be synchronized. The question now becomes, which clock should be used to establish simultaneity? There is no way to make a consistent choice, since depending on the clock chosen, L_E and M_E would or would not be simultaneous. Grünbaum writes:

> **Hence, this dependence on the particular clock used prevents transported clocks from defining relations of absolute simultaneity within the class of physical events. And it also prompted Einstein to *deny* that even *within* a single inertial system, the physical basis of the simultaneity of two spatially separated events E and E' can be constituted, in part, by the reading produced by clocks...[in transport][20]**

It is the next paragraph that provides more of Grünbaum's ontology. He tells us that the failure of transported clocks to define a relation of absolute simultaneity does not entail that these separated events are not physically related at all. These separated events can "sustain physical relations of one kind or another only in virtue of the presence or absence of some kind of actual (or physically possible) physical linkage between them.[21] What links the events? Grünbaum says that it is a causal chain of which the events are the termini.

Grünbaum's key assertion is that events can sustain a temporal relation if and only if they are causally connectible.[22] In other words, given two events, it is either the case that a signal connects (or could connect them) or not. If they cannot be connected, they have no temporal ordering. In other words, which

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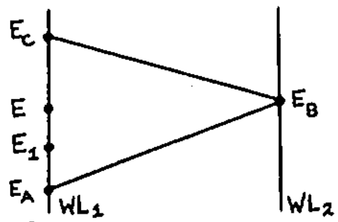
[20] **Grünbaum, *Philosophical Problems of Space and Time*, 347.**

[21] **Grünbaum, *Philosophical Problems of Space and Time*, 347.**

[22] **As we shall see in the conclusions, to hold absolutely to this assertion will tend to force Grünbaum into a strong verificationist position which he tries to avoid.**

event is before or after the other cannot be determined. For clarification, consider the following diagram:



Suppose we have two events, E_A and E_B. Suppose further that we send our fastest signal (light) from E_A to E_B where it is reflected back to E_C. WL_1 is the world-line which contains the events E_A, E_C and all events between them. WL_2 is the world-line containing E_B. No other signal leaving E_A could reach WL_2 quicker. In terms of the diagram, the faster the signal the more horizontal its trajectory becomes. We can say that E_B is between E_A and E_C. However, to say anything more about the location of E_B has no physical basis since it is physically impossible for there to be any causal link between an event within E_AE_C and E_B. Note that this is a physical fact, not a logical impossibility of verification.[23]

Because the temporal continuum is continuous, E_AE_C has a non-enumerable cardinality, hence, E_B is topologically simultaneous with an $\aleph_0$ of (possible) events. Furthermore, topological simultaneity (TS) is not transitive since:

	E_1 is TS to E_B
and:	E_B is TS to E
but not:	E_1 is TS to E[24]

[23] **Reichenbach says all this about signals in his work as well. The point here is that the limiting speed of causal connectibility *is the basis* of simultaneity for Grünbaum. When Grünbaum considers a Newtonian universe in §3.3.2.1, simultaneity is no longer conventional. On the other hand, Reichenbach would still assert it to be conventional due to logical considerations.**

[24] **This is the result of their causal connectibility.**

Grünbaum, as we have seen, rejects conventionalism with respect to topology. In the STR, E_A and E_B would be regarded as being connected by the fastest possible signal regardless of the relative velocity of a possible observer's inertial frame. Consequently, no inertial observer could observe a "collapsed triangle" such that E_A temporally coincides with E_C.[25] The reason for this is that the clock, call it Q, which is on world line WL_1 is, in its own reference frame, motionless, and will regard E_A and E_C to be temporally disparate, yet spatially coincident. Q will therefore, by the STR, give not simply a one-dimensional temporal measurement, that is, a time difference, but a four-dimensional space-time interval.[26] Another inertial observer, Z, would say that Q undergoes dilation by a factor of:

$$\sqrt{1-\beta^2}$$

(β is the relative velocity of the frames divided by the speed of light) and that the temporal separation is in fact (according to Z's clock), larger. However, all observers other than Q would need to factor in a spatial separation of E_A and E_C and would still arrive at the same result for the space-time interval. The important point is that Q measures the smallest temporal separation of E_A and E_C. Consequently, all observers would observe some temporal separation. This separation (topologically speaking) is

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[25] **Although clearly in the reference frame of Q, E_A and E_C are *spatially* coincident.**

[26] **I say "a temporal measure" since these are not invariant in the STR. Each observer will claim a different temporal interval between E_A and E_C, all will concur with respect to the space-time interval.**

absolute, although its numerical value (metrically speaking) is not. All observers would agree that E_B is located between E_A and E_C. Thus, for Grünbaum, topological simultaneity is not conventional. The conventional issues with respect to time parallel those of space: they arise only when we attempt more precise descriptions by going beyond topological considerations into metrical ones.

The determination of which event along E_AE_C is metrically simultaneous with E_B is simply a convention. This is a physical result of the physical fact that no signal can connect events belonging to the open interval E_AE_C to event E_B. To use Reichenbachian parlance, the events on the continuum E_AE_C and E_B are indeterminate with respect to time order.

To package the conventionalist view with respect to simultaneity, consider what follows from Einstein's claim that the common time is simply defined. Recall equation (2) which says:

$$t_{B2} = \tfrac{1}{2}[\ t_{A3} + t_{A1}\ ]$$

We can perform a little algebra to arrive at:

$$t_{B2} = t_{A1} + \tfrac{1}{2}[\ t_{A3} - t_{A1}\ ]$$

We can express conventionalism in the formulation:

$$t_{B2} = t_{A1} + \varepsilon[\ t_{A3} - t_{A1}] \quad \text{where: } \{\varepsilon/\varepsilon\in\mathbf{R}, 0<\varepsilon<1\}^{27} \quad (3)$$

(3) encapsulates the conventionalist position with respect to intra-frame simultaneity. Grünbaum writes:

> **This freedom to decree definitionally the relations of temporal sequence merely expresses the objective indeterminateness of unique time relations between *causally non-connectible events*; and, of course, such freedom can be exercised only with respect**

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[27] **This is Reichenbach's notation, *cf*, *The Philosophy of Space and Time*, 127.**

to such pairs of events.[28]

Grünbaum then goes on to consider a number of objections to conventionalism. To examine all of his responses is beyond the scope of this investigation. What I do want to examine is briefly mentioned by Grünbaum in connection with the work of P.W. Bridgman. Bridgman's A Sophisticate's Primer of Relativity, is the source for slow-clock synchrony upon which E&B build. A brief description of Bridgman's view will set the context for E&B's attack since their weapon was originally cast in Bridgman's forge.

[28] **Grünbaum, *Philosophical Problems of Space and Time*, 353-354.**

CHAPTER THREE: SLOW-CLOCK TRANSPORT

§3.1 Transported Clocks: Bridgman

Bridgman describes a method which will provide a unique calibration for distant clocks. Transported clocks indicate their transport time (proper time) and can measure their velocity. To do so, a moving clock releases a tape measure, compares distances and times, and arrives at a velocity measurement. We then calculate the differences between various clocks and a particular clock, perhaps the clock with the least self-measured velocity. We will call the reading on this slowest clock c_1. We have n other clocks $[c_2, c_3, \ldots, c_i, \ldots, c_n]$ which are transported at various speeds along the same path from A to B in the inertial frame. The STR tells us that the slower the clock moves from point A to point B within an inertial frame the less time dilation it suffers. For the transported clocks the time differences to be examined are given by $c_1 - c_i$. As the speed, v_i, of the clocks increases, c_i decreases, hence, the difference $c_1 - c_i$ increases. Since the clocks are moving inertially, a graph of $c_1 - c_i$ will be linear. Thus, we can extrapolate from the graph to get the value of $c_1 - c_i$ when v_i is zero. This limit is the value of the difference between the slowest clock and an infinitely slow clock. Consequently, we can correct all our clocks for time dilation and thus arrive at a unique time for B.

Bridgman, however, says that although one can devise different methods for determining distant simultaneity and so determine $\varepsilon = \frac{1}{2}$, "nevertheless the decision to use one or the other method is a decision in our control, involving a corresponding definition of distant simultaneity."[1] But E&B argue that slow-clock transport actually demonstrates the falsity or triviality of the view that in the STR the simultaneity of distant points includes an important conventional ingredient.

Bridgman asks, before he speaks of ascertaining simultaneity, what we demand of spreading time through space.[2] That is, when we try to assign a temporal value to a spatial distribution of points, what are our minimal demands with respect to our methodology? This is an extremely important question and will lead into some central questions of the epistemology of science.

For Bridgman, there are two important considerations: first, the method of spreading time through space must be describable. Second, this method must yield unique values for distant clocks.

Grünbaum, in the epilogue to Bridgman's work, argues that these are necessary but not sufficient conditions for a physically acceptable criterion of simultaneity. It cannot be enough to say that distant events are simultaneous simply because a physical procedure assigns the same time value to them. It should also be the case that there are physical grounds which say that one cannot assign different time values to them.[3] This point is crucial and will be developed by Grünbaum in his defence of the conventionality

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[1] P.W. Bridgman, *A Sophisticate's Primer of Relativity* (Middletown: Wesleyan University Press, 1962) 67.

[2] Bridgman, *A Sophisticate's Primer of Relativity*, 58.

[3] Bridgman, *A Sophisticate's Primer of Relativity*, 184.

of simultaneity against E&B. With these issues in mind, E&B's view of slow-clock synchrony and its ramifications will be examined.

§3.2 Transported Clocks: Ellis And Bowman

Their paper, "Conventionality in Distant Simultaneity," will be examined in detail here.

§3.2.1 $\varepsilon \neq \frac{1}{2}$ In One Inertial Frame

The main idea of this section is that E&B agree that $\varepsilon \neq \frac{1}{2}$ is possible. Their first section begins by listing two empirically acceptable principles.[4]

(I) Two-way light principle:
--for any two spatially separate points of the same inertial frame, the average round-trip velocity of light is a constant. (This constant, denoted by c, is the two-way velocity of light.)

(II) Transitivity of synchrony:
--for any three spatially separate clocks A,B and C, of the same inertial frame, if A is synchronized with B according to standard signal synchrony, and B with C according to standard signal synchrony, then A and C are also simultaneous by the same condition.

Standard signal synchrony:
--given two spatially separated clocks C_1 at A and C_2 at B of the same inertial frame K, they are in standard signal synchrony if and only if: $t_B - t_A = s/c$.[5]

To say $\varepsilon = \frac{1}{2}$, presupposes that the one-way velocity of light is

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[4] Brian Ellis and Peter Bowman, "Conventionality in Distant Simultaneity," *Philosophy of Science*, 34, 1967, 117.

[5] Where: t_A: departure time of signal from C_1
t_B: arrival time of signal at C_2
s: distance between C_1 and C_2
c: one-way velocity of light

c. Dropping this presupposition, ε is not necessarily ½ and the one-way velocity of light, c_{AB}, becomes a function whose domain is: the distance from A to B, the direction of B from A, and A's position in K.

To explicate E&B's assumptions, since they assert (3) but do not show it, we have:

Average Velocity = (total dist/total time)

$$= \frac{2AB}{\left(\frac{AB}{C_{AB}}+\frac{BA}{C_{BA}}\right)}=C \qquad (1)$$

(1) *entails*: $$\frac{1}{C_{AB}} + \frac{1}{C_{BA}} = \frac{2}{C} \qquad (2)$$

(2) *entails*: $$\varepsilon_{AB} + \varepsilon_{BA} = 1 \qquad (3)$$

where: $$\varepsilon_{AB}=\frac{1}{2}\left(\frac{C}{C_{AB}}\right), \quad \varepsilon_{BA}=\frac{1}{2}\left(\frac{C}{C_{BA}}\right)$$

From (3) there is a restriction that ε_{AB} must be less than one and more than zero. If $\varepsilon_{AB}<0$, the signal would arrive at its target earlier than its emission time. (This is rejected as absurd.) If $\varepsilon_{AB}=0$, the signal would take no time to travel the distance AB. (This is ruled out by the STR.) If $\varepsilon_{AB}>0$, the reflected signal would return earlier than its reflection time. (This is rejected as absurd.) This restriction is referred to as the "topological condition for light" and is always assumed to hold by all participants in the debate.

What E&B proceed to do is use principles I and II to derive a three-way light principle. This principle must be satisfied by all synchronizations otherwise "the light signal relationships between the clocks of our system would not be transitive, and hence would not define a relationship of synchrony."[6]

The last derivation of the section is that of a non-standard synchrony. They then state their conclusions:

> **We conclude that at least one kind of non-standard signal synchronization of the clocks of any inertial system is possible, and that it is sufficiently characterized by specifying the value chosen for ε_0, and the direction for which ε_0 is assigned this value.**[7]

Thus, it is possible to have $\varepsilon \neq \frac{1}{2}$ according to E&B. But, as they go on to remark, there is a method by which we can determine ε for any direction. Consequently, the main point in this section is that even if we can argue for $\varepsilon \neq \frac{1}{2}$, what in fact ε should be set to is an empirical issue. If that is the case, then conventionalism is misguided.

Having admitted $\varepsilon \neq \frac{1}{2}$ as a possibility, E&B try to impose further restrictions on the choice of ε. According to the conventionalists, to say $\varepsilon = \frac{1}{2}$ is simply to make a choice: a choice which is governed solely by considerations of descriptive simplicity. This type of simplicity only deals with how laws are written. It has nothing to do with truth. For example, changing coordinate definitions modifies the appearance of the laws;

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[6] **Ellis and Bowman, "Conventionality in Distant Simultaneity," 119.**

[7] **Ellis and Bowman, "Conventionality in Distant Simultaneity," 121.**

however, this does not mean that the new laws are "more true." The analogy between descriptive simplicity and choosing metres or feet for expressing laws is often stressed by conventionalists. E&B take Grünbaum to task for pushing this analogy too far. They agree that a switch from metres to feet will not change the forms of expressions of physical laws. But they argue that employing different values of ε certainly would. Consequently, to use different values of ε in different frames is to violate the principle of relativity which is an empirical principle. Hence, conventionalism, once again, is misguided.

However, bringing in arguments from relativity principles serves to complicate matters. The amount of spilled ink over the formulation of such principles, namely the strong principle and the principle of equivalence, not to mention Mach's principle, indicates how complicated this quickly becomes.

The principle of relativity has two basic forms: the strong and the weak. The former is associated with Poincaré and declares it impossible to determine absolute motion between inertial frames. Given two rectilinearly moving frames, we cannot say which is <u>truly</u> in motion. Furthermore, the strong form rules out any difference in quantitative measurements between inertial frames. For example, suppose an object, O, is at rest in inertial frame, F_1, and then at rest in another frame, F_2. The lengths of O measured in both frames would concur. The weak form is mostly associated with Einstein (although he did sometimes employ the strong as well). This form declares that the expressions of laws must be invariant with respect to inertial frames.[8] E&B claim that $\varepsilon\neq\frac{1}{2}$ violates both forms of the principle. In sum, $\varepsilon\neq\frac{1}{2}$ would cause a change in the expressions of laws, thus violating the weak, and would lead to problems with the strong when relative frames are at issue. This latter violation of the strong form will be examined in the next section.

§3.2.2 $\varepsilon\neq\frac{1}{2}$ In More Than One Inertial Frame

In this section as in the last, E&B agree that $\varepsilon\neq\frac{1}{2}$ is possible. In this case, they are looking across inertial frames to support their view of $\varepsilon=\frac{1}{2}$ for a single frame. E&B's basic strategy is to demonstrate how choosing ε as anything other than $\frac{1}{2}$ for a single frame entails difficulties when dealing with other frames.

It is necessary to impose the condition of linearity when examining more than one inertial frame. Theoretically, the condition ensures that Newton's first law holds in all frames. Experientially, it asserts that if an observer sees a uniform straight line motion in his or her inertial system, all other inertial observers will concur.[9] Without this principle:

> we should either have to have different laws of motion for different inertial systems (or a single law containing system-dependent constants) or allow that there may be universal forces whose magnitude is a function of the inertial system in which they are

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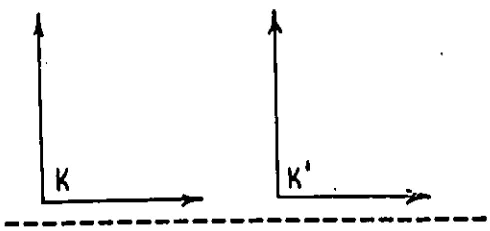
[8] For more information on the variations of the principle *cf.* G.H. Keswani, "Origin and Concept of Relativity," in *The British Journal for the Philosophy of Science*, Part I: Vol. 15; Part II: Vol. 16; Part III: Vol. 17; 1966.

[9] Ellis and Bowman do not note this, but there will be one inertial frame that regards the motion as non-existent. This is not a problem since the first law will not be affected as the body is at rest in this system. The main point is that no inertial observers will observe non-inertial motion.

measured.[10]

To illustrate the possibility of $\varepsilon \neq \frac{1}{2}$ in more than one frame, E&B consider coordinate transformations between two inertial frames K and K' whose relative motion lies along a parallel axis. (The common axis is assumed for the sake of simplicity.) No assumptions are made about the relation of v (the non-zero velocity of K' with respect to K) and v' (the non-zero velocity of K with respect to K'.)



- c_o: one-way velocity of light along the positive x axis as determined by K.
- $c_{o'}$: same but determined by K'.

↑ common line of motion

The coordinate transformations are given as follows:

$$x' = \gamma\,(x - vt) \qquad (4)$$
$$x = \gamma'\,(x' - v't')$$

Through some algebraic manipulations E&B reproduce the result known as McPhee's theorem.[11]

$$\frac{c}{2}\left(\frac{1}{v'} + \frac{1}{v}\right) = \varepsilon + \varepsilon' - 1 \qquad (5)$$

This equation, coupled with the principle of the reciprocity of velocities, that is, v = -v', almost, as E&B themselves write, entails $\varepsilon = \frac{1}{2}$. To unpack the "almost," consider that, if reciprocity holds, then (1/v' + 1/v) = 0. Consequently, we have:

[10] Ellis and Bowman, "Conventionality in Distant Simultaneity," 123.

[11] Here $\varepsilon = \frac{1}{2}(c/c_o)$ and $\varepsilon' = \frac{1}{2}(c/c_{o'})$.

$$\varepsilon + \varepsilon' = 1 \qquad (6)$$

But suppose we add a third frame, K", to our story. We then have the following system of equations, providing we adhere to McPhee's theorem and the reciprocity of velocity.

$$\begin{aligned} \varepsilon + \varepsilon' &= 1 \\ \varepsilon + \varepsilon'' &= 1 \\ \varepsilon' + \varepsilon'' &= 1 \end{aligned} \qquad (7)$$

Solving this system gives $\varepsilon = \varepsilon' = \varepsilon'' = \frac{1}{2}$. E&B then state: "the conditions of linearity and reciprocity of relative velocities can both be satisfied only if the clocks of all inertial systems are in standard signal synchrony."[12] To keep $\varepsilon \neq \frac{1}{2}$ requires the abandonment of reciprocity. Consequently, Grünbaum, as well, is in violation of the strong principle of relativity, since by McPhee's theorem different values of ε for different systems would entail system-relevant velocities of light for frames; in that case, we would be able to distinguish between frames.

§3.2.3 The Conventionality Of Simultaneity

Following the misleading view which, as argued in §2.1, must be approached cautiously, E&B place Reichenbach and Grünbaum into the same camp. The quotation that E&B cite to justify this move does not have the force to do this type of work. This quotation, essentially the circularity argument of Reichenbach's with respect to distant simultaneity and velocity measurement, is used by

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[12] Ellis and Bowman, "Conventionality in Distant Simultaneity," 124.

Grünbaum to refute Whitehead's view of simultaneity.[13] Grünbaum's conventionalism, as argued in §2.2, stems from the limiting speed of light. However, he has a vested interest in defending Reichenbach as well since, as noted earlier, his own program is an attempt to clean up Reichenbach's metaphors. Any notion of a "true" simultaneity would severely damage his interpretation of the STR's philosophical foundations.

Reichenbach and Grünbaum both consider, and reject, transported clocks as able to define distant simultaneity. They reject this procedure because of the time dilations predicted by the STR. But, E&B state that Reichenbach's epistemological maxim (one for which Grünbaum tried to provide an ontological basis) is trivial. That is, it is trivial that there is no way of knowing how separated instruments behave when they are separated. Knowing whether or not there are universal distorting forces is not terribly important.

The question as to whether or not this is a trivial issue, is a crucial part of this entire debate over simultaneity. E&B use the term "trivial" to eradicate a key concern in twentieth-century philosophy of science: the problem of distant comparisons. Furthermore, they do not provide the criteria for "triviality." From the brief history of simultaneity in §1.1 it would appear that most, perhaps even all (with the exception of a few Mahayana Buddhist philosophers of the first century) thinkers before those

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[13] For the quotation in question *cf.* Grünbaum's *Philosophical Problems of Space and Time*, 344.

in the late nineteenth century would have regarded the entire issue of simultaneity as trivial. The main point is that E&B have introduced the concept "trivial" and use it as a major plank in their rejection of the conventionality thesis. Hence, it is incumbent upon them to provide an explanation of this concept. The triviality question will be returned to in §3.3.2.2 of Grünbaum's response.

§3.2.4 Slow-Clock Transport In One Inertial Frame

This type of transport, E&B argue, can give us a physical relationship that is both symmetric and transitive and thus can be used to define distant simultaneity. "It is therefore like the relationships that may be used to determine distant mass equality, which is not held by anyone to be conventional in any but a most trivial sense."[14] Of course this project, and indeed the entire ensuing discussion, is based on the assumption that the STR is a true theory of the world, for the project here is grounded on the STR's time dilation equation.

To illustrate E&B's deduction, we will begin by simply stating the dilation equation. (Its derivation can be found in any standard text-book on relativity theory.)[15] If we have the following situation where a clock, Q, is uniformly moving from A to B, which are separated by distance s, the difference in the time as measured

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[14] **Ellis and Bowman, "Conventionality in Distant Simultaneity," 127.**

[15] **A highly readable text is Max Born's *Einstein's Theory of Relativity*.**

by Q and the time measured by the clocks at rest in the system is given by:

$$T_B - t_A = \sqrt{1-\beta^2}\,(t_B - t_A) \qquad (8)$$

where:

- clocks at A and B are in standard signal synchrony
- t_A: time on A's clock of Q's departure
- t_B: time on B's clock of Q's arrival
- T_B: time on clock Q of Q's arrival
- β: ratio of Q's velocity v and the speed of light c

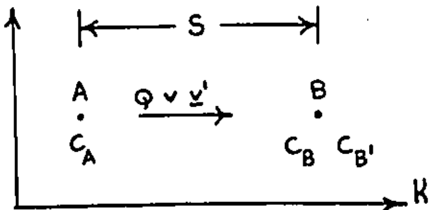
Note:
both Q's velocity and the speed of light are determined with respect to the clocks A and B. ($v=s/t_B-t_A$)

We can rearrange (8) as follows: $t_B - T_B = \frac{1}{2}(vs/c^2)$ (9)

(8) evaluates how much slower Q is compared to the "stationary" clock at B. This difference varies according to the velocity of transport as well as the path. Thus, it is argued that clock transport will not give a unique temporal value to distant points. Which clock we choose is arbitrary.

The above overlooks the following: for any value of s, a v can be chosen such that the time dilation can be made arbitrarily small. Essentially, we are then looking at the limit of (9) as the velocity approaches zero.

The reply to this is that, in order to make any statements about the limit, we enter the logical circle of Reichenbach since the value of v cannot be known unless we already know that the two clocks are synchronized. To circumvent this problem, E&B construct what is called an intervening variable. Rather than using v they construct the intervening "velocity" <u>v</u>'. To clarify E&B's argument, we will reconstruct their theory of slow-clock transport, and then, the practice of slow-clock transport. The following diagram is referred to in these constructions.



- Clocks C_A and C_B are in standard signal synchrony.
- $C_{B'}$ is set arbitrarily.

- t_A: Q's departure time on C_A
- t_B: Q's arrival time on C_B
- $t_{B'}$: Q's arrival time on $C_{B'}$
- v: Q's velocity of transport; $v=s(t_B - t_A)$ (10)
- $\underline{v}'$: Q's intervening velocity; $\underline{v}'=s/(t_{B'} - t_A)$ (11)

§3.2.4.1 The Theory

Notice that we can combine (10) and (11) to get:

$$v = \frac{v'}{1-(k/s)\underline{v}'} \qquad (12)$$ [16]

From (12) we can say that, regardless of the value of k, as $\underline{v}'\to 0$, so too does v. If we take the limit as $v\to 0$ in (9), we get the following:

$$\lim_{v\to 0} (t_B - T_B) = 0 \qquad (13)$$

From our knowledge of the limit relationship of v and $\underline{v}'$ we can rewrite (13) as:

$$\lim_{v'\to 0} (t_B - T_B) = 0 \qquad (14)$$

[16] In this derivation $t_{B'} - t_B = k$ has been used. The constant k will depend upon the setting of $C_{B'}$. This will be clearer when the practice is described. Furthermore, all clocks are assumed to run at the same rate.

Finally, if $t_B = t_{B'} - k$ is substituted into (14) we have:

$$\lim_{v' \to 0} (t'_B - T_B) = k \qquad (15)$$

Theoretically (15) tells us that the lower the intervening "velocity" of Q, the smaller the difference between travel time as measured by the arbitrarily set clock, $C_{B'}$, and the travel time measured by the moving clock, Q. This difference ultimately converges to a constant, k. Couple this result with (14), which tells us that the difference between the clock, C_B, set by standard signal synchrony, and the moving clock, Q, tends to zero. Consequently, the difference between arbitrarily-set clock, $C_{B'}$, and standardly-set clock, C_B, converges, as the zero limit is approached, to k.

§3.2.4.2 The Practice

Unfortunately, no one offers a good, clear and complete description of how to actually perform this synchronization. Hence, it is necessary to do so here. To begin with, we will examine how distant clocks are set by signals. When distant observers set their clocks according to signals, they must first have an agreement as follows. First, when the sender's clock reads a certain value, for example, zero (for simplicity's sake), he will send the signal. Second, the receiver agrees to reflect the signal upon reception. Third, the receiver's clock is set to zero plus the time taken for the signal to reach her from the source. Fourth, she will start her clock running upon reception of the signal. The problem is: how much should B set her clock ahead of zero? In other words, how long did the signal take to reach the receiver?

With standard synchrony, light speed is assumed to be isotropic and equal to c. Suppose A is the sender and B is the receiver. They have entered into the previous agreements and are separated by distance AB. Therefore, the time B should set her clock ahead is zero plus AB/c. She starts her clock upon reception of the light signal and the two clocks are in standard signal synchronization.

We have seen that the argument over the conventionality of simultaneity centres on the seemingly innocuous assumption of isotropy in light speeds. E&B's argument tries to bypass this assumption. Their method is such that it is irrelevant which ε is chosen to begin with since it will be shown to converge to ½.

Suppose A and B want to set their clocks by slow-clock transport instead of by standard signal synchrony. They enter into the previous four agreements; however, the assumption made by A and B in agreement three is not necessarily AB/c. First, they set their clocks arbitrarily. That is, B sets her clock to zero plus q and starts it running upon the reception of the signal; q is arbitrary, but must obey the topological condition for light, hence: $(0<q<2AB/c)$. The difference between the standard setting and the slow-clock setting at the outset is given by: $k=q-AB/c$. (16) B does not know this value since she does not have a standardly synchronized clock beside her. A releases clocks $\{Q_1, Q_2, \ldots, Q_i, \ldots, Q_n\}$ with constant, yet differing velocities $\underline{v}_i'$. What

B will find is that there is a linear relationship between the arrival times of the clocks Q_i (as measured by them), and by her arbitrarily-set clock. The smaller the <u>v</u>' of Q_i, the smaller the difference between the arrival time on B's clock and the arrival time on Q_i. Mathematically this difference will converge to k as slower and slower clocks Q_i eventually reach B'. Without waiting until infinitely slow-moving clocks reach her, B could, perhaps by plotting this linear relationship on a graph, extrapolate the trend and find the value of k. From (16) and the domain of q, k can be negative, zero or positive, depending on the value of q used. The possible results and actions required for slow-clock synchrony are given in Table A.

Table A: Summary Of Slow-Clock Synchrony

q	k	problem	solution
$0 < q < AB/c$	$k < 0$	B was set too far back at first	move B ahead by amount k
$q = AB/c$	$k = 0$	B was standardly set at first	nothing need be done
$AB/c < q < 2AB/c$	$k > 0$	B was set too far ahead at first	move B back by amount k

In essence, if B follows this chart accordingly, her clock will be in slow-clock synchrony with A's clock. Furthermore, her clock will also be in standard synchrony with A's clock. Because slow-clock overlaps with standard signal synchrony, we:

> also know that the relationship of slow-transport synchrony is transitive, symmetric and reflexive, and is consistent with both the n-way light principle and the topological condition for light.[17]

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[17] Ellis and Bowman, "Conventionality in Distant Simultaneity," 130.

§3.2.5 The Rejection Of Conventionality

Again, E&B state that if all that is ultimately involved in the conventionality of distant simultaneity is that which is expressed by the view that comparison-at-a-distance is conventional, then the thesis is trivial. E&B admit that we could sit back and say that ascertaining the simultaneity of distant events via slow-clock transport involves comparison at a distance. We could base this on the fact that we just do not know what really happens under transport and so simultaneity of distant events is ultimately conventional. Yes, E&B reply, but this is trivial.

The main thrust of the E&B's entire paper is that we have a method of ascertaining distant simultaneity which avoids Reichenbach's logical circle of velocity and simultaneity. In addition, the method of slow-clock synchrony can ascribe unique temporal values to spatially separated points, thus overcoming the inconsistencies arising from the dependence of clock readings on trajectories. Finally, the slow-clock method's result for distant clocks is the same as the standard signal synchrony method which assumes $\varepsilon=\frac{1}{2}$.

E&B argue that because these two methods agree, to allow $\varepsilon\neq\frac{1}{2}$ is possible but to do so would be to accept some odd and, by the tone of their concluding paragraphs, fantastic results. Ultimately, were we to allow $\varepsilon\neq\frac{1}{2}$, we would need to postulate two types of universal forces.

> One set would be needed to account for the anisotropy of the empirically determined one-way velocities of light, and a second set would be needed to account for the

> acceleration or retardation of infinitely slowly transported clocks.[18]

Basically, because the two methods agree and since $\varepsilon \neq \frac{1}{2}$ entails anisotropy in light speeds, we need a universal force which affects all electromagnetic signals equally and cannot be shielded against. Furthermore, a second force would have to equally affect our clocks and also be a force from which there is no escape. Finally, these two forces would need to obey the exact same distribution laws. In other words, if we agree, for example, that the anisotropy in light velocities between two points is a function of distance and direction, then this function's results would need to be mirrored by another function describing the effects on moving clocks. E&B are not willing to entertain this possibility.

On the other hand, if we are willing to dismiss these forces by setting them to zero, we end up with two independent and concurring methods to define simultaneity. Each method yields a unique temporal value. This, E&B conclude, gives us a "good physical reason" for accepting one of the definitions.

> **If physical reasons such as these are ruled out of court then there can be no good physical reason for adopting any definition of any quantitative equality between any two things at a distance.**[19]

Clearly it would be difficult, and perhaps impossible, to give a general definition of what constitutes a "good physical reason." However, E&B are setting up an unnecessarily alarmist dichotomy. Perhaps, and we shall see more of this in Grünbaum's defence, it is

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[18] **Ellis and Bowman, "Conventionality in Distant Simultaneity," 134-5.**

[19] **Ellis and Bowman, "Conventionality in Distant Simultaneity," 135.**

simply the case that we have conventional elements in our laws and that restricted anisotropies remain. Therefore, instead of saying "no physical reason" we should say "no purely physical reason." As we shall see, in some universes conventionality is trivial and in others, not.

It appears that E&B are playing a traditional philosopher's game: set up a demand which is either fulfilled and order prevails, or unfulfilled and chaos ensues.

§3.3 Transported Clocks: Grünbaum's Response

Grünbaum divides his response to E&B into two sections. The first examines the principles employed by E&B's account of the transitivity of ε as well as an investigation into the principle of relativity. This principle, according to Grünbaum, must be clarified since it has a factual as well as a conventional component. From his point of view, $\varepsilon \neq \frac{1}{2}$ is untouched by its factual component, and whether or not the conventional aspect allows or disallows $\varepsilon \neq \frac{1}{2}$ depends on the particular formulation of the principle we choose. Hence, to choose a particular convention, build it into the principle of relativity, and then use that principle to interdict conventionalism is, at best, question-begging, and at worst, self-contradictory.

The second section investigates E&B's philosophical thesis that clock transport enables one to speak of the true relation of distant simultaneity. Grünbaum constructs a quasi-Newtonian universe in order to show that clock transport cannot bestow factual physical truth on simultaneity relations. Essentially, if in this simpler and better behaved universe (that is, no time dilation), we cannot establish convention-free simultaneity, then the universe of the STR will only be worse. However, in a Newtonian universe, absolute or convention-free simultaneity exists alongside the thesis of the alternative metrizability of the sub-manifolds of space and time.[20]

Grünbaum is at pains to stress that he is not at variance with the claim that clock transport can establish a unique time coordinate between two spatially separated events. In other words, the conflicting accounts engendered by the dilation equation can be overcome. What he does ask, however, is whether or not there are conventions which lurk behind the claim that this unique time coordinate is a "true time coordinate."

§3.3.1 Transitivity And Conventionality In The Principle Of Relativity

§3.3.1.1 $\varepsilon \neq \frac{1}{2}$ In One Inertial Frame

Let t_1 be the time on a clock, U_A, at A when a light ray is emitted towards a clock, U_B, at B. Further, the light ray is reflected at B and returns to A at t_3, and let the time of reflection be t_2. Finally, the light is again reflected and returns to B at t_4. Let us denote that the clock, U_B, is set according to

[20] The difference between space-time intervals and space and time intervals must be stressed. When the space-time manifold is asserted to be metrically amorphous, it concerns the sub-manifolds of space and time. The claim that a space-time metric is lacking is another issue. This will be further examined in §4.1.

U_A by: $U_B syn(\varepsilon_{AB}) U_A$.

Grünbaum's point is that, although we have the empirical principle of the isotropy of round-trip times, that is, $t_4-t_2=t_3-t_1=T$, it does not follow that $\varepsilon_{AB}=\varepsilon_{BA}$. In other words, it is not necessary to require that since $U_B syn(\varepsilon_{AB}) U_A$, it is also the case that $U_A syn(\varepsilon_{AB}) U_B$. If this is not the case, then the following move of E&B is not valid:

From: (1) $t_2 = t_1 + \varepsilon_{AB}(t_3 - t_1)$ and (2) $t_3 = t_2 + \varepsilon_{BA}(t_4 - t_2)$

Substitute (1) and (2) into: $t_2-t_1+t_3-t_2=t_3-t_1$

Which entails: $\varepsilon_{AB}T + \varepsilon_{BA}T = T$ (3)

To: $\varepsilon_{AB} + \varepsilon_{BA} = 1$ (4)

Essentially, from the round-trip times statements about one-way velocities do not automatically follow. In essence, a "two-way light principle cannot itself entail any relation between the two distinct one-way light synchronisms specified by ε_{AB} and ε_{BA}.[21]

The way to validate this enthymematic deduction of equation (4) involves accepting what Grünbaum calls the rule of committed synchronism (RCS). This rule tells us that if we use a clock, X, and ε_{XY} to set a clock, Y, then we must accept X as being set by Y as well as any other clock, Z.[22]

The problem with E&B, according to Grünbaum, is that there is an ambiguity in their account of $\varepsilon=\frac{1}{2}$ between a generalized form of

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[21] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," *Philosophical Problems of Space and Time*, 673.

[22] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 672.

RCS (GRCS) and a much stronger principle, the transitivity of simultaneity. GRCS tells us that, if we set clock, Y, from X, then we must use this setting of Y as a basis for setting any other clock Z. Furthermore, Z must be accepted as being in synchrony with X. Note that there is no restriction as to whether or not the ε's need be equal. For transitivity, however, it is necessary to use the same ε for all settings. Transitivity can be succinctly illustrated as follows:

B is synchronized according to ε by A
C is synchronized according to ε by B
A is synchronized according to ε by C

Hence, transitivity is a much stronger principle (more restrictive) than GRCS. Grünbaum then algebraically demonstrates that, if transitivity is demanded, there is only one solution: $\varepsilon=\frac{1}{2}$. On the other hand, the GRCS's lack of restrictions on the ε's will allow $\varepsilon\neq\frac{1}{2}$.

Grünbaum is addressing the issue of how to formulate the principle of transitivity. A priori, to demand it to restrict all ε's to equality, is to restrict ε to ½. However, nothing requires us to do this. Grünbaum argues that there is no physical fact to the ε value here either because there is nothing that compels us to employ RCS (much less strict transitivity) in the first place.

In sum, Grünbaum argues that E&B are conflating principles, transitivity and GRCS, as well as not realizing the implicit conventions in their assertions.

§3.3.1.2 The Principle Of Relativity

A. The Weak Principle

This version demands that the laws of nature with respect to inertial frames must be invariant under linearly related Lorentz transformations. But, Grünbaum says, suppose in one frame we have the law of light propagation expressed in rectangular coordinates and in another frame, polar coordinates. These two frames would not be related by the linear Lorentz transformations.

> But presumably no one would say that such a state of affairs is incompatible with *factual physical content* of the given version of the principle of relativity.[23]

In essence, the bare appeal to the weak form of the principle by E&B is not <u>sufficient</u> to ground the assertion that $\epsilon \neq \frac{1}{2}$ will change the form of the laws from frame to frame and on that basis be disallowed. It may be that there is a convention which governs the form of laws, but that is not a factual argument on which to rule out other forms. Grünbaum's main point is that there are conventions within what is meant by "the form of a law."

B. The Strong Principle

Grünbaum argues that E&B have incorrectly formulated the strong principle in their paper. My concern here is not so much with the "correct form" of this principle but with what E&B say follows from it. E&B say that, by imposing the condition of linearity, $\epsilon = \frac{1}{2}$ follows from McPhee's theorem when the further condition of reciprocity of relative velocities is imposed.

[23] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 680.

However, Grünbaum asks whether these conditions themselves are convention-free.

Reconstructing E&B's conclusion clearly illustrates what Grünbaum is concerned about. Essentially, E&B say: the condition of linearity and the reciprocity of velocities is satisfied only if $\varepsilon=\frac{1}{2}$. But, as Grünbaum reminds us:

> It is plain that McPhee's result does not entail that non-standard synchronisms must violate velocity reciprocity. What it does entail is the weaker conclusion that $\varepsilon=\frac{1}{2}$ violates *either* the condition of linearity or the condition of velocity reciprocity.[24]

The condition of linearity is the requirement that Newton's first law holds in all frames. Yet, this law, according to Grünbaum, has factual as well as conventional elements. Consequently, he argues that it cannot be taken for granted as E&B have done.

Newton's first law states:

> Every body continues in its state of rest or of uniform speed in a straight line unless it is compelled to change that state by forces acting upon it.[25]

This law requires that an empirical correlate be ascribed to the concept of uniform speed. At first this seems quite straightforward: an object is travelling at a constant speed if and only if it travels equal distances in equal times. However, the problem that arises is that of comparison-at-a-distance. In other words, it is necessary that successive temporal intervals are equal

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[24] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 683.

[25] Douglas C. Giancoli, *General Physics* (New Jersey: Prentice Hall, 1984) 59.

as are spatially separate intervals.[26] Whether or not comparisons such as these are ultimately conventional has been one of the most difficult questions in the philosophy of space and time in the twentieth century. Grünbaum's main point is well taken: E&B have simply moved too quickly here, they have taken too much for granted.

On the other hand, if the principle of reciprocity is simply accepted, the result is that two inertially moving frames must measure equal and opposite velocities.[27] But the case is not this simple. It has been shown that there is a dependency on simultaneity to determine the one-way velocity of light. In fact, this dependency cuts across determinations of any one-way speed. Consequently, whether or not two frames measure equal but opposite velocities depends on the choice of ε. The conventionality of simultaneity entails a conventionality of relative velocities. Consequently, although we cannot conclude that it is necessarily the case that relative velocities are conventional, at least a bare appeal to the principle of reciprocity is not sufficient. Winnie sums this issue up nicely:

> Unless independent grounds are given at the outset for accepting the reciprocity condition as a synchrony-free principle (which it clearly is not), the result in no way mitigates against the C.S. [conventionality of simultaneity] thesis.[28]

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[26] The problem of finding an inertial frame provided much debate in nineteenth century physics. Furthermore, this problem became the organizing difficulty around which Reichenbach built the first two chapters of *The Philosophy of Space and Time*.

[27] For the mathematics of this, *cf*, Winnie, "Special Relativity Without One-Way Velocity Assumptions: Part II," *Philosophy of Science*, 37, 1970, 224.

[28] Winnie, "Special Relativity Without One-Way Velocity Assumptions: Part II," 224.

As argued in §2, Grünbaum's conventionality of simultaneity differed from Reichenbach's in that the former regarded the conventionality as arising solely from the limiting speed of light while the latter saw it as ultimately a logical problem. Now it will become apparent that Grünbaum modifies his position from conventionality predicated on the finite speed of light, to conventionality ultimately arising from the metrically amorphous space-time manifold. He does not abandon the importance of the limiting speed of light, but augments it.

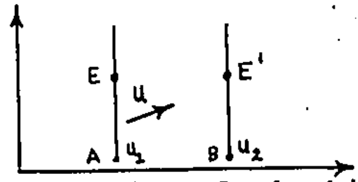
§3.3.2 Slow-Clock Transport In One Inertial Frame

From the slow-transport theory a method which establishes a unique temporal value for spatially separated events can be devised. In other words, the problem of time dilation as well as the round-trip interval of the light-signal method can be circumvented. Furthermore, the behaviour of clocks under slow-transport gives us clocks in synchrony by $\varepsilon=\frac{1}{2}$. Grünbaum investigates the claim that $\varepsilon=\frac{1}{2}$ obtains as a matter of temporal fact. To show that his view of the conventionality of simultaneity is not simply a logical result, but derives from ontological considerations, Grünbaum discusses three universes: the Newtonian, the quasi-Newtonian and that of the STR.

§3.3.2.1 The Newtonian Universe

Suppose we have the following:

- A,B: points in an inertial frame
- U_1: clock at A
- U_2: clock at B



● E : event on U_1's world-line
● E': event on U_2's world-line

U: a moving clock which intersects U_1's world-line at some time, t. (U and U_1 will have the same readings after the intersection for any subsequent encounter.)

Event E is unique in that a moving clock that contains this event cannot also contain E'. As Grünbaum writes, this is simply another way of saying that a single clock cannot be in two different positions at once. Yet, it is important to notice that E divides the world-line of U_1 into two disjoint sub-intervals of events; call them X and Y. These intervals have the following properties:

(i) for any events $x \epsilon X$ and $y \epsilon Y$, these events can belong to the world-line of a moving clock whose intersection with the world-line of U_2 is E'.

(ii) for all moving clocks, U, locally synchronized with U_1, the time, t', given by U of E' is the same.

If any events $x \epsilon X$ and $y \epsilon Y$ are selected, E' is always found between them. Hence, E' is the only event on the world-line of U_2 that sustains this relationship with respect to <u>all</u> the members of X and Y. In other words, suppose a point, Q, on U_2 other than E' is selected. An $x \epsilon X$ and a $y \epsilon Y$ such that a suitably fast-moving clock containing x and y on its world-line could be found which would say that it is <u>not</u> the case that Q is between x and y. Essentially, E and E' share the property of uniquely dividing the temporal ranges, X and Y. Grünbaum writes:

> **Hence on the basis of temporal betweeness relations alone, E' is uniquely simultaneous with E within S [the world-line of U_1], and E is uniquely simultaneous with E' within**

the career of U_2.[29]

Grünbaum stresses that there is no appeal to comparing the durations given by clocks here, thus, the issue of the conventionality arising from the metrically amorphous nature of space-time does not apply. The simultaneity of E and E' is established because clocks can move arbitrarily fast. In essence, any arbitrarily small interval, xy, will contain both E and E'. No other point on the same world-line as E' bears this property. On purely topological considerations alone a unique simultaneity is established. Hence, simultaneity is a physical fact. There is no conventional ingredient here except for "the particular identity of the time number assigned alike to all members of a class of simultaneous events."[30] Whatever this time number happens to be follows from our initial setting of one clock and that is arbitrary.

Prima facie, this looks tenable. Later, one of Ellis' responses which attempts to show that Grünbaum himself has smuggled in a convention of his own will be developed and examined. (In fact, if Grünbaum's convention is relaxed, it would appear that Newton's universe is much more "badly behaved" than that of the STR.)

Grünbaum stresses that he has broken a key logical link

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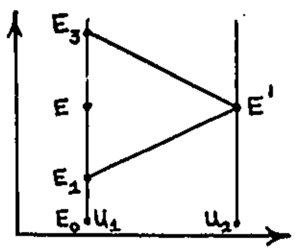
[29] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 685.

[30] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 688.

exploited by E&B. E&B assert that all measurements of quantitative equality which depend on local comparisons are conventional and that was indeed a trivial conventionality. Locality of comparison is a sufficient condition for conventionality. However, Grünbaum's Newtonian universe illustrates that this is erroneous. In this universe, local comparisons (that is, the intersections of U_1 and U at which these clocks are locally compared), do not engender conventional simultaneity relations.

§3.3.2.2 The Quasi-Newtonian Universe

The quasi-Newtonian universe is exactly the same as the Newtonian but for one property: light and gravitational influences, although the fastest signals, are now finite in velocity. The situation is the following:



- No event belonging to the open interval E_1E_3 is connectable by any physical chain to E'.
- No event belonging to the closed interval E_1E_3 is connectable by a transported clock.

Clocks are still well-behaved for they do not suffer time dilation under transport. Consequently, all clocks U, synchronized locally with U_1, will give the same temporal value, t', for E'. In other words, clocks will read t for E and t' for E' such that t=t'.

Grünbaum's next move is similar to that which was explicated in §2.2. Suppose we look at the open intervals E_1E and EE_3. Events in these intervals are non-connectable to E'. If there is no possible connection between two events and if an event is non-connectable with a range of other events, then these events are indeterminate with respect to time order. Consequently,

> the purely ordinal significance of the equal coordinates t and t', which U_1 and U assessing respectively *on their own world-lines* to the spatially separated events E and E', is not sufficient at all to order E and E' *in relation to each other* as uniquely belonging to the same instant within a common system of quasi-serial temporal order.[31]

To say that E and E' belong to the same instant in a common temporal system, it is necessary to show that E and E' are durationally equidistant from some event, E_0, where the two clocks, U_1 and U, were locally synchronized. However, unlike in the previous universe where topological relations provided a common temporal system, metrical relations are needed because the lengths of intervals-at-a-distance must be compared. According to Grünbaum, both clocks generate a continuum of dimensionless instants. Although the clocks assign coordinates to these instants, there is no intrinsic durational measure of these intervals of instants. Whether or not they are equal involves a non-trivial convention.

As mentioned before, it is important to note that Grünbaum does not say it is simply separation alone which engenders conventionalism. For in the previous universe, separation of events did not give rise to conventionalism with respect to simultaneity. Separation is a necessary ingredient, but it is not sufficient for a non-trivial conventionalism. It is when separation is coupled to the limiting speed of connectability plus the thesis of the intrinsic amorphousness of the submanifolds of space and time or the space-time manifold that simultaneity becomes conventional.

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[31] Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 690.

In §3.2.3 the difficult questions concerning "triviality" as well as the possibility of running separate concepts together were raised. In a similar spirit here, Grünbaum suggests that we should step back at times to consider how we approach issues in philosophy. In essence, there is a Wittgensteinian spirit to the following comment which tells us to slow down our discussions lest we gloss over questions, run concepts together, and end up confusing ourselves. Grünbaum wants to avoid these types of muddles which can stem from the haste to "get somewhere" in space-time philosophy.

> **Besides, even if it *were* true that "every relationship of quantitative equality that depends upon local comparison is conventional" *in one and the same sense*, it would not follow that the *generality* of this convention establishes its triviality. It does not trivialize the attribute of mortality to point out that all men possess it alike.**[32]

Whether or not one agrees with Grünbaum's position with respect to space and time, his point, which says that E&B are simply moving far too quickly, is well-taken. Furthermore, there is a more subtle point operating here: we have to be careful that we do not regard issues as trivial simply on the basis that we have become accustomed to them. No one would find it surprising to hear of the mortality of all humans and on that basis declare it trivial. Also, no one would find it surprising that one cannot be in two places at once. So why conclude this is trivial and then go on to say that the problems of comparison-at-a-distance are perhaps conventional, but this is certainly a hollow kind of conventionality? I do not

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[32] **Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," 692.**

agree that the problem of comparison-over-distance is at all hollow. I find it a fruitful issue around which I have organized twentieth-century philosophy of space and time.

The essence of Grünbaum's approach to the philosophy of science is guided by a particular moral, namely the rejection of uncritical literalism with respect to scientific theories.[33] This literalism is a "telephone book" approach to theories. It assumes that given a theory, T, the philosophical content can be read straight off the equations and that the strength of the scientific acceptability of T is <u>the</u> basis for certifying the viability of this content. Grünbaum is not saying that the scientific acceptability is irrelevant, just not the sole basis. The path from theory to ontological commitment is not so straightforward. Grünbaum's position, a type of hesitant realism, is branded by many as a form of scepticism. As with "trivial," it is extremely important (as well as difficult) to articulate what "scepticism" means. For example, one person's "scepticism" may be deemed by another as "common sense." It is crucial to note that as science becomes increasingly mathematicized, the question of interpretation becomes increasingly pertinent. Finally, the philosopher's hesitation is not an impediment to the scientist's advancement.

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[33] **Grünbaum makes this point particularly with respect to Earman, but we can apply it as well to Ellis and Bowman. *cf.* Grünbaum's "Why I Am Afraid of Absolute Space," in *Australasian Journal of Philosophy*, 49, 1971, 96.**

§3.3.2.3 The STR Universe

Here clocks no longer ascribe the same temporal values independently of transport. In this section Grünbaum gives an alternative proof of the theorem that in the limit (as velocity approaches zero) intra-systemic disagreements among clocks disappear and these moving clocks give the same value as clocks synchronized by $\varepsilon = \frac{1}{2}$. The main thrust of Grünbaum's alternative proof is to show that one can perform the proof without making use of E&B's "intervening velocity."

Grünbaum regards it as fallacious to infer (as E&B do) from the fact that, moving clocks come to agreement, to it being a physical fact that E' occupies the same place on U_2 in terms of temporal order as E does on U_1. As we have seen, this inference requires the introduction of a temporal metric and so engenders the issue of comparison-at-a-distance.

In essence, because there is the equality of the time coordinates E and E', we have the equality of the differences of the <u>coordinates</u> E_1E and E_1E'. Grünbaum's point is that we still are not compelled to assert a <u>physical</u> simultaneity between E and E'.

Suppose we counter Grünbaum as follows: Reichenbach's logical circle of simultaneity and velocity has been bypassed. Time dilation and its ensuing discordant readings on transported clocks has been rendered innocuous. Furthermore, when distant clocks are set by slow-clock synchrony they are found to be in standard signal synchrony which presumes $\varepsilon = \frac{1}{2}$. In sum, there are two independent methods which yield the same results. Clearly most would agree that concurring, independent, methods must say something about the universe.

Grünbaum's reply is that both of these methods have a convention in them and can be made to concur. (Refer to the diagram in §3.3.2.2.) If we look at the world-line of U_1, the duration of E_1E would be $t-t_1$ (t is the time of E and t_1 the time of E_1). But for the outgoing ray, we are free to say that the durational measure of E_1E' is $2\varepsilon(t'_1 - t_1)$ where $(0<\varepsilon<1)$ and t'_1 is the reading of U at E'.[34]

Grünbaum further shows that, if we take $\varepsilon \neq \frac{1}{2}$, event, E_x on U_1, other than E, is declared simultaneous with E'. Because of the lack of physical connection, which event is really simultaneous with E' is a conventional issue, not a physical one. Which event, E_x is simultaneous with E', will be a function of the choice of ε. Furthermore, because we still have a non-trivial element of conventionality here, we cannot assert the empirical equality of the to and fro velocity of light. These values are governed by the following equations:

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[34] Grünbaum just states this but this result follows from the physical fact that events on the open interval E_1E_3 are non-connectable with E'. We are free to employ, within limits, a non-standard time metric on the outgoing rays. We know that:

$$t'_s = t_1 + \varepsilon(t_3 - t_1)$$

We know non-conventionally that t'_s is between t_1 and t_3.

We know that: $t'_s - t_1 = \varepsilon(\text{round-trip time})$

So we can say that the temporal duration of $t'_s t_1$ is given by:

$$2\varepsilon(t'_s - t_1)$$

And so, $t'_s t_3$ is $2(1-\varepsilon)(t_3 - t'_s)$. The important idea here is that we are free to employ different time metrics on different world-lines.

$$v_{AB} = \frac{d}{2\varepsilon(t'_{s} - t_{s})}$$

$$v_{BA} = \frac{d}{2(1-\varepsilon)(t_{3} - t'_{s})}$$

What we ultimately have here is the possibility of two conventions coinciding. If we assume isotropy in light speeds, they coincide. But this coincidence of conventions, as Salmon writes, does not cleanse them of their conventionality, "it merely reduces the motivation to adopt a non-standard convention."[35]

Slow-clock synchrony cannot assert the equal velocities of light and so cannot confer factual truth on the simultaneity relations it establishes. If we are is willing to say that slow-clock synchrony stipulates simultaneity, then the to and fro velocities become empirical. (In other words, distant simultaneity is achieved and a measurement of one-way light speeds is possible.)

Clock behaviour under slow-transport is a physical fact. Moreover, it is a necessary condition for simultaneity relations to be established by a physical procedure. However, it is still Grünbaum's contention that clock transport is not sufficient. The grounds for this insufficiency are now evident -as they are not in the epilogue to Bridgman's work. Unlike the epilogue to Bridgman, it is now more evident why it is insufficient. The insufficiency stems out of Grünbaum's thesis that space and time intervals are metrically amorphous. E&B remarked that conventionality in

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[35] **Wesley Salmon, "The Conventionality of Simultaneity,"** ***Philosophy of Science*****, 36, 1969, 52.**

simultaneity is interesting only if distant simultaneity is established solely by light signals.[36] This is not the case. There is another method, yet the conventionality of simultaneity is anything but an uninteresting issue. The debate over the status of the metric is not to be glossed over.

In sum, the question of the conventionality of simultaneity includes the metric amorphousness as a necessary part. Moreover, it is only necessary (and not sufficient) because we have seen that non-conventional simultaneity held in the Newtonian universe, and yet that world postulates continuous temporal and spatial manifolds.

§3.4 Transported Clocks: Ellis' Reply

Ellis begins by stating that "Conventionality in Distant Simultaneity" has been completely misunderstood by not only Grünbaum but also van Fraassen, Salmon and Janis, all of whom replied in various ways to E&B. This misunderstanding is quite justified in my opinion, since the E&B paper clearly looks like it is trying to refute the view of the conventionality of simultaneity. But Ellis emphatically insists that he and Bowman were not out to refute the thesis that distant simultaneity is Riemann-conventional. Rather, they only wished to show that this is a "hollow kind of conventionality."[37] This type of conventionality

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[36] Ellis and Bowman, "Conventionality in Distant Simultaneity," 127.

[37] Ellis, "On Conventionality and Simultaneity -A Reply," *Australasian Journal of Philosophy*, 49, 1971, 177.

does not entail that there is no good physical reason for asserting simultaneity of distant points. The main point of their paper was to refute the view that the time dilation predicted in the STR precludes a consistent transport criteria. This, I agree, they have done.

The hollowness of Riemann-conventionality, according to Ellis, stems from the fact that, for every assertion of quantitative equality of two objects with respect to some quantity X, which depends on local comparisons, it is a convention whether or not we say the separated objects are still equal with respect to X. In other words, hollowness or triviality according to E&B is co-extensive with generality. It was pointed out in §3.3.2.2 that Grünbaum rejects this view. It is necessary, however, to clarify the issue. Is Riemann-conventionality a logical problem of comparison-at-a-distance, or is it a product of ontological considerations? For Grünbaum, it is the lack of structure in the universe that engenders this conventionality. E&B treat it as a rather trivial problem stemming from logical considerations. Whether or not Grünbaum's thesis of the structure of space-time holds, this is not a trivial issue.

Although Ellis' paper contains much of interest, unfortunately, it often makes a straw man out of Grünbaum. Ellis claims that much of the debate between himself and Grünbaum is an epistemological one. In section one of the paper Ellis lays out the epistemological background. He sets up an argument to show that given a system of relations, R_1, satisfied on a domain, D, there is a symmetry exhibited by situations calling for the rejection of laws and retention of conventions and vice-versa. His point is that this symmetry illustrates that the same epistemic level applies to what are called "conventions" and to what are deemed "empirical laws." Essentially, this is a rejection of the analytic-synthetic distinction in the philosophy of science.

Ellis asks us to suppose that we have an alternative and incompatible set of relations, R_x on D, which corresponds to R_i. By an analogous argument, we do not have the empirical-conventional split within R_x either. Ellis wishes to stress that the laws which emerge from the two sets of relations will be empirically equivalent but not compatible. (Suppose that R_i yields isotropic laws and R_x, anisotropic.) It is Ellis' next few moves which require commentary.

He says that to accept R_x would be to accept "anisotropic or spatially or temporally dependent laws, and normally to accept such a set of laws is to be committed to there being some explanation for their anisotropy...."[38] What is the force of "normally" here? In this sentence, it is an argument from the practice of scientists. However, this <u>alone</u> is not sufficient since practices change. Ellis intensifies his argument when he asserts that "to accept any anisotropic law is therefore to accept that it is not fundamental...."[39] This is now a metaphysical argument: there is

[38] Ellis, "Conventionality in Distant Simultaneity -A Reply," 183.

[39] Ellis, "Conventionality in Distant Simultaneity -A Reply," 183.

a certain "natural state" or "proper form" from which discrepancies must be explained. But, what is the status of this assertion? Can it not be the case that anisotropies are simply brute facts?[40] Furthermore, Ellis begs a key question since he assumes in the first place that there is some sort of "intrinsic structure." Therefore, anisotropies are real deviances from the "true values" (for length, duration, velocity, etc.) accorded by this structure. Grünbaum denies such an intrinsic structure in his amorphous manifold thesis. Again, whether or not this thesis is acceptable, Ellis is still making huge presuppositions. In sum, Ellis needs to support these types of appeals since from the work of Kuhn the argument from practice may be shaky, or at least not perfectly straightforward. Furthermore, from quantum theory, there may be brute effects without causes (the issue of hidden variables in quantum theory is still controversial.) Finally, he would have to directly refute, or at least attack, the amorphous thesis.

Ellis further remarks that the main difference between himself and Grünbaum is the issue of equating theories. He states that Grünbaum simply regards empirical equivalence as a necessary and sufficient condition for theoretical equivalence. Ellis proceeds to construct a general attack on this view. This is a straw man tactic since Grünbaum does not advocate this type of equivalence tout

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[40] This type of answer, not one Grünbaum would completely agree with, parallels Lawrence Sklar's manoeuvre which says that we may incorporate absolute motions such as "A is absolutely accelerated" into a relationalist ontology. Such terms are no longer regarded as elliptical; they are now regarded as monadic predicates. All I am suggesting is that one may perform a similar move here. We do not have to agree that all anisotropic talk is elliptical talk. For more on Sklar *cf.* his *Space, Time and Spacetime* (Berkeley and Los Angeles: University of California Press, 1974) 229-234.

court. For instance, he tells us that, although he may use it in certain instances, he rejects applying it as Reichenbach does in all areas of inquiry.[41]

Ellis also asserts that we need a convention which says that all isotropic laws must be expressed in isotropic equations and that all anisotropic laws, in anisotropic equations. Lacking this convention, we do not know what our theoretical commitments are. However, the situation is not as extreme as Ellis says. Suppose we have two empirically equivalent theories: T_1 and T_2. The former's laws are isotropic, $\varepsilon=\frac{1}{2}$, and the to and fro velocities of light are equal. T_2 has anisotropic laws, $\varepsilon\neq\frac{1}{2}$, and the to and fro velocities are unequal. Grünbaum would say that the two theories have to at least be committed to the topological condition for light. We would be committed to enough structure by either theory to satisfy this topological restriction. Yet we would not know anything about metrical commitments. We simply cannot achieve that fineness of grain in our theories. In essence, we could violate Ellis' call for a convention and still not lose all sense of theoretical commitment.

Earlier Grünbaum told Ellis to slow down and examine the implicit conventions within his own arguments. Interestingly, Ellis turns the tables and beats Grünbaum at his own game. Recall that Grünbaum employed a Newtonian world to show that absolute simultaneity can coexist with a metrically amorphous space-time.

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[41] **Grünbaum, *Geometry and Chronometry in Philosophical Perspective*, 52. Also, *cf.* 67 for a flat-out rejection of these types of assertions.**

But Grünbaum used a causal order to define temporal order. In other words, time order between events was structured according to the idea that the events were or were not the termini of casual chains. But Ellis quite rightly points out that this is importing a metaphysical presupposition of the causal theory of time into this world. Certainly Newton, who views time as independent, would regard this to be an illegitimate move.

Ellis states that to define time ordering in Grünbaum's fashion is to no longer use a local comparison. There is no restriction on the distance between compared events. Hence, this does not impugn the view that, if we use local comparisons to define simultaneity, it is conventional in the sense that any relationship of quantitative equality which is a function of local comparisons is conventional.

Thus, the question is whether or not comparing clocks in the way Grünbaum did is still to be called a local comparison. Certainly it is local in that the clocks were compared when close to each other. The question is whether the use of arbitrarily fast chains renders clock comparison a non-local comparison. This appears to be simply a debate about semantics. When should we use the term "local?" We <u>could</u> simply say that there is a combination of local and non-local comparison in Grünbaum's view. But what Grünbaum was mainly after still stands. The point is that even though we may have a metrically amorphous manifold, it does not automatically follow that all types of distant comparisons become conventional. We must also have a limiting speed for conventionality in simultaneity to arise.

But we may simply ask Grünbaum: "why use causal order to define temporal order?" Grünbaum does not explicitly address this question. He does examine the problems of <u>how</u> to construct such a definition, but not why. The use of causal connectedness, as illustrated in §1.1, goes back at least to Leibniz. This usage cannot be written off simply as a positivist manoeuvre.

The convention employed by Grünbaum in the Newtonian universe is that, although there is no upper limit on the round-trip speed of a signal, there is a lower limit to the round-trip signal time, zero.[42] If we let the round-trip time from point A to B and back be t_{ABA}, we have the following equation:

$$t_{ABA} = t_{AB} + t_{BA}$$

As the velocity increases, t_{ABA} goes to zero; however, it does not follow that either t_{AB} or t_{BA} goes to zero. We could have negative one-way signal times. Indeed, if negative signal times are allowed, then zero round-trip times lead to the possibility of infinitely many planes of simultaneity for any event. If we have event A and we send a signal out, it <u>may</u> be the case that the signal travels equally fast in all directions thus defining the common sense view of simultaneity. Suppose we have negative signals. In this case, the signal left A at t_o, travelled at a finite speed backwards in time, was reflected at B at some t_x prior to t_o, and travelled at a finite speed forwards in time to arrive at A at t_o. Consequently,

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[42] **Ellis, "Conventionality in Distant Simultaneity -A Reply," 190.**

A and B are to be classified as simultaneous. If the topological condition for light here is simply obeying the zero round-trip time, then we can construct as many planes of simultaneity as we like. There is more freedom here than in the STR's universe.

Grünbaum may respond that this is not a convention since if we agree to having negative signal-times we could have causal violations. But we do not observe such violations. However, Grünbaum does universalize our limited non-observance to a general result and this is clearly a convention. My point here is simply to stress that Grünbaum as well employs certain assumptions to keep his view intact. Time travel has been more the domain of science fiction than of science. Philosophically, it engenders paradoxes, although it has crept into the domain of particle physics. It appears that Grünbaum would have to close it off a priori. I find it problematic when a philosophical conviction blocks possible avenues of scientific advancement and philosophical interpretation.[43] This issue will be examined in more detail in §4.

I wish to look briefly at the issues of non-standard simultaneities, and the weak and strong versions of the principle of relativity. To begin with, Ellis replies that, if we want all **R** to be numerically the same, then Grünbaum is quite right that it is the case that only $\varepsilon=\frac{1}{2}$ will work. But Ellis says he only insisted that if R_0 is any relationship which could be considered as a

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[43] **This does not contradict my view expressed in §3.3.2.2. There, the philosopher's worry was a *posteriori*, that is, after a concept is accepted, the concern is over what type of ontological status it should be awarded. The a *priori* worry here could reject even the entertaining of a concept. Metaphorically speaking, the philosopher should be an active reader of science, neither a monk nor a judge.**

criterion for synchrony, then: [(AR_0B) & (BR_0C)] then AR_0C. The point was that if $\varepsilon \neq \frac{1}{2}$, R_0 is an anisotropic relation. In other words, if we choose anything other than $\varepsilon = \frac{1}{2}$, the setting of clocks is a function of the angle of a line segment connecting them and some fixed standard line. Ellis calls R_0 a single relationship; Grünbaum does not. Different values of ε can be entertained within R_0 according to Ellis, and the above syllogism is valid. If one follows Grünbaum, the above syllogism is not valid.

Ultimately, this particular issue is not terribly interesting since all agree that $\varepsilon \neq \frac{1}{2}$ are possible. How we ultimately wish to phrase the principle of transitivity is not very important. The important disagreement is over whether $\varepsilon \neq \frac{1}{2}$ is acceptable.

Recall Grünbaum's argument that, two equations, one in Cartesian coordinates, the other in polar, are in different forms since they are not linked by the linear Lorentz transformations. However, we would not say this violates the weak principle's factual side. Ellis says that these two equations are not really in different forms since:

> **By saying that two expressions have the same mathematical form I mean only that either can be derived from the other by the uniform substitution of variables.[44]**

For example, given an x,y plane equation, Z, in Cartesian coordinates, we simply substitute rcosΘ for x, rsinΘ for y, and Z is now expressed in polar form. But this still is in the spirit of §3.3.2.1 where Grünbaum argued that it is a convention as to what is meant by the "form of a law." Ellis' reply simply offers a

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[44] **Ellis, "Conventionality and Distant Simultaneity -A Reply," 194.**

convention which states when equations are in the "same mathematical form." In sum, it is all still a case of conventions. Consequently, Grünbaum is correct in this area.

The argument over the strong principle is more complicated because neither side even agrees on the formulation of the principle itself. Ellis replies that Grünbaum has failed to clarify what he thinks the distinction between the strong and the weak principle to be. To settle this particular dispute would be a formidable task since agreement is first needed on the formulation of the principle. But this would be merely the start since formulations contain assumptions or conventions, hence, we would need to settle the status of any conventions involved in the agreed-upon formulation. For example, the concerned parties disagree over how and where the condition of linearity fits into the strong principle. Grünbaum thinks this condition has an important conventional element; E&B do not, they agree it does have a conventional component, albeit trivial. Settling this dispute is tantamount to settling the argument over the status of Riemann-conventionality -is it simply true but trivial? This is an important issue in the debate over slow-clock synchrony and will be discussed in the conclusions. As a last note on this principle, it is important to note that, if we achieved some sort of agreement on the aforesaid issues, we would still need agreement as to how this principle fits into the STR. Furthermore, we would need agreement on its importance to the STR.

We could argue that "common sense" about time and space would side with Ellis. It seems rather odd to admit differences in the to and fro v locities of light, thus, accepting non-standard simultaneities, and yet agree that not only can we not offer any reason for these differences -perhaps because of technical limitations- but that there simply is no explanation. However, Grünbaum is asking us to investigate what we think are sacrosanct notions such as common sense. On the other hand, there is a common sense reaction to the highly metaphysical notion of time as expressed by Newton. What Grünbaum is <u>trying</u> to do is de-mystify the notion of time as being something absolute.

§3.5 Transported Clocks: Summary

I have argued at length that Grünbaum can defend himself against E&B. Their attempt to restrict non-standard simultaneities by incorporating relativity principles either smuggles in conventions at the outset or simply makes incomplete appeals. Most importantly, their view of Riemann-conventionality as hollow stems from their view that it is simply a result of measurement theory and not an ontological claim about the lack of structure in the universe. It is the Riemann-conventionality of simultaneity that allows Grünbaum to maintain his view in spite of the physical behaviour of clocks under slow-transport.

There is a meta-argument which runs through Grünbaum's writings in this exchange over simultaneity: he asks us to accept that science does not give a complete picture of the world. I do not think this notion of incompleteness is necessarily that of anti-realism, that is, science _just_ gives an empirical fit. Rather, I interpret it as an incompleteness with respect to our questioning of the world. What is to be called _real_ in the first place is set up by a conceptual scheme. The world may or may not cooperate with our schemes. For example, we just may have to tolerate a restricted range of formulation for theories which includes what we would _call_ anisotropic as well as isotropic ones. This is not simply because we cannot explain them (due to mental or physical human limitations), nor because our science does not give any information of the world and therefore any number of empirically equivalent descriptions work, but because the world itself may be such an entity that contains gaps corresponding to our instinctual calls for explanations. To use Quinean parlance, in some cases there is just no fact of the matter. The fact that there is no fact of particular matters may strike at the heart of our intuitions.

All this of course, does not entail immunity from other possible attacks, some of which shall be examined in the concluding chapter. Also, as we have seen, Grünbaum's views themselves may block investigations of the world and interpretations of them; these too, shall be examined.

CHAPTER FOUR: CONCLUSIONS

§4.1 The Amorphous Manifold: An Open Problem

It has been shown that Grünbaum's defence of the conventionality of simultaneity ultimately rests on two arguments: the metric amorphousness of the space-time manifold and the limiting speed of light or causal connectibility. Consequently, there are two main fronts on which to launch an attack: either refute his view of the metric or show that causal connectibility can do more than Grünbaum thinks. The former, extrinsic critique, has not been successfully achieved. The latter, intrinsic critique, has been articulated by Malament and will be examined in detail.

The classic attack on the conventionality of the metric is Putnam's "An Examination of Grünbaum's Philosophy of Geometry."[1] Putnam argues that Grünbaum's position is, at bottom, a trivial semantic issue of assigning a meaning to the uncommitted noise "congruent."[2] Grünbaum defends his position, argument by argument, in "Reply to Hilary Putnam's 'An Examination of Grünbaum's Philosophy of Geometry.'"[3] There is not enough space to examine all his arguments, but Grünbaum does manage to save his position. However, this should not be regarded as an endorsement of his position, merely that it remains plausible.

I will offer a few reasons why this is so. I will briefly

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[1] Putnam, *Mathematics, Matter and Method*, 93-129.

[2] Putnam, "An Examination of 'Grünbaum's Philosophy of Geometry,'" 103.

[3] Grünbaum, *Geometry and Chronometry in Philosophical Perspective*, 195-371.

examine Michael Friedman's criticisms of Grünbaum. Friedman is chosen since he embodies perhaps the strongest anti-conventionalist view and articulates the standard criticisms. He also tries to shore up Putnam's case by responding to Grünbaum's responses. In addition, Friedman, like many others, regards Malament's attack as the complete refutation of the conventionality of simultaneity issue. I will argue that Friedman's criticisms are not wrong, but inconclusive.

The main problem with Grünbaum's view of the metric is that it is an unclear doctrine.[4] Stating necessary and sufficient conditions for either extrinsic or intrinsic relations on manifolds has not been successfully accomplished. However, this problem alone is reason for further investigation, not outright rejection.

§4.1.1 Friedman's Extrinsic Concerns

Friedman calls Grünbaum an ideological relationalist. This ideology places limits on theoretical vocabulary.

> It wishes to limit the vocabulary of our theories to some stock of preferred, not obviously spatio-temporal, predicates: for example, predicates definable in terms of "causal" relations.[5]

The standard criticism of Grünbaum is as follows. The fact that metric relations are definable from topological relations in discrete space and not so in continuous space does not entail that metric relations do not exist in continuous space. For that, we

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[4] Indeed, Winnie shares this concern, *cf*, "The Causal Theory of Space-Time," 193-194.

[5] Friedman, *Foundations of Space-Time Theories*, 217.

need an additional premise, and this is where the ideology enters. The missing premise is that "only spatio-temporal properties and relations that objectively exist are topological properties and order relations."[6] As I mentioned in the previous chapter, and Friedman also complains, why should we start with such a basis?

Grünbaum's response is simply that given the state of our present knowledge, this is the best position with which to start. He starts with such a basis because of pragmatic concerns. However, such a basis, Grünbaum admits, may not be the best position tomorrow. Consequently, Grünbaum softens the "positivistic" senses that are currently, and erroneously, attached to this view.[7]

It is important to realize that, in addition to the problems surrounding the metric in a continuous space, it is not even clear what we would say about the metric of a discrete space. As outlined in §2, it is possible that, on the results of the quantum theory, space is indeed quantized and so an intrinsic metric would be built-in. This would not only affect Grünbaum but all those who incorporate a smooth continuous manifold as a fundamental part of their space-time philosophy. But even in this case, why should we, as Sklar writes (bypassing the difficult issue of what a multi-dimensional granular space would mean), take a one-dimensional granular space as problem free?

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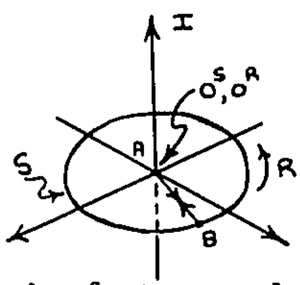
[6] Friedman, *Foundations of Space-Time Theories*, 304.

[7] Winnie makes the same point that causal theories are not necessarily positivist or relationalist theories. We could attribute an ontological status to the causal structure thus embracing a realist position. *cf*, "The Causal Theory of Space-Time," 198-199.

Even in the one-dimensional case of a simple ordered set, it is not clear why we should take the *real* distance between points to be a function of the number of points between them.[8]

To support his ontological view of the amorphous nature of space-time, Grünbaum argues that relativity theory itself employs alternative metricizations. He employs two such arguments against Putnam and it is this use that Friedman attacks. The first deals with two coordinate systems. Suppose we have a rectangular system, I, which is inertial. I has axes, x,y,z and temporal axis, T. Superimposed on the x,y plane of I are two systems of polar coordinates: one stationary, S, the other rotational, R. Let O^S and O^R be the coinciding centres of S and R respectively. Refer to the following diagram for clarification:



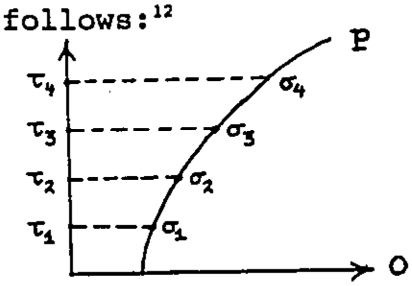
- A: emitted signal from O^S,O^R
- B: reception of the signal at a space-time point
- C: return of the signal to O^S,O^R
- ds_4^S: space-time interval of AC according to S
- ds_4^R: space-time interval of AC according to R
- ds_{1AB}^S: temporal separation of A and B according to S
- ds_{1BC}^S: temporal separation of B and C according to S
- ds_{1AB}^R: temporal separation of A and B according to R
- ds_{1BC}^R: temporal separation of B and C according to R

Here $ds_{1AB}^S=ds_{1BC}^S$ and $ds_{1AB}^R \neq ds_{1BC}^R$. This variance however, does not entail that $ds_4^S \neq ds_4^R$. So far, all this follows from relativity theory, for spatially separated and relatively moving frames. However, what is crucial to this example is that the clocks which make the temporal measurements are spatially coincident upon the

[8] **L. Sklar, "Facts, Conventions, and Assumptions in the Theory of Spacetime," in *Philosophy and Spacetime Physics* (Berkeley and Los Angeles: University of California Press, 1985) 121.**

time of measurement.[9] Although S and R agree on the magnitude of the space-time interval, they will not agree on the temporal magnitude.[10] Since they are measuring the <u>same</u> temporal intervals, AB and BC, there is a clear case of alternative temporal metricization. Hence, Grünbaum concludes that relativity theory supports at least the absence of any temporal metric.[11]

Friedman argues that this is very misleading. But when he explains why, he bases his explanation on another situation: a single accelerating object in an inertial frame. His approach is as follows:[12]



- o: inertial frame
- τ: time in the inertial frame
- p: accelerating object's trajectory
- σ: time along this trajectory

Clearly, the temporal intervals congruent according to τ are not so according to σ. It is not necessary to complete the rest of Friedman's argument since the concern is with this first move.

Why change the situation? Friedman simply asserts that Grünbaum's argument can be dealt with more simply in this way, but does not argue for it. It is difficult to say whether or not the

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[9] **The clocks at O^S and O^R are spatially coincident and so too are the clocks at event B.**

[10] **Note that the coordinate systems will agree on the spatial separation of the events. The relative angular velocity of the coordinate systems is perpendicular to the spatial measurement in question; therefore, no spatial Lorentz contractions exist. This situation does not hold in Friedman's model.**

[11] **Grünbaum, "Reply to Hilary Putnam's 'An Examination of Grünbaum's Philosophy of Geometry,'" 306-307.**

[12] **Friedman, *Foundations of Space-Time Theories*, 306-307.**

two different situations lead to exactly the same conclusions. Unlike Grünbaum's example, the clocks are no longer spatially coincident when temporal measurements of the events are made. Secondly, in Grünbaum's example, which deals with uniform circular motion, the acceleration is not a change in speed but in velocity. Velocity is a vector quantity; it has magnitude and direction. In uniform circular motion it is only the latter that changes. Yet in Friedman's explanatory model there is a change in speed. Finally, the spatial measurements between events made in the coordinate systems would not agree due to Lorentz contractions whereas this does not occur in Grünbaum's example. (Both S and R would give the same numerical value to distance AB.) Because of these concerns it is this first step that I hesitate to grant to Friedman. He needs to argue for this move before proceeding. However, if this move is granted, his argument succeeds.

Finally, it must be noted that Grünbaum's argument from relativity only shows whether or not relativity (in this particular case) employs alternative metricizations. Even if it were demonstrated that, no argument could be constructed from relativity which would support Grünbaum's view of the metric, this would not automatically refute his ontological thesis of alternative metricizability. However, it certainly would diminish the plausibility of his thesis given the success of relativity. In sum, it would only be the case that his thesis does not enjoy support from relativity theory.

The other argument Friedman attacks is Grünbaum's contention that:

> With a suitable *change* in the matter distribution and hence in the metrical field, metersticks will coincide with different disjoint intervals under transport in the *same* region of space of a given reference system. But *since there is no intrinsic metric, the stick can be considered self-congruent under transport in the given region in each of infinitely many DIFFERENT patterns of coincidence behaviour under transport.*[13]

Consequently, Grünbaum argues, there is no sense in talking about the metric of a manifold. The same manifold may be ascribed different metrics. Friedman says that this argument only shows that the metric is dynamical, and not conventional.[14] Friedman is correct that the argument does not accomplish what Grünbaum claims, but this is because there is some question-begging here. If it is granted that there is no "real length to the stick" in the first place then the argument goes through and even talk of the dynamic character of space-time is conventional. This argument of Grünbaum's is, to begin with, inconclusive since it simply begs the whole issue. Consequently, Friedman's criticism does not conclusively say anything either. Again, all this does not refute Grünbaum's view, but simply illustrates that it does not enjoy theoretical support from relativity in this particular case.

§4.2 General Concerns: Theories And Domains

We may argue more directly against Grünbaum's ontological position by saying that his project constrains us to classical views. His notion of causal connectibility relies on the assumption

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[13] Grünbaum, "Reply to Putnam's 'An Examination of Grünbaum's Philosophy of Geometry,'" 231.

[14] Friedman, *Foundations of Space-Time Theories*, 307.

that particle trajectories in the world are continuous like those of billiard balls on a pool table. Quantum Mechanics' uncertainty relations question this assumption. Furthermore, Grünbaum's bearers of causal connections, genidentical particles, could be problematic. Quantum theory questions the existence of such particles. However, even if they exist, are they the sole bearers of causal relations?[15] It is important to note that, before bringing in quantum theory, it must first be interpreted. This is a huge issue in contemporary philosophy of science, far beyond the scope of the present work, but it is necessary to stress the following: the domain of which Grünbaum speaks and that of quantum theory are different. Grünbaum acknowledges the results of particle theories which suggest backwards time travel. It may be the case that the particle is in "two places at once."

> But this fact does not disqualify our definition of simultaneity. For the topology of time whose physical basis our analysis is designed to uncover is defined by (statistical) *macro*-properties for which these difficulties do not arise.[16]

In essence, Grünbaum could defend himself by saying that temporal relations, grounded on his view of causal connectibility and thus the conventionality of simultaneity are emergent properties. Granted that scientists have tried, in a Cartesian fashion, to achieve the finest-grained primitives possible, it is nonetheless

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[15] This is suggested by quantum theory's reduction of the wave packet. Prior to observation, we ascribe a state S_a to a quantum-mechanical system. S_a has a definite probability distribution for any quantity we may wish to measure. A strong realist interpretation would regard the change in the system after observation, from S_a to S_b (the reduction of the wave packet), as a real, discontinuous and instantaneous change in the system. Consequently, there is space-like causation unmediated by genidentical particles.

[16] Grünbaum, *Philosophical Problems of Space and Time*, 207.

true that such emergent properties are taken seriously. Consequently, if temperature is an allowable, statistically emergent property, why not time?[17] What is being suggested here is that, if we automatically rule out different explanatory primitives for different domains with respect to Grünbaum, we agree not to grant it to other cases.

The unity of science is an exceptionally powerful and compelling theme. But even granting this, the point being made here still stands: interpretation of theories and their respective domains has to be done before the results of one are used to support or refute results of another.

§4.3 The Main Conclusion: Protean Simultaneity

The main conclusion of this investigation is that simultaneity is a concept which will not be experimentally captured. For every experiment set up, there will be too much open to debate. Philosophers rightly argue that it is dangerous to make such generalizations, hence, some reasons are required.

First, with respect to slow-clock synchrony, it has been shown in detail just how quickly a seemingly simple desire to determine distant simultaneity leads into some of the most difficult problems in the ontology of space and time in twentieth-century philosophy

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[17] Although it is beyond the scope of my work here, it is appropriate to note that this approach, the emergence view, has been applied to the space-time manifold. For more on this *cf*, E.J. Zimmermann, "The Macroscopic Nature of Space-Time," *American Journal of Physics*, 30, 1962, 97-105. Furthermore, this approach may prove to be useful in the present controversy over the hole argument. It may be fruitful to treat the manifold as a statistical entity, thus avoiding the so-called problems associated with ontological commitment.

and physics. Furthermore, it has also been shown how this leads into the central epistemological debate of just what we take a theory to be and what the fundamentals of explanation are. Finally, the most difficult issue raised is the most innocent in appearance: when do we call something trivial?

Second, it is important to consider a paper of Wesley Salmon's. In "The Philosophical Significance of the One-Way Speed of Light," he provides an overview of the difficulties surrounding experiments to determine the one-way velocity of light. Throughout the history of science and up to the present, attempts to determine one-way light speeds have incorporated non-trivial conventions.[18] Experiments are still going on today although these too incorporate many of the conventions Salmon uncovers.[19]

We may wish to counter the main conclusion arguing that it is yet another example of a "philosopher's a priori worry" which were rejected in general in §3.4. However, this type of argument still must be used quite carefully. To clarify, the argument from Salmon's work to support the elusiveness of simultaneity is an historical argument. It is analogous to the call for a new approach to the philosophy of mind because of the repeated failures of the previous approach. With respect to simultaneity, it is not simply

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18 Salmon, "The Philosophical Significance of the One-Way Speed of Light," *Nous* 11, 1977, 253-292.

19 For a more recent examination of an attempt and an exposition of the implicit conventions which resemble those discussed by Salmon *cf.* R.K. Clifton, "Some Recent Controversy Over the Possibility of Experimentally Determining Isotropy In The Speed Of Light," *Philosophy of Science*, 56, 1989, 688-696.

the case that <u>one</u> experiment has failed; many attempts have failed. In essence, there is a family of conventionalist assumptions that run through these attempts. However, it does not follow that we should embrace a verificationist line and declare simultaneity itself meaningless or void. We simply have to look at the concept more holistically. How many experimental failures do we need to call off the empirical investigation? This question is probably unanswerable, since we never can say what the next day will bring. But there comes a time when we should consider old problems in new ways. Perhaps an analogy will make this clearer. Just as the search for the driving force behind Aristotle's projectile was abandoned because the approach to the question of motion was changed, the search for a physical method to ascertain distant simultaneity should be abandoned and a new approach towards determining simultaneity taken. This view is embodied by criticism such as Friedman's which argues against Grünbaum from theoretical positions. In other words, Friedman does not offer physical methods to refute Grünbaum's view; rather, he tries to counter it by arguing that it does not enjoy support from relativity. His endorsement of Malament's argument is much the same type of approach. Only now the attack is much more serious since Grünbaum's conventionality appears to be fundamentally <u>contradicted</u> by the causal theory of space-time formulated by A.A. Robb.

It must be stressed that Grünbaum has neither been vindicated nor vitiated. This is too simple a dichotomy. I will clarify this presently.

The fact that experiments in simultaneity do lead us into so many questions in the ontology of space and time as well as the epistemology of science provides a clear example of how many auxiliary assumptions are built into these types of investigations. In other words, my investigation here dovetails with the holistic view of Duhem and Quine. Hence, the examination of simultaneity should proceed on the theoretical level. Can we formulate the STR without one-way velocity assumptions? The work of John Winnie demonstrates that it is possible to consistently formulate the STR without assuming any value for Reichenbach's ε. In Winnie's work, ε is simply carried through the formulation as a free variable.[20] Winnie derives the Lorentz transformation equations in just such a fashion. This does not exhaustively show that the one-way velocity of light is conventional and thus the conventionality of simultaneity, but it does lend further weight to the call for the end of simultaneity methods. This stems from the fact that an STR formulation with ε as a free variable entails key experimental results predicted by the standard STR ($\varepsilon=\frac{1}{2}$) formulation. Experimentally, or kinematically, the STR without a specific ε value is equivalent to the STR with an ε value.[21] Reichenbach's theory of equivalent descriptions would stop here, claiming nothing more need, and more importantly, can, be said. Indeed, nothing can force us to decide between these empirically equivalent

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[20] **Winnie, "Special Relativity Without One-Way Velocity Assumptions."**

[21] **However, the possible epsilon value in the former must still satisfy the topological condition for light.**

formulations. Which formulation of the STR we accept is based on descriptive simplicity only: whichever formulation makes the equations the easiest to use. It turns out that $\varepsilon=\frac{1}{2}$ is the easiest to use, but this has nothing to do with truth. However, Grünbaum, since he is not a positivist, could not stop here. His conventionalism is ontologically grounded. Experimentally or kinematically speaking, the Copernican and Ptolemaic systems are equivalent although dynamically they are not. It is in this latter dynamical sense that Malament seems to have refuted the conventionality thesis by using Grünbaum's non-conventional causal connections. Consequently, even though the two formulations of the STR are empirically equivalent, Grünbaum would be forced to admit that they are not theoretically equivalent. This is not surprising since Grünbaum admits that empirical equivalence is a necessary - but not a sufficient- condition for full equivalence.

§4.4 The Hidden Strength of Causality: Malament's Intrinsic Concerns

A number of issues must be kept clear. First, Malament's result does contain metaphysical presuppositions and these will be exhibited.[22] Second, it does not follow from the unique causal definition of standard simultaneity "that the adoption of an alternative (non-causally definable) simultaneity relation must yield empirical predictions in conflict with those yielded by the

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[22] I am in full agreement with Sklar who writes that "one can extract only so much metaphysics from a theory as one puts in."("Time, Reality and Relativity," in *Philosophy and Spacetime Physics*, 292.)

adoption of standard simultaneity."[23] Hence, experimentally, nothing changes even if Malament's proof goes through. Also, the conventionality thesis per se is unaffected, only Grünbaum's defence of it is destroyed.[24] Reichenbach's, for example, is fundamentally unaffected.

Malament's argument raises a number of interesting issues. The first is that of formalization. It seems that, as soon as a scientific theory gains recognition, philosophers formalize it. However, as Sklar argues at length, formalization is not simply an empty exercise in logic.[25] There are presuppositions buried in a formalization. Hence, we must be cautious about accepting ontological results from a given formalization for they may have been previously inserted. Clearly, Sklar's warning must be heeded in the present case for Malament writes that his result, that is, the causal and unique definition of simultaneity, "is a trivial consequence of basic facts about the geometric structure of Minkowski space-time first noted by A.A. Robb."[26] It must be stressed that it is the interpretation of the mathematics -not the mathematics itself- that is currently under investigation.

Another issue is that of local and global considerations. The

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[23] Winnie, "Introduction," *Nous*, 11, 1977, 208.

[24] David Malament states that he does not share the view of defining time causally. What he is after in this proof is the defeat of the conventionalist defence on its own terms.

[25] For more details *cf.*, Sklar, "Facts, Conventions and Assumptions in the Theory of Spacetime."

[26] Malament, "Causal Theories of Time and the Conventionality of Simultaneity," *Nous*, 11, 1977, 294.

discussion here will help settle the semantic game that Ellis and Grünbaum were caught in towards the end of chapter three.

Briefly, Robb's formalization of the STR is a causal reconstruction. His primitives are a domain of point events and a relation called, "after," defined on this domain. The "after" relation can be intuitively thought of as follows: "a is after b" means that we can send a causal signal from b to a where a and b are distinct events.[27] On this relation are imposed twenty-one axiomatic conditions to guarantee an isomorphism between the structure of real and causally connected points and the mathematical structure. Furthermore, Robb shows that one can introduce definitions which can capture concepts such as time-like, space-like and null-like connectibility, as well as congruences between separated intervals. Malament extends these results by showing that, on the basis of Robb's formalization, a simultaneity relation can be defined which is unique and corresponds to $\varepsilon = \frac{1}{2}$. Any other relation defined will give non-unique values. Thus, Grünbaum's view that causal relations underdetermine the metrical relations goes by the boards. But is it this simple?

Again, this is not an experiment that supposedly refutes conventionality. Hence, it does not impugn what was said earlier. This is an argument from a global perspective; it involves the entire STR. There is no mention of an experiment here at all.

[27] We may object to the presupposition of the anisotropy of time here, but it is possible to drop this presupposition and perform the Robbian construction with a symmetric relationship "either a is before or after b." *cf.* R. Latzer, "Non-directed Light Signals and the Structure of Time," *Synthese*, **24**, 1972, 236-280.

However, this argument has to be approached very carefully. First, we must investigate Robb's formalization with respect to its presuppositions. This construction assumes that space-time is Minkowskian in the STR sense, and <u>not</u> that of the GTR. In essence, Robb's definitions involve global claims. The key issue involved comes forth at the beginning of Malament's argument. Consider the following:

> **It is a basic assumption of the theory of special relativity that the class of all point events under the relation of causal connectibility is isomorphic to $(\mathbb{R}^4, k)$. To simplify notation, it is convenient to suppress the distinction and refer directly to k as the causal connectibility relation.[28]**

It is important to note that the first statement immediately rules out certain viewpoints with respect to the STR. First, this "basic assumption of special relativity" automatically disqualifies any verificationist approach. The assumption asserts a <u>global</u> claim to be a fundamental structure of the STR. Clearly, such claims are not verifiable. Second, it is important to consider just what is being asserted here. Call the class of all real point events, $\mathbb{R}^4$. Call the relation of causal connectibility, that is, the possibility of a photon connecting two events, c. The question to be answered is: is there any presupposition smuggled in when asserting an isomorphism between $(\mathbb{R}^4,c)$ and $(\mathbb{R}^4,k)$? There are different issues with respect to asserting isotropy that need be clarified. With respect to time, c is isotropic since it does not require one event to be labelled "before" and the other "after." But, because one-way velocities cannot be measured without including a non-trivial

[28] **Malament, "Causal Theories of Time and the Conventionality of Simultaneity," 294.**

conventional component, a non-conventional numerical value for c cannot be given. It is only with respect to round-trips that numerical values may be so assigned. There is isotropy only for round-trip times as well. To clarify, from a point A, a signal in any direction may be emitted and if it is reflected from points equidistant from A, the round-trip time will not vary. Hence, the question remains as to whether this isotropy extends to one-way trip times.

But k asserts precisely this latter kind of isotropy. The relation, k, is derived from the Minkowski inner product on $\mathbb{R}^4$ as follows: suppose p,q belong to $\mathbb{R}^4$ where $p=(p_0,p_1,p_2,p_3)$ and $q=(q_0,q_1,q_2,q_3)$. The inner product is <u>defined</u> by $(p,q)=p_0q_0 - p_1q_1 - p_2q_2 - p_3q_3$. From the inner product a norm may be defined: $|p| = (p,p)$, and also a symmetric, two-place relation, k: $pkq \equiv |p-q| \geq 0$.

There is a shift to a notion of causal connectibility which is different from Grünbaum's notion. From the definition of k, it follows that the same numerical value is given to pkq and qkp. Furthermore, the same numerical value is given to pkq and pk(q') (where the spatial coordinates of q have been multiplied by -1). This would have a physical interpretation of q being transported. In essence, pkq and pkq' are causal connections in physically -that is, spatially- opposite directions. Consequently, if this kind of isotropy is permitted by suppressing the distinction between c and k, then a mathematical isotropy has been transformed into a physical one. (But this <u>physical</u> isotropy was the one in question in the first place!) However, <u>if</u> the mathematical isotropy of k is interpreted to be physical as well, to conclude that only $\varepsilon=\frac{1}{2}$ simultaneity can be defined by k, would naturally follow. As a final note, consider Friedman's comments on Malament's argument which also help (although they were most likely not meant to) illustrate the "building-in" of isotropies. Friedman writes that:

> nonstandard simultaneity relations introduce an asymmetric orientation into otherwise "isotropic" Minkowski space-time...nonstandard simultaneity relations cannot be defined in terms of our "isotropic" relation k.[29]

In sum, the main problem is whether k is a good representation of c. Whether or not it is needs further argument. As it stands, this proof assumes an isotropy which is in question. Grünbaum, it must be stressed, is not advocating that we <u>should</u> adopt non-isotropic relations, just that, when we adopt isotropic ones, we should realize that it is a choice made on non-empirical grounds. Hence, other choices <u>could</u> be made as well. Friedman grants that it is ultimately by the principle of parsimony that we rule out non-isotropic relations.[30] Both at least agree that simplicity is involved when ruling out such relations.[31] In essence, unless one has already been convinced by simplicity arguments, namely that it is easier to use isotropic light speeds in physical formulation, Malament's argument will not be convincing as a refutation of the conventionality of simultaneity thesis.

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[29] Friedman, *Foundations of Space-Time Theories*, 320.

[30] Friedman, *Foundations of Space-Time Theories*, 312.

[31] Friedman thinks that non-isotropic relations would further complicate our ontology (introducing *ad hoc*, and unverifiable, structures) while Grünbaum thinks such relations would complicate our mathematical expressions.

I will use Sklar's quote to organize some further comments on Malament's argument. The key point is that the strength of the concept of a primitive (such as causality) varies from universe to universe. Sklar writes:

> ...the question of what kinds of observation would or would not be sufficient to determine fully all relevant physical features of the world depends upon what possible worlds one is willing to contemplate. And that depends upon the fundamental theory one believes.[32]

§4.4.1 Causality In The STR Universe

Suppose we are living in the pre-GTR era. We would not consider space-time as anything but flat. Consequently, we would assume the entire universe to be one type of space-time, homogeneous and isotropic. In this universe Robb's construction holds everywhere; the causal relations coincide with metrical ones. Consequently, we would agree that the coextensive nature of the predicates is a universal law-like connection, in other words, a fundamental law of nature. The universe is presumed to have a global causal structure and the isomorphism between physical space-time and $(\mathbf{R}^4, k)$ would be assumed to hold. In this universe, Grünbaum would be in some trouble. But it is hasty to assert his outright collapse.

Grünbaum could argue that we cannot use Robb's constructions to refute his view since the construction itself makes use of global properties of space-time. No experiments can test these types of claims. As a matter of fact, Grünbaum does accept this

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32 Sklar, "Facts, Conventions, and Assumptions in the Theory of Spacetime," 117. The following discussion draws heavily upon this article.

type of argument when determining the class of inertial frames.[33] He follows Reichenbach, who argues that we cannot use limited spaces, that is, local spaces, to rule out any reference frames which may appear locally inertial yet are globally accelerated.[34] No local experiments will determine the kind of space-time we are in -whether it is, or is not, Minkowskian. Thus, the global claim is meaningless, Robb's construction is based on it, therefore, it too, is ultimately meaningless, or at least underpinned by conventions. This is a verificationist defence of conventionality. We may be in a space-time which can be mapped by causality and thus simultaneity is causally, uniquely defined or we may not. Locally we could not tell the difference. Hence, let us employ a convention. Consequently, Reichenbach's approach still stands. However, Grünbaum wants an ontological, not verificationist, defence of conventionality. He used the former against Ellis and Bowman. Is it permissable to shift to the latter now? If so, then he could extend the verificationist defence by stating that the events belonging to the open topologically simultaneous interval are not themselves causally connectible with the so-called simultaneous event on another world line. Consequently, conventionality in simultaneity still stands even though we have Minkowskian space-time in the STR sense.

Lest we be too quick to condemn any mixing of realist and

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[33] Grünbaum, *Philosophical Problems of Time and Space*, 414.

[34] Reichenbach, *The Philosophy of Space and Time*, 173.

verificationist approaches, it is important to note that relativity theory itself has verificationist components in its foundations. Consider the Michelson-Morely as well as the Kennedy-Thorndike experiments. Text books on relativity theory often say that these experiments demonstrated that the absolute reference frame does not exist. That is somewhat misleading since these tests merely failed to provide evidence for the absolute reference frame. It is by a verificationist interpretation of the results that this frame is declared void. Einstein's STR does not explain the null results of these experiments; it simply asserts them as postulates. Furthermore, Einstein's critique of classical simultaneity is verificationist. This is the main pillar upon which the shift to relativistic space-times rests. In sum, whether the STR's transformation equations are derived completely algebraically, as they are in Einstein's 1905 paper, or by postulating the full Minkowski structure and geometricizing these experimental results, there is still a verificationist component which gets relativity theory off the ground in the first place. Hence, there is a mixture of principles in the foundations.

Reichenbach carries this verificationism right through the topology. Grünbaum assumes an ontological approach with respect to the topology and derives the conventional aspect of the metric from it. However, in the end, his conventionalism may have a verificationist as well as an ontological flavour. With respect to the issue of mixing principles, I find myself in the same quandary as Sklar. He points out a verificationist component in the foundations of relativity but is unable to say how to "find a natural stopping point for verificationist claims of underdetermination and conventionality."[35] It must be stressed that it is not a good defence for Grünbaum to exclaim tu quoque, but that it is pertinent to realize that other approaches to the philosophy of space-time embody a mixture as well. For example, Friedman uses verificationism to dispose of classical space-time but then abandons the principle by postulating the full structure of Minkowski space-time.

Prohibiting verificationism with respect to the topology but applying it to the metric has been argued to be unfair treatment to pieces of theoretical structure. Furthermore, Grünbaum allows global topological claims such as continuity, why does he not allow global metrical or causal ones? Or, why not be verificationist throughout? We have seen Grünbaum's reaction to the attempt to extend conventionalism into topology.[36] But what about the other types of questions? Grünbaum, modifying his position somewhat in a later essay, agrees that there is no principle of dispensation which grants the underlying four dimensional manifold absolution from the investigation that the metric is required to bear. For speaking sub specie aeternitatis, all geometric structures must be examined; we are not to take any as absolute. The use of the smooth manifold is only provisional. But in light of our present

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[35] **Sklar, "Time, Reality and Relativity," in *Philosophy and Spacetime Physics*, 304.**

[36] ***cf*, §1.3.**

knowledge, he says that "we are presumably stuck with it as seemingly rock bottom."[37] Because of the problems associated with the hole argument, namely the clash of substantivalism and determinism, it is prudent to treat this manifold with caution. It may be needed to get good theories going, but to assert its foundational character may be too hasty. Furthermore, what is meant by ascribing existence to it is not clearly known, and this ascription will lead quickly into the problems of metaphysics mentioned in §1.3.

Although it appears that Grünbaum must ultimately employ verificationism to defend himself, it is possible for him to make one last ontological defence. First, Robb's constructions define congruency between intervals that either share a space-like, or time-like interval.[38] Second, to define congruency between separated intervals which do not share an interval, Robb must presuppose that the causal structure is static. In other words, causal structure is presumed to be constant throughout space and time. This, however, cannot be demonstrated. Indeed, Robb's constructions define spatially separated lengths to be equal in order to get the constructions going in the first place.[39] It is

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[37] Grünbaum, "Absolute and Relational Theories of Space and Space-Time," *Foundations of Space-Time Theories* (Minneapolis: University of Minnesota Press, 1977). [*Minnesota Studies in the Philosophy of Science*, Vol.8.] p.262.

[38] Alfred A. Robb, *The Absolute Relations of Time and Space* (Cambridge: Cambridge University Press, 1921) 56-61.

[39] Robb's parallelograms are defined to have congruent opposite sides. This, Grünbaum could argue, is a convention. It is conventional because there is no intrinsic length and so it must be defined at the onset.

true that Robb does not mention rigid rods and clocks, but that does not mean he does not use something analogous, namely, a rigid causal structure.

Ultimately, causal connectibility is stronger in the universe of the STR than Grünbaum thinks. It can give a precise definition of simultaneity which corresponds to $\varepsilon=\frac{1}{2}$. Yet, it is not strong enough to do so without a conventionalist assumption. In essence, the conventionalism is not at the level of which Grünbaum argues. It is located at a much deeper level. But this raises an old question in a new form. Can we assert causal congruence-at-a-distance? Is it the case that the causal structure is rigid? Furthermore, the old difficulty comes back as well in the following: is the assumption of congruency (whether it be rods, clocks, or causal structures) over space and time simply trivial?

§4.4.2 Causality In The GTR Universe

Currently, we think the universe is as the GTR describes it.[40] In this case, the assumption that all space-time is Minkowskian cannot be taken for granted. Minkowski space-time is but one possible model for the field equations of the GTR. Consequently, we would resist asserting law-like connections between the metrical relations and the causal ones. These predicates coincide in a particular space-time simply because of its de facto flatness. Therefore, in some regions of the GTR universe, Robb's

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[40] I say this simply because the GTR is currently the best space-time theory we have.

constructions could be isomorphic to the actual space-time structure and in some regions not.

When dealing with causality in the GTR universe it is not so simple. Here, as Weyl has shown, causal connectibility will not determine whether or not space-time is flat.[41] We could have a space-time locally conformal to Minkowski space-time; thus, in our experience it would seem Minkowskian and Robb's causal relations would appear to hold. Yet, globally, the situation could be quite different. Hence, what is the status of causal connectibility here? In the STR world it is a primitive which plays a key role in determining the metric. In the GTR world it does not play such a role.

Finally, in the GTR world the notion of a Lorentz frame is used as a mathematical device to help solve the field equations. Like the law of universal gravitation which rules out perfect inertial frames, there is no region of space-time which is perfectly flat, perfectly Lorentzian. We could argue that there are no regions where the causal theory really applies. This does not help Grünbaum's case much since his conventionality of simultaneity thesis would not apply anywhere either.

4.5 Interdependence: Primitives And Worlds

Not only do primitives get their strength from the possible worlds in which they are entertained, but so too (in part) do

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[41] For more on this, *cf*, Sklar, "Facts, Conventions, and Assumptions in the Theory of Spacetime," 116.

methodological principles. For instance, based on what we have seen in the STR universe, were Grünbaum to use verificationist arguments to save his approach, he would need to apply them promiscuously. Yet, in the GTR universe, his verificationist defence does not appear overpowering. To clarify, in the STR universe, verificationist approaches rule out law-like claims because in this universe the causal and metrical predicates everywhere coincide. To block a causal description is to rule out a particular description of all space-time. Hence, verificationism in this universe rules out an extremely powerful primitive. I suggest that once methodological principles clash with primitives, one or the other must go. (But it should be kept in mind that this clash is within a theoretical framework.) Because Minkowski space-time is the only space-time available here, the verificationist principle should be relaxed. Thus, because of these theoretical concerns, Grünbaum's view either forces him to be ideologically verificationist in this universe -which damages his whole ontological project- or retains his attempt at an ontological defence of conventionalism but shifts conventionality away from simultaneity and locates it at the base of the entire causal structure.

In the GTR universe, a verificationist defence does not deny law-like connections. Furthermore, causal connectibility is not regarded as a primitive. Consequently, verificationism here is not as powerful. For Grünbaum to use it in this universe would not damage his ontological project as it would in the STR universe.

§4.6 Final Conclusions: World-Making

How does all this relate to the debate over slow-clock synchrony? Grünbaum has shifted his conventionalism away from Reichenbach's all-encompassing conventionalism as illustrated in §2.1. In that section the conventionality arose out of the limiting speed of causal connections only. Then, in §3, the defence of conventionality incorporated the metrically amorphous manifold along with the limiting speed of causal connections. Finally, against Malament, provided the parameter is the STR, Grünbaum would have to claim that, ontologically, it is ultimately the amorphous nature of space-time which engenders conventionality even with respect to causal constructions. Or, Grünbaum could simply embrace a strong verificationist line and abandon his ontological defence of conventionalism. No doubt E&B would regard this last ontological defence of Grünbaum's, which essentially worries about comparisons at-a-distance, trivial. Once again, I agree with the position that worries about what happens to supposedly static structures, such as clocks, rods, and causality, over large spatio-temporal intervals. Nevertheless, none of these final issues vindicates E&B, since their experiment is still simply another attempt to define simultaneity.

This examination of Grünbaum's possible defences shows that he is using local considerations in his philosophy. Global claims are rejected by him. Hence, it appears Ellis is using another meaning for "local" when he claims that Grünbaum is no longer using local comparisons. "Global" and "local" are mathematical terms relative to the entire space or space-time considered. They are not relative to our intuitive ideas of "large" and "small" as Ellis seems to suggest.

Finally, what bearing does all this, that is, the slow-clock debate as well as the conclusions in this chapter, have on the original placement of Grünbaum in the deductive/inductive dichotomy of §1.3? Whether or not he can maintain this position is dependent on a number of choices we must make. First, if we want to completely avoid verificationism, the inductive approach collapses (or is at least in serious trouble) and Grünbaum would have to extend his respect for topology to the metric as well. But completely avoiding verificationism is problematic because of its foundational role in the move from classical to relativistic space-times. On the other hand, being completely verificationist engenders all the traditional problems associated with positivism and prevents us from using a good piece of theoretical structure: the continuum. However, must we demand that Grünbaum have at least a stable position in the middle (or anyone anywhere along the continuum for that matter)? Need we rule out the possibility of sliding between the poles when confronting different question in space-time? I think that, ultimately, we cannot demand an absolutely constant position with respect to the problems in space-time. I do not see why someone cannot employ different types of argument (that is, verificationist and realist) within a theory while being allowed to do the exact same thing in order to get a theory off the ground. But having said this, it does not follow that there are no restrictions on employing different types of arguments. What we will have to do is examine theories oase by case not only for their conventional as well as non-conventional components, but for how much verificationist or realist-type arguments we will use or accept. As argued in §4.5, the latter examination will depend upon what kind of a world in which we believe ourselves to live.

The question (and this brings us all the way back to Collingwood), "what time is it over there?" has anything but a trivial answer.

ANNOTATED BIBLIOGRAPHY

Alexander [1984]
H.G. Alexander (ed.), The Leibniz-Clarke Correspondence. New York: Barnes and Noble, 1984.

• This book is a collection of letters exchanged between Leibniz and Clarke via the Princess of Wales. Although a wide variety of philosophical topics are discussed, from miracles to forces of nature, Leibniz' theory of space and time as relations is of interest to me. His theory is difficult to extract since it is not clear whether Leibniz maintains consistency throughout his letters. As for Clarke, he usually follows Newton (that is, space and time as absolute structures), although when speaking of the property view of space he is propounding his own view. More interesting than what is said, is what is not said. In this discussion, no one questions the concept of a global time. Distant simultaneity is presumed.

Anderson [1967]
J.L. Anderson, Principles of Relativity Physics. New York: Academic Press, 1967.

• Many books on relativity theory have been published, however, this one is among the most philosophically interesting since it does more than expound the mathematics. Anderson also examines philosophical interpretations of relativity theory and distinguishes between mathematical terms which were previously thought to be synonymous. Furthermore, much of the recent philosophical literature, whether relationalist or absolutist, refers to him.

Barnes [1984]
J. Barnes (ed.), The Complete Works of Aristotle. 2 vols. Princeton: Princeton University Press, 1984.

• The section relevant to my work is Aristotle's discussion of time in the "Physics."

Beauregard [1979]
L. Beauregard "Reichenbach and Conventionalism," pp. 305-320 in Salmon [1979].

• This article contains a brief, yet quite thorough, overview of Reichenbach's conventionalism. It explains the source of it, that is, the logical underpinnings, as well as contrasting Reichenbach and Grünbaum.

Born [1962]

M. Born, Einstein's Theory of Relativity. New York: Dover Publications, 1962.

• This is an introduction to Einstein's theory. Born provides a clear, and non-mathematical, overview of the fundamentals of classical mechanics. He then explains how these key ideas shift in the context of special and then general relativity. Although not explicitly concerned with philosophical matters, the text is completely framed by a implicit positivist perspective on physics.

Bridgman [1962]

P.W. Bridgman A Sophisticate's Primer of Relativity. Middletown: Wesleyan University Press, 1962.

• This is an introduction to Einstein's theory; however, unlike most introductory texts, this one investigates some of the philosophical problems connected with the theory. The formulation of relativity theory is essentially from an operationalist position. The key idea of this book which is relevant to my project is Bridgman's view of slow-clock synchrony.

Clifton [1989]

R.K. Clifton, "Some Recent Controversy Over the Possibility of Experimentally Determining Isotropy in the Speed of Light," Philosophy of Science, 56 (1989): 688-696.

• This article attacks a recent method proposed by Stoklas to measure the one-way velocity of light. Clifton shows that the method incorporates a convention, that is, one-way velocities of light are equal to the round-trip value. This is very similar to a method examined in Salmon [1977]. Clifton concludes that although we still lack a successful one-way velocity measurement, it is a controversial issue just how "trivial" the conventionality of simultaneity is in the current philosophy of physics.

Coffa [1979]

J.A. Coffa, "Elective Affinities: Weyl and Reichenbach," pp. 267-304 in Salmon [1979].

• Coffa shows how relativity theory was interpreted in two very different ways in the early part of the twentieth century. Essentially, he shows the realist approach of Weyl and the conventionalist approach of Reichenbach. The article is basically expository: the positions are laid out with no final judgment.

Collingwood [1970]
R.G. Collingwood, An Autobiography. London: Oxford University Press, 1970.

• In this text Collingwood relates the story of his intellectual development.

Duhem [1906]
P. Duhem, La theorie physique, son objet et sa structure. Paris, 1906. 2nd ed. 1914. The Aim and Structure of Physical Theory. Trad. P.P. Wiener.

• Although not directly related to my area, this work offers background information by laying out the fundamental approach of conventionalism. Conventionalism plays a large role in space-time philosophy even at the present time.

Earman [1970]
J. Earman, "Who's Afraid of Absolute Space?" Australasian Journal of Philosophy 48 (1970) 287-319.

• This article revives a Newtonian approach to space and time. Earman defends Newton as a philosopher by arguing against a common view the Newton's musings on space and time were "mystico-theological" rubbish. Furthermore, Earman investigates what is meant by "absolute" in "absolute space and time." He examines how the notion of "absolute" in space and time relates to "absolute" in space-time. Earman argues that relativity theory is closer to Newtonianism than Leibnizianism. Mach and Berkeley are harshly criticised. Finally, the view that the physics and philosophy of space-time are intertwined is presented.

Earman et al. [1977]
J. Earman, C. Glymour and J. Stachel (eds.), Foundations of Space-Time Theories. Minneapolis: University of Minnesota Press, 1977. [Minnesota Studies in the Philosophy of Science, Vol. 8].

• This volume consists of a number of wide-ranging articles which are described separately in this bibliography.

Earman [1979]
J. Earman, "Was Leibniz a relationalist?", Midwest Studies in Philosophy, 4 (1979): 263-276.

• Earman argues that Leibniz' position is intermediate between absolutism and relationalism. The article begins by illustrating what is -and is not- at issue between Leibniz and Newton. The crux of the issue is whether or not space is an object of predication. Earman then examines Leibniz' "nutcracker argument" which is composed of (I) the principle of the identity of indiscernables and (II) the principle of sufficient reason. The nutcracker, according to Earman, crushes absolute space as well as bodies; however, the result is not simply a collection of empty shells. There is a nut, but it is not relationalism.

Earman [1989]
J. Earman, World Enough and Space-Time: Absolute versus Relational Theories of Space and Time. Cambridge: The MIT Press, 1989.

• Here Earman explores the history of the problem of space and time with respect to the issue of curvilinear motion. Essentially, he argues that the responsibility of explaining this motion falls upon the relationalist. After arguing that relationalism collapses, Earman turns his sights on substantivalism. This too, he argues, collapses under the weight of Einstein's hole argument which states that we keep either determinism or substantivalism. Earman argues that determinism must not be a priori ruled out; it must be given a fighting chance. Consequently, general relativity must not be interpreted as substantivalist since this will automatically rule out determinism. Hence, a new position is needed. Unfortunately, Earman only makes the call and not the delivery.

Einstein [1949]
A. Einstein, "Autobiographical Notes," pp. 3-105 in Schlipp [1949].

• Here Einstein traces the development of his ideas of relativity from the time he was a boy. He also elaborates on philosophical matters connected with physics.

Einstein [1952]
A. Einstein, "On the Electrodynamics of Moving Bodies," pp. 35-65 in The Principle of Relativity. Toronto: General Publishing Company, 1952.

• This is perhaps one of the most famous papers in the history of science. It is the first critique and subsequent dismantling of classical simultaneity. It contains the gloss on distant simultaneity which forms the basis of the conventionalist approach. Furthermore, there is a derivation and reinterpretation of the Lorentz transformations dealing with both mechanical and electromagnetic phenomena.

Einstein [1959]
A. Einstein, Ideas and Opinions. New York: Crown Publishers Inc., 1959.

• This is a collection of papers and lectures given by Einstein. It contains many papers of philosophical interest since they delve deeply into ontological questions about space-time. For example, one of his most famous papers on the epistemology of geometry, "Geometry and Experience," is included.

Ellis and Bowman [1967]
B.Ellis and P. Bowman, "Conventionality in Distant Simultaneity," Philosophy of Science, 34 (1967): 116-136.

• This paper picks up on Bridgman's method of slow-clock synchrony and tries to argue that it refutes the position of the conventionality of simultaneity. It forms the basis for my investigation into the concept of simultaneity.

Ellis [1971]
B. Ellis, "On Conventionality and Simultaneity -A Reply," Australasian Journal of Philosophy, 49 (1971): 177-203.

• Because the previous paper, Ellis and Bowman [1967] was attacked by numerous philosophers, mostly Grünbaum, this paper was written in defence of it. The main point Ellis makes is that his paper was seriously misunderstood. Philosophers misunderstood it to refute conventionality when it was intended only to trivialize conventionality. Furthermore, he argues that philosophers approaching the philosophy of science from a general conventionalist perspective will misunderstand the paper.

Fine [1973]

A. Fine, "Reflections on a Relational Theory of Space", pp. 234-267 in Suppes [1973a]

• Fine presents a different set-up of the absolutist-relationalist debate. Rather than drawing it with respect to the nature of space and time, he draws it with respect to the approach to the problem. Newton is classified as an absolutist since he regards the problem holistically, that is, within the greater context of physics. Hence, Einstein becomes an important figure within the Newtonian tradition. Leibniz regards the question of space and time as outside that of physics and has a contemporary representative in Grünbaum. The bulk of the paper is a critique of Grünbaum's relationalism. Fine argues that although it has strong points, there are nonetheless logical gaps. One gap in particular is located in the move from continuity in a manifold to its metric amorphousness. Another criticism, one which strikes more deeply, is that the attempt to separate geometry and physics in order to deal independently with the question of space and time rests on a logical circle.

Friedman [1983]

M. Friedman, <u>Foundations of Space-Time Theories</u>. Princeton: Princeton University Press, 1983.

• In this book on absolutism in space and time, Friedman devotes a good deal of room to reformulating Newtonian physics in terms of geometry rather than the flat spatio-temporal framework plus forces form that it normally has. He argues that there are good geometric frameworks (those that unify disparate pieces of theory) as well as bad (those that do not unify). Furthermore, Friedman stresses that a theory is ontologically committed to the existence of whatever is invariant (whether observable or not) in all its representations. He also includes an interesting discussion of the development of positivism and relativity theory and how they influenced each other.

Giancoli [1984]

D. Giancoli, <u>General Physics</u>. New Jersey: Prentice Hall, 1984.

• This is a standard university text in physics. Perhaps its chief merit, one which separates it from most other texts in the field, is that it starts with concrete examples and then abstracts the concepts. Unfortunately, most texts start with abstract theorems and skip detailed applications. Furthermore, the text contains a clear introductory chapter on special relativity.

Grünbaum [1956]
A. Grünbaum, "Operationalism and Relativity," pp. 84-95 in Phillip Frank (ed.), The Validation of Scientific Theories. Boston: The Beacon Press, 1956.

• In this article Grünbaum attacks the view that relativity theory is to be operationally defined. He argues that pragmatics and semantics of physical terms should not be confused. Operationalism essentially absorbs the latter into the former. Relativity theory is about the world and is not merely some sort of logical construction with no empirical content.

Grünbaum [1963a]
A. Grünbaum, Philosophical Problems of Space and Time. New York: Knopf, 1963. 2nd edition revised and enlarged. Dordrecht: Reidel, 1973.

• The original edition contains Grünbaum's views on space and time as well as how Reichenbach's metaphors needed to be straightened out since they have lead to many misconceptions. It is here that Grünbaum lays out his view of conventionalism arising from the metric amorphousness of a continuous manifold. He also deals in depth with special relativity and its development. Finally, he admits that the project of expunging physics of absolute space-time is by no means finished with general relativity. The augmentation of this text consists of specialized papers responding to criticisms of views expressed in the original.

Grünbaum [1963b]
A. Grünbaum, "Simultaneity by Slow Clock Transport in the Special Theory of Relativity," pp. 670-708 in Grünbaum [1963a].

• This is Grünbaum's criticisms of Ellis and Bowman [1967]. Grünbaum attacks their supposed refutation, or trivialization, of conventionality by showing that were ontological conditions different, that is, Newton right and Einstein wrong, conventionality would not hold. The conventionality of simultaneity stems from ontological considerations and is not simply a logical problem as Ellis and Bowman assume.

Grünbaum [1968a]
A. Grünbaum, Geometry and Geochronometry in Philosophical Perspective. Minneapolis: University of Minnesota Press, 1968.

• This text is a compilation of previous articles. The articles are organized around a single theme: defend and clarify the concept of an amorphous manifold.

Grünbaum [1968b]
A. Grünbaum, "A Reply to Hilary Putnam's "An Examination of Grünbaum's Philosophy of Geometry," pp. 195-378 in Grünbaum [1968a].

• This is a point by point reply to Putnam [1979]. Grünbaum tries to unearth scientific errors and philosophical blunders in Putnam's attack. Furthermore, Grünbaum attempts to further buttress his ontological views by showing how general relativity employs Riemann conventionality.

Grünbaum [1971]
A. Grünbaum, "Why I Am Afraid Of Absolute Space," Australasian Journal of Philosophy, 49 (1971): 96.

• This article responds to Earman [1970]. It is only a single page, and it is essentially not an argument against Earman in any particular area, but a simply a global rejection of Earman's approach. Grünbaum rejects the uncritical literalism of Earman's as simply reading ontology from mathematical equations and regarding scientific acceptability as the criterion of acceptability. Grünbaum rejects this approach. He claims that the path from theory to ontological commitment is not so straightforward.

Grünbaum [1977]
A. Grünbaum, "Absolute and Relational Theories of Space and Space-Time", pp. 303-373 in Earman et al. [1977].

• This article further answers the criticisms Grünbaum received about his book [1963b]. In particular he expands and clarifies his treatment of Reimann. As well, he explains how theoretically identifying objects that are not available to the senses does not entail ascribing monadic properties to them and thus beg the whole issue in the space-time debate. He also discusses the interpretation of the metric tensor in relativity theory and argues for the relationalist position.

Hartz and Cover [1988]
G.A. Hartz and C.A. Cover, "Space and Time in the Leibnizian Metaphysic," Nôus, 22 (1988): 493-519.

• Hartz and Cover argue that Leibniz the relationalist or phenomenalist, is not the mature Leibniz. In essence, his views change in his later years, especially if one considers his correspondence. The later Leibniz regards space and time much like a logical space which fits and organizes the world, but is ontologically independent of it.

Holton [1960]
Holton, "On the Origins of Special Relativity," American Journal of Physics, 28 (1960): 601-650

• This is simply a history of the development of the theory of special relativity.

Hooker [1971]
C.A. Hooker "The Relational Doctrines of Space and Time", British Journal for the Philosophy of Science, 22 (1971): 97-129.

• Hooker provides a lucid overview of the merits as well as problems of the relational view of space and time. The main problem with this view is that it has a difficulty in choosing suitable relata for its relations. (For example, if external spatial relations are derived from bodies what about the internal spatial relations of bodies? Are we caught on either the horn of an infinite regress or arbitrary absolute relata?) It also tries to address, sometimes rather weakly, the attacks on the absolutist view of time.

Hughes [1989]
R.I.G. Hughes, The Structure and Interpretation of Quantum Mechanics. Cambridge: Cambridge University Press, 1989.

• Hughes divides the book into two parts: the first deals with the basic mathematics of the theory, namely vector spaces and how they represent states of systems, and the second with the interpretation of the mathematics. The book is essentially along the lines of interpretation of quantum theory lead by van Fraassen.

Hussey [1972]

E. Hussey, The Pre-Socratics. New York: Charles Scribner's Sons, 1972.

• This is a standard overview of the philosophy of the pre-Socratic philosophers. The chapter on Heraclitus is particularly interesting since it explores the notions of dynamic and static tension in the universe.

Jammer [1969]

M. Jammer, Concepts of Space: The History of Theories of Space in Physics. 2nd edition. Cambridge: Harvard University Press, 1969.

• An extremely clear, and fairly in-depth, overview of views of space from Archytas to Einstein. Jammer attempts to be quite non-partisan, and concludes that the debate over the nature of space as lively as it ever was although it is now much more sophisticated. The strength of the text, and its relevance to my project, lies in its treatment of the Leibniz-Newton debate and the appearance of Reimann in the nineteenth century.

Kant [1965]

I. Kant, The Critique of Pure Reason. Tr. Norman Kemp Smith, New York: St. Martin's Press, 1965.

• The sections relevant to my project are Kant's discussion of time in the "Transcendental Aesthetic" and the "Third Analogy."

Kant [1970]

I. Kant, Metaphysics of Natural Science. Tr. J. Ellington, New York: Bobbs-Merill, 1970.

• This is Kant's attempt to give the necessary and sufficient conditions for Newtonian physics.

Keswani [1965]

G.H. Keswani, "Origin and Concept of Relativity," The British Journal for the Philosophy of Science, Part 1, 25 (1965): 286-305; Part 2, 26 (1965): 19-32; Part 3, 26 (1966): 273-294.

• Part 1 deals with questions surrounding the time previous to the 1905 special relativity paper. How much did Poincaré contribute and what did Einstein know of Poincaré's work? Furthermore, what did Einstein know of Lorentz' work? Part 2 looks at relativity according to these three thinkers as well as Minkowski's mathematical model of the special theory. The geometric interpretation lessened the impact of the theory, but made it more comprehensible. Also, some criticisms of Einstein's 1905 paper are considered. Part 3 examines the principle of equivalence and moves into Einstein's theory of gravitation.

Lacey [1970]

H. Lacey, "The Scientific Intelligibility of Absolute Space: A Study of Newtonian Argument", The British Journal for the Philosophy of Science, 21 (1970): 317-342.

• Lacey tries to elucidate the logical gap in Newton's examination of the bucket experiment. He argues that Newton cannot fill in his inference from the appearance of centrifugal motion by a claim to motion with respect to absolute space. Lacey argues that the continuing significance of Newton is that he also employed empirical investigations into the nature of space and time rather than only philosophical arguments.

Latzer [1972]

R. Latzer, "Non-Directed Light Signals and the Structure of Time," Synthese, 24 (1972): 236-280.

• This paper is an examination of the causal theory of time. It is essentially an attempt to investigate the structure of time based on signal connection which does not discriminate between sender and receiver.

Leibniz [1951]

G.W.F. Leibniz, "Metaphysical Foundations of Mathematics," pp. 201-216 in P.P. Weiner (ed.), Leibniz: Selections. New York: Charles Scribner's Sons, 1951.

• The key interest here is how Leibniz grounds his notions of mathematics in the structure of time and space. Furthermore, Leibniz provides one of the first attempts to explain the concept of simultaneity at a distance rather than simply assuming it.

Malament [1977]

D. Malament, "Casual Theories of Time and the Conventionality of Simultaneity", Nôus, 11 (1977): 293-300.

• Here Malament tries to refute Grünbaum's position thesis of the conventionality of simultaneity by an internal proof. He assumes a causal theory of time, and, building on the causal construction of Robb [1921], shows that simultaneity is not conventional even on what he claims to be Grünbaum's own terms.

Manuel [1968]

F.E. Manuel, A Portrait of Issac Newton. Cambridge: The Belknap Press of Harvard University Press, 1968.

• This is a biography of the life and intellectual development of Issac Newton. It differs from other views on Newton since it tries to see Newton as a child of his times.

Neidorf [1963]

R. Neidorf, "Is Einstein a Positivist?" Philosophy of Science, 30 (1963): 173-188.

• The article presents the key statements and arguments of Einstein's which do, or do not, support a positivist epistemology of science. Neidorf argues that a distinction between semantics and pragmatics with respect to physical concepts is maintained by Einstein and that this distinction entails a non-positivist epistemology. Furthermore, this distinction provides the key to understanding Einstein's apparently positivist utterances.

Newton [1962]
I. Newton, "De Gravitatione," pp. 201-230 in A.R. Hall and M.B. Hall (eds.), Unpublished Scientific Papers of Issac Newton. Cambridge: Cambridge University Press, 1962.

• Newton enters a philosophical-theological discussion of the nature of space. He places himself squarely within the Neo-Platonic tradition by regarding it as an emanation of God.

Newton [1966]
I. Newton, Sir Issac Newton's Mathematical Principles of Natural Philosophy and His System of the World. Orig. tr. A. Motte. Revised tr. Florian Cajori. Berkeley and Los Angeles: University of California Press, 1962.

•Arguably one of the greatest and most influential books ever written. Here Newton systematises and justifies tracts of previous knowledge as well as presenting his revolutionary theory of gravitation and his musings on the nature of space and time.

Paxton [1964]
H.J. Paxton, Kant's Metaphysic of Experience. 2 vols. London: George Allen and Unwin Ltd., 1964.

• This is a section by section analysis of Kant [1964].

Poincaré [1902]
H. Poincaré, La science et l'hypothese, 1902. Science and Hypothesis. New York: Dover, 1952.

• This text is a major work of the early twentieth century. Not only was it a further clarification of Poincaré's conventionalism, but it was a source of inspiration for the early Albert Einstein. Poincaré starts by examining the nature of mathematical reasoning showing that, although it is a construction of our imagination, it does not follow that this is an arbitrary structure. He then examines the epistemology of geometry. He argues that geometry is not derived from experience and concludes that geometric principles are only conventions. Again, Poincaré stresses, this does not entail arbitrariness. Finally, he examines mechanics and electro-dynamics. Their principles are more directly related to experience. Yet, these principles still share the conventional nature of the geometric principles.

Putnam [1979]

H. Putnam, "An Examination of Grünbaum's Philosophy of Geometry," pp. 93-129 in Mathematics, Matter and Method. Cambridge: Cambridge University Press, 1979.

• This is the classic attack on Grünbaum's position. It is quoted by most scholars opposed to Grünbaum. The article tries to refute the position simply by showing it ultimately to be a type of semantic conventionalism. In other words, it is simply a problem of language as to how we assign a meaning to terms such as "congruent." There is nothing ontologically interesting in Grünbaum's thesis.

Quine [1963]

W.V.O. Quine, "Two Dogmas of Empiricism," pp. 20-46 in From A Logical Point Of View. New York: Harper and Row, 2nd edition, 1963.

• A paper this famous hardly needs annotation. The relevant idea to my work is Quine's attack on the second dogma: statements can be isolated from their embedding theories. Essentially, this is an expression of holism.

Quine [1975]

W.V.O. Quine, "On Empirically Equivalent Systems of the World", Erkenntnis, 9 (1975): 313-328.

• This paper separates two theses which are often confused: holism and under-determination. The bulk of the paper is devoted to the exploration of the thesis of under-determination since it is a rather obscure concept. The thesis retains its strength not under all possible observations, but under all humanly possible observations.

Reichenbach [1928]

H. Reichenbach, Philosophie der Raum-Zeit-Lehre, 1928. The Philosophy of Space and Time. New York: Dover, 1958.

• This book is an early standard in positivistic views with respect to relativity theory. Reichenbach argues that metrics are explained by coordinate definitions and are simply conventions. The type of frameworks constructed will determine the type of geometric framework within which we will couch our theories. He first applies this conventionalist approach to space, time, and finally space-time.

Reichenbach [1948]
H. Reichenbach, Philosophical Foundations of Quantum Mechanics. Berkeley and Los Angeles: University of California Press, 1948.

• This text is an attempt to give a positivist interpretation of quantum theory. The relevant part to my work is that Reichenbach issues forth one of his strongest and all-embracing arguments for equivalent descriptions.

Reichenbach [1949]
H. Reichenbach, "The Philosophical Significance of The Theory of Relativity," pp. 289-311 in Schlipp [1949].

• This is another presentation of Reichenbach's positivist position. Essentially, in this paper he argues that the theory of relativity supports his own theory of equivalent descriptions. Finally, he makes a passionate plea for philosophy to stop wandering and to follow behind science in the effort to explicate the latter's concepts and presuppositions.

Riemann [1973]
Riemann, "On the Hypothesis Which Lie at the Foundations of Geometry," tr. H.S. White, pp. 411-425 in D.E. Smith (ed.), A Source Book in Mathematics. New York: McGraw Hill Book Company Inc., 1973.

• This classic text is perhaps one of the most interesting, yet brief, pieces of philosophy and mathematics. It discusses the problem of ascribing a metric to a continuous manifold and assumes that such a manifold's metric must come from elsewhere. Riemann anticipates Einstein's curvature of higher dimensional space; however, he never discusses anything to do with time. This paper is the main source for Grünbaum's views of the metric.

Robb [1921]

A.A. Robb, The Absolute Relations of Time and Space. Cambridge: Cambridge University Press, 1921.

• Robb thought that Einstein's relativity of simultaneity turned the universe into a nightmare. Robb attempted to provide an absolute causal structure to the universe in the hopes of saving some absolute structures of time and space. His main primitive is the notion of "after." From the ability to recognize events in such a relation, Robb, with the help of several postulates, constructs a theory of flat space-time.

Salmon [1969]

W. Salmon, "Conventionality In Distant Simultaneity," Philosophy of Science, 36 (1969): 44-63.

• This paper is Salmon's response to Ellis and Bowman [1967]. Salmon argues that Reichenbach's position is still valid since when clocks are separated we have no way of knowing how they behave. Consequently, we do not know what time they read. We can know such information only by returning the clocks to nearly coincident positions. However, we still are checking coincident clocks, not separated ones. Ellis and Bowman's supposedly trivial conventionality is claimed by Salmon to be one of the most controversial issues in twentieth-century philosophy of space-time.

Salmon [1977]

W. Salmon, "The Philosophical Significance of the One-Way Speed of Light," Nôus, 11 (1977): 253-292.

• This paper illustrates the history of the attempts to measure the one-way speed of light. It starts with Roemer and continues to experiments in progress in the late seventies. The key idea is that Salmon points out many conventions that are common to various attempts to perform such a measurement.

Salmon [1979]

W. Salmon, (ed.), Hans Reichenbach: Logical Empiricist. Dordrecht: Holland, 1979.

• This is a collection of papers, some critical, some expository, on the philosophy of Hans Reichenbach. Salmon's introductory paper is a nice overview of Reichenbach's general position with respect to a variety of topics in the philosophy of science.

Schlipp [1949]

P. Schlipp, (ed.), Albert Einstein: Philosopher-Scientist. New York: Tudor Publishing Company, 1949.

• This is a collection of papers interpreting the philosophy of space and time as expressed in relativity theory.

Sklar [1974]

L. Sklar, Space, Time, and Spacetime. Berkeley and Los Angeles: University of California Press, 1974.

• This rather large book accomplishes what few others do: it gives a balanced overview of an enormous philosophical domain. The book contains much historical information and interpretation of historical arguments. Not only does Sklar go into much detail with respect to twentieth-century space-time debates, but he also gives a lot of mathematical background without simply stringing formulae together. He stresses that you cannot do philosophy of science without getting both your philosophy and physics right.

Sklar [1985a]

L. Sklar, Philosophy of Spacetime Physics. Berkeley: University of California Press 1985.

• Sklar picks up some themes of his earlier book [1974] and clarifies them. This is a collection of essays that range over specific issues in space-time to questions on the philosophy of science in general.

Sklar [1985b]

L. Sklar, "Time, Reality and Relativity," pp. 289-304 in Sklar [1985a].

• Sklar explores the view which asserts that the special relativity theory disqualifies any irreality of the past or future. Sklar agrees that the theory does place restrictions upon what we call "unreal;" however, he argues that we cannot simply read off ontological conclusions from the theory. What we get out of a theory will depend on how much we read in at the outset.

Sklar [1985c]

L. Sklar, "Facts, Conventions and Assumptions in the Theory of Spacetime," pp. 73-147 in Sklar [1985a].

• Sklar presents different versions of Robb's causal construction of flat space-time to illustrate the thesis that to formulate a theory is not to indulge in an empty logical exercise. Consequently, Sklar argues that we must be careful when trying to read off metaphysical considerations from the formalization of a theory. The main result of the paper is that a primitive in epistemology will depend on what type of world one lives in. Because this is a global, and hence, unverifiable proposition, it follows that the type of world one believes oneself to be in, is a result of what theory is accepted.

Stein [1967]

H. Stein, "Newtonian Space-Time", Texas Quarterly, 10 (1967): 174-200.

• In this article Stein attempts to dig into Newton's writings on space and time not only to reveal what he said, but also what is -and is not- presupposed by his writings. Stein begins by giving two formulations of Newtonian space-time according to Newton's dynamics. He then goes on to explicate the central argument of the Principia. Stein tries to interpret what Newton intended when he remarked at the end of the "Scholium on space and time" that the text was to show how one discerns true from apparent motions. Stein credits Huygens with recognizing that the Newtonian theory involved the special principle of relativity for intrinsic accelerations but did not entail intrinsic velocities; curvilinear motions are different than rectilinear motions. There is also a discussion of how Newton's focus was the incoherent vortex theory of Descartes and not the relational view of Leibniz. According to Stein, Newton, Leibniz and Huygens were interested in truth, not the propounding of pet theories or the scoring of points in debates. Reichenbach is then used as an example to show how the level of debate has degenerated.

Suppes [1973a]

P. Suppes (ed.), Space, Time and Geometry. Dordrecht: Reidel, 1973.

• This is a collection of essays by various authors. They will be commented on separately.

Suppes [1973b]
P. Suppes, "Some Open Problems in the Philosophy of Space and Time", pp. 383-401 in Suppes [1973a].

• Suppes divides this paper into two sections: (I) The Geometry of Space, and (II) Physical Space and Space-Time. The first deals with trying to give a foundation to operationalism with respect to geometric measurement and also with examining how to give a theory of error within geometric parameters. The second part examines axiomatizations of special relativity and theories of bodies. The main thrust of the paper is to try and formulate problems in space and time which require fusing foundational investigations in mathematics (that is, investigations in the foundations of geometry), with foundational investigations in physics.

van Fraassen [1970]
B.C. van Fraassen, An Introduction to the Philosophy of Time and Space. New York: Random House, 1970. 2nd edition, 1985.

• Van Fraassen describes the attempts to arrive at satisfying theories of time and space from Plato to the end of the nineteenth century. He also discusses the causal theory of time and includes Leibniz as well as Reichenbach and Grünbaum. Van Fraassen regards time and space as logical spaces, as mathematical constructs which represent certain conceptual interconnections.

Weyl [1918]
H. Weyl, Raum-Zeit-Materie. Berlin, 1918. Trad. H.L. Brose, Space-Time-Matter. New York: Dover, 1952.

• The text starts with a review of Euclidean space and its mathematics. Weyl then moves on to Riemannian geometry and then the special theory of relativity. The book concludes with Weyl's interpretation of general relativity. Throughout the text Weyl argues for the shift from an axiomatic geometry to an infinitesimal one. In other words, since no action at a distance is tolerated in physics, it should also be banned from mathematics.

Weyl [1927]

H. Weyl, Philosophie der Mathematik und Naturwissenschaft. Muenchen, 1927. Trad. O. Helme. Philosophy of Mathematics and Natural Science. New York: Atheneum, 1963.

• In this text Weyl examines the philosophical problems stemming out of modern mathematics and physics. He also includes discussions of those philosophers of the past who had ideas of such notions. The text also helps to clarify some of Weyl's realist approaches.

Winnie [1970]

J.A. Winnie, "Special Relativity Without One-Way Velocity Assumptions," Philosophy of Science, Part 1, 30 (1970): 81-99. Part 2, 30 (1970): 223-238.

• Winnie shows how one can formulate the special theory of relativity without assuming any particular value for Reichenbach's ε. Winnie also tries to clearly separate the conventional and factual elements of the theory.

Winnie [1977a]

J.A. Winnie, "The Causal Theory of Space-Time", pp. 134-205 in Earman et al. [1977].

• Winnie begins with the causal theory of time as espoused by Leibniz. After exposing the difficulties in Leibniz' view, Winnie moves to an exposition of the causal theory of space-time as formulated by Robb.

Winnie [1977b]

J.A. Winnie, "Introduction," Nôus, 11 (1977): 207-209.

• This is an introduction to a volume dedicated to the philosophy of space and time. Winnie provides a brief overview of the articles in the volume and comments on the relationship of Malament [1977] and Salmon [1977].

Zimmerman [1962]

E.J. Zimmerman, "The Macroscopic Nature of Space-Time," The American Journal of Physics, 30 (1962): 97-105.

• Because quantum theory has no use for space-time descriptions in its formulations, Zimmerman suggests that space and time are much like temperature: they arise out of macroscopic configurations, but have no analogues in the microscopic. The space-time manifold is suggested to have merely a statistical existence.