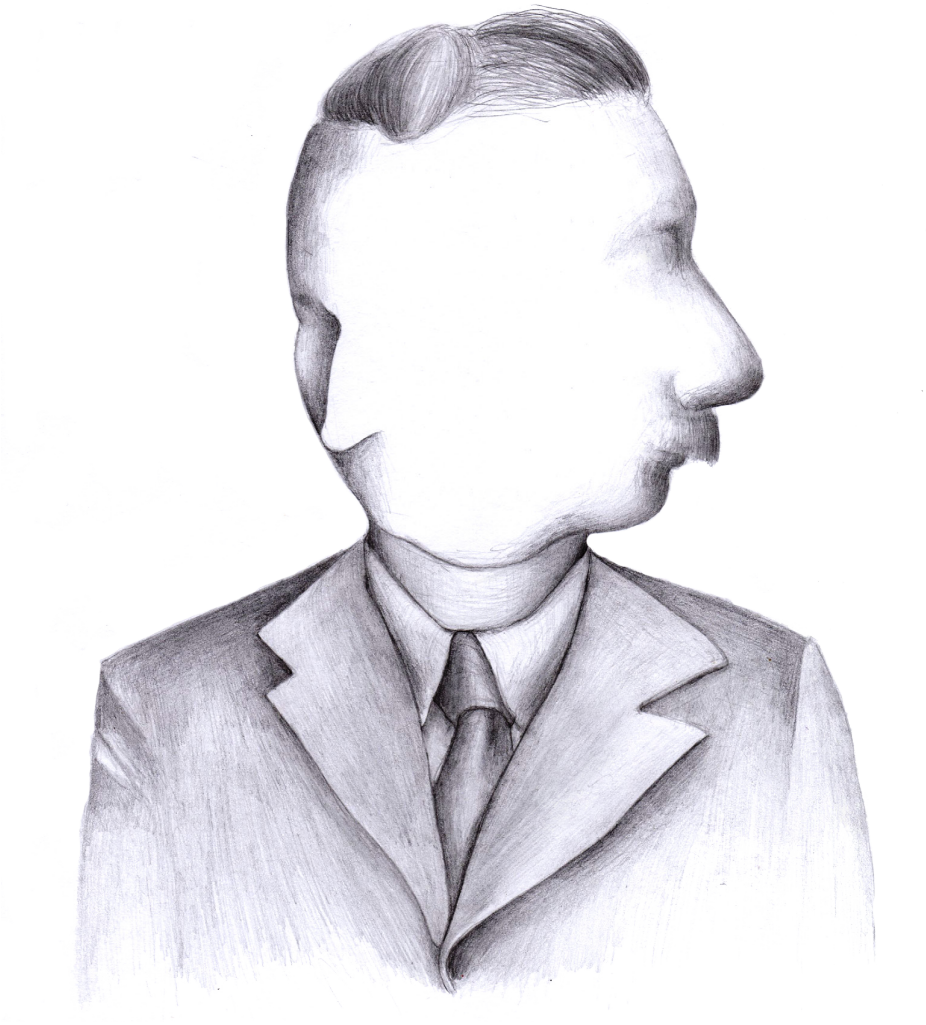
Ernst Cassirer and the Theories of Relativity



MSc Thesis for the graduate programme in History and Philosophy of Science at the University of Utrecht

by

Olle Spoelstra

under supervision of dr. J.A.E.F van Dongen

August, 2014

Illustration by Kwennie Cheng

Contents

Introduction

When in 1919 Arthur Eddington confirmed the deflection of light by the sun, predicted by Einstein, the general theory of relativity soon became world-famous. it did not take long before philosophers jumped on it and gave their commentaries. Neo-Kantians, representing the largest share of Germany's philosophers at the time, were challenged in particular by the new physics. Apparent discrepancies between the theory of relativity and Kantian epistemology quickly arose and challenged them to respond. The years that followed proved to be a chaotic period in the philosophy of science in which a wild variety of interpretations of the new physics were proposed, a great deal of which only to quickly be criticized and rejected as misinterpretations. In the middle of these interpretations we find the one developed by Ernst Cassirer (1874-1945). This thesis is an exploration of his interpretation, its origins, reception and its philosophical arguments.

On the basis of three chapters, I will analyse the role played by Cassirer and his interpretation of the special and general theories of relativity in the debate that surrounded thee theories. The first chapter serves to give the background information to understand Cassirer's interpretation. It explains the essential elements in Cassirer's pre-relativistic philosophy of science and traces them back to their roots, as well as clarifying their differences with the original Kantian doctrine. The second chapter concerns the interpretation itself. Its historical context, as well as the most important arguments by which Cassirer claimed to have shown that Einstein had confirmed his philosophical theses, are examined. The third chapter concludes this thesis by placing Cassirer's interpretation in the larger context of the philosophical debate on the theories of relativity in the early 1920's. It answers the questions how this interpretation compared to those put forward by others, how his views were received by some of the most notable philosophers and scientists at the time and analyses Cassirer's views on the debate.

The answers to these questions will support the view that Cassirer's interpretation of the theories of relativity belonged to the most sophisticated ones found in the 1920's. Moreover, they will reveal that the criticism given by Schlick played an important role in the reception of Cassirer's interpretation but were based on misconceptions of Cassirer's reinterpretation of the traditional Kantian doctrine. Moreover, by analysis of Cassirer's correspondences during the relativity debate, a coherent picture of Cassirer's personality will

appear. This personality will serve to understand some of the philosophical viewpoints Cassirer took.

Chapter 1

Cassirer's Philosophy of Science

In order to understand Cassirer's ideas on the theories of relativity, some background information and explanation of his early philosophy of science is required. This chapter gives this information by zooming in on Cassirer's philosophy in three consecutive steps. By treating the essentials of Kantian epistemology, the first section is the most general and outlines many of the fundamental ideas from which Cassirer's theories sprang. The second section then shows how Cassirer's contemporaries in Marburg emphasised certain of these ideas whilst rejecting others and thereby developed a renewed Kantianism. The third and final section discusses Cassirer's particular contribution to this Marburg Kantianism and in doing so describes the ideas that functioned as the breeding ground for his interpretation of the theories of relativity.

1.1 Kantian Background

1.1.1 A Copernican revolution

Epistemology before Kant (1724 - 1804) was mainly a discussion between those labelled empiricists on the one side and those known as the rationalists on the other. The question that divided the two groups was how we can guarantee a relation between the objects of our thoughts and those of reality. This question is closely related to the most fundamental epistemologist question asking for an explanation of how we can have knowledge. Our knowledge exists only in the forms of thoughts, expressed by judgements claiming facts of the world. In the seventeenth century the question of how these claims relate to the world was equated with the question of how we can guarantee that the objects of our thoughts indeed correspond to the objects of the real world. If an individual makes an epistemological judgement by claiming that the table in front of him is green, the rationalist and the empiricist wondered how the mental object of

this thought, the green table, related to the actual table in the external world. The rationalist claimed that the fundamental explanation of this relation was to be found in human reason. The structure of rational thought, in this view, is believed to somehow correspond to the structure of nature. The empiricist on the other hand attributed this task to experience, claiming that knowledge must be founded on information acquired by the senses. Both claims had to cope with strong arguments put forward by advocates of the other camp.[1]

Kant's contribution to this debate, elaborated in *Critique of Pure Reason*,[2] is often considered an alternative to both the empiricist and the rationalist viewpoints. It relied on elements of both movements, but deviating from each to such an extent that it succeeded in coping with many of the objections to rationalism and empiricism that fed the debates. The *Critique* thus conceived is mainly a work of epistemology, and as such it played a foundational role in Cassirer's philosophy of science.[3]

One of the most crucial new insights put forward by Kant was the repudiation of what he considered to be a shared error in thought between rationalists and empiricists alike. Although both groups differed in their beliefs as to where our knowledge ultimately originated from, neither of them denied that it is possible to have knowledge of the external world. Without giving in to skepticism, which deflates philosophy from any potential use, Kant did not agree with the possibility of knowledge of the world the rationalists and empiricists claimed we could have knowledge of. To avoid the skeptic threat, Kant introduced a new distinction that plays a central role in his epistemology. On the one hand, he recognised the world of the real objects, the *Dinge an sich*, that make up the entirety of reality. He explicitly denied that we can have knowledge of this world, since it is inaccessible to our minds. There is, however, a 'second world', that of the appearances. This is the world we experience, the one our thoughts are about and the one of which we make (true or false) judgements. Knowledge thus is possible, but it is never about the *noumenal* world, always about the *phenomenal*.

A corollary of this new distinction is that it changes the essence of the epistemological question that the rationalists and empiricists debated about. The question how the objects of our thoughts can be guaranteed to relate to that of the world of true objects simply is irrelevant since our thoughts are not about this world in the first place. The epistemological task for Kant is thus to justify the relation between the objects of our thoughts and those of the experienced world. Whereas the rationalists and empiricists both struggled

[1] See for more information (Gardner, 1999, 1-26)

[2] (Kant, 1998) Kant published two editions of the book, with some significant differences between them. In citing from the *Critique* I will, as is common in modern commentary on Kant, refer to the first edition by 'A' and to the second by 'B', followed by the pagination of the original German text.

[3] Although in Cassirer's days, the *Critique* was indeed considered a work of epistemology, later this view would be criticised by some. Notably Martin Heidegger, with whom Cassirer would have a debate centred around this issue in 1929, objected and argued that Kant's work was first of all one of metaphysics. For discussions on the 'Davos confrontation' and its consequences, see (Friedman, 2000)

with the task of justifying a relation between the internal mind and the external world of reality, Kant, by put his finger on a different distinction, and in doing so tremendously simplified the problem. The accessibility of the world of our experience by our mind is, Kant argued, much more easily explainable. Indeed, it was Kant's claim that it is established by it. The objects of our experience, are only those that are allowed by the mind. Thus, whereas the empiricists and the rationalists had attempted to explain how the objects of reality can find their way into our thoughts, Kant reversed the direction of explanation and explained how the mind constitutes the objects of our thought. This shift of perspective is what he considered his Copernican revolution in epistemology.[4] Our knowledge is taken as a fact and rather than questioning how it corresponds to reality, the new question was which conditions are met in order to make it possible. This change of perspective is central in Kant's 'critical philosophy'.

1.1.2 Concepts and Intuitions

Insight in the constitution of knowledge according to Kant's epistemology will further clarify how the objects of knowledge are constituted by the mind. Knowledge for Kant does not arise instantly, instead for an individual to be able to make any judgement, he must go through a process in which two distinctive phases can be recognised. Kant sides with the empiricists in recognition of the character of the start of this process, and claims that all knowledge starts with experience.[5] But sensory impressions alone are never sufficient to yield knowledge. They come to the mind in a chaotic manner that cannot directly yield cognition. If impressions are to produce knowledge, they need to be structured. After the reception of impressions, the process of the constitution of knowledge thus consists of ordering them in such a manner that they become comprehensible. Both steps, reception of the impressions and their organisation are necessary and it is only a conjunction of the two that can bring forth knowledge.

The terms that Kant used for the constituents of knowledge, or representations, of each of these two phases are *intuitions*, for those of the reception of sensory impressions, and 'concepts', for those giving structure to these impressions. The faculties of the mind that are responsible for these representations are those of sensibility and understanding respectively. Intuitions are the bare impressions, they supply the mind with something, which Michael Friedman has recently called a 'field of objects'.[6] Reception of such objects is brought under concepts by the mind so that one gets an understanding of the world. To be able to get knowledge of a white table that is found in a room, it is of first importance that the sensory impression, of the table is received by the mind. Subsequently, the mind needs to apply the concepts of 'table' and 'white'. Only then can a subject know that there is indeed a white table in the room. Without the possession of these concepts, the impression is not understood. Intuitions

[4] Bxvi
[5] (A1/B1)
[6] (Friedman, 1990, 96)

thus are representations supplying the object of our thought to the mind directly, they are given to it without any form of mediation.[7] Concepts, on the other hand, relate the the object only in an indirect manner. According to traditional Kantian epistemology, concepts make us able to think of an object due to properties this object shares with similar objects.[8] Intuition gives a table, with all its sensible properties, as an object to me directly. The concept 'table' subsequently, by reliance on table-like properties such as its shape that it shares with other perceived objects, make me able to understand the table as a table and thus brings me in a state of cognition.

It thus follows, and Kant emphasised this, that the requirement of both types of representation for the constitution of knowledge is essential:

> Without sensibility no object would be given to us, without understanding no object would be thought. Thoughts without content are empty, intuitions without concepts are blind. It is, therefore, just as necessary to make our concepts sensible, that is, to add the object to them in intuition, as to make our intuitions intelligible, that is, to bring them under concepts. These two powers or capacities cannot exchange their functions. The understanding can intuit nothing, the senses can think nothing. Only through their union can knowledge arise.[9]

Concepts and intuitions both serve a unique purpose which individually cannot yield knowledge. Intuitions are directly given but essentially chaotic. Concepts provide the required organisation but, due to their very nature, their functioning relies on intuitions. Only when concepts are applied to intuitions, by abstraction of their properties, knowledge can arise.

1.1.3 Space and Time

The critical philosophical quest for the requirements of knowledge was explainned by the thesis that there are certain structures that are prevalent in all experience. They are those requirements necessary for the possibility of experience at all and hence can never be absent in it. Necessarily, every knowledge claim adheres to it and it is impossible by definition that an object of experience corresponds to these principles. Since they do not derive from experience itself, but rather precede it, they are a priori. Since they are nto reducible to statements about definitions, they are synthetic. Although most synthetic a priori claims were understood to be conceptual, there were two notable exceptions.

Repeatedly and explicitly, space and time are argued to be synthetic a priori intuitions and thus are neither empirical nor conceptual.[10] Moreover, the character of each of these notions supplies a number of synthetic priori principles. In interpreting the relativity theories, both Cassirer's criticism of Kantian intuition as well as that of several of the derived synthetic a priori principles is important. Since the criticism of the notion of intuition concerns that notion in general rather than the particular assignment of space and time as intuitions,

[7] A19/B33
[8] A320/B377
[9] A51/B75
[10] e.g. A23-24/B38-39 and A30-31/B46)

Kant's argumentation for his choice can be omitted in the current discussion. The distinction between the two terms as discussed above will suffice to understand Cassirer's disagreement. To understand the criticism resulting from the a prioriness of space and time, however, some further insight in Kant's elaboration on this idea is required.

The reasons for Kant to consider space and time to be a priori rather than empirical, is illustrated by two well-known arguments. Although the arguments given here are the two better known arguments concerning space, arguments along the same lines were given to argue for the a priori status of time. Kant first argued that any empirical claim, any claim concerning an experience of something that is not one's own mind, presupposes the representation of space. Any imagination of the empirical world necessarily requires a space in which this world can be represented. Now, if space itself would be something empirical, it would require itself in order to be represented, which obviously is a problematically circular idea. Space therefore cannot be empirical and must be a priori. The second argument complements the first and argues that the dependence relation between space and the empirical world is asymmetric. Although we cannot think of an object without the presupposition of space, it is unproblematic to think of a space which is empty of objects. The dependence thus is not a mutual one and consequently space must be prior to any experience.

For Kant these two arguments were sufficient to demonstrate the a priori nature of space and time. It is important to see that these arguments reveal that the notion of a priori here means more than merely 'non-empirical'. Indeed, Kant emphasised the presuppositional character of space and time. Both were necessarily to be assumed in order to have an experience and hence to have knowledge. It is then easy to see why Kant believed a priori judgements to also be necessary judgements. The presuppositions of space and time were not coincidentally prevalent in every experience, they were its ultimate requirements without which experience would be impossible. They thus would be prevalent in all experiences ever to be had; they were apodictically valid.

The terms 'space' and 'time' used so far have been rather abstract. What exactly must be presupposed when presupposing either of them has not yet been explicated. Fortunately, Kant gives clear implementation to these terms, and thus gives such explication. A number of statements on the nature of space and time are made, revealing what Kant believed to be apodictic principles concerning the nature of space and time. It are these principles that caused a debate on the tenability of Kant in the light of the relativity theories in the early twentieth century and hence became the central topic of the neo-Kantian discussions on these theories. Cassirer too, pays extensive attention to these principles in his interpretation of Einstein's physics. His ideas are analysed in chapter 2. It must be noted that some of the Kantian principles about space and time had already been a point of discussion before the twentieth century. Whilst the absoluteness of space had been attacked by philosophers, the unique status of Euclidean geometry had been threatened by science. Both shall briefly be discussed before a definitive move from Kant to the neo-Kantians is made.

1.1.4 Two Pre-relativistic Problems for Kant

Absolute space

Kant understood the space we necessarily presume in any experience in a substantivalist manner. That is, space is presumed to have an existence independent of the objects found in it. Newton's physical theories, sovereignly reigning in the time Kant wrote his *Critique*, had relied on absolute space and Newton himself had emphasised the absolute nature of space and time in the definitions he had given in his *Principia*. A correspondence between the Newtonian-minded Clarke and his challenger Leibniz, turned into one of the best known debates in the philosophy of science. Leibniz, claiming that space was nothing but the relations between material bodies, objected to the substantivalist point of view. He thus challenged the advocates of the Newton notion of space to overcome the 'principle of indescribables' by explaining how a world oriented in one particular way with respect to absolute space differed from a world that would be oriented in a different way with respect to absolute space.[11]

Despite Leibniz's objections, Kant defended the substantivalist standpoint and offered an argument of his own. In contrast to Leibniz's argument, Kant's starts with the assumption that there exists a difference in the world and concludes that it can only be explained by the recognition of absolute space. The difference this argument, known as the 'argument from incongruent counterparts', assumes is that between a left and a right hand. The difference may be attributed either to internal or external relations. The first option would mean that the relations between the parts that constitute either hand differ, which is not the case. The difference therefore must be due to the relation between the hand and something external to them. Kant argued that since the differences would remain if all objects except for the two hands are removed from our thoughts, the only viable option left is that the source of explanation is found in the relation between the hands and an absolute space. The existence of left and right hands in our world and the differences between them therefore necessitates the substantivalist position towards space.[12]

Euclidean geometry

A second property which Kant had assigned to space was that of having a structure that was describable by Euclidean geometry. It may be noted that nowhere in the *Critique* Kant refers explicitly to Euclid. That nevertheless Kant had his "Elements" in mind when stating that "geometrical properties are one and all apodeictic, that is, they are bound up with the consciousness of their necessity; for instance, that space has only three dimensions."[13] is highly

[11] This challenge was based on the 'principle of the identity of indiscrenibles' stating that any distinction between two things must be based on a distinction of a recognisable difference. (Leibniz et al., 1956, 37)

[12] The argument is not found in the *Critique*, but in a paper originally published in 1764. (Kant, 1911)

[13] B40-41

probable since Euclidean geometry was largely undoubted and uncontested in the eighteenth century.

If there existed any doubt about it at all, it concerned the fifth of Euclid's postulate, which appeared less self-evident than the other postulates found in the *Elements*. The postulate stated:

> That, if a straight line falling on two straight lines make the interior angles on the same side less than two right angles, the two straight lines, if produced indefinitely, meet on that side on which the angles are less than the two right angles.[14]

This assertion is equivalent to the statement that for any given straight line and on any given point outside that line, there is only one line that is parallel to the first, as well as to the claim that the sum of the angles of a triangle is equivalent to the sum of two right angles.

During the century following Kant's death in 1804, cracks started to appear in the foundation of this system. Most importantly were the discoveries of Lobachevsky, Bolyai and Riemann, who each had designed alternative geometrical systems that did not adhere the fifth of Euclid's postulates. Although the constructions of Lobachevsky and Bolyai allowed for multiple parallel lines to be drawn on a point outside a given straight line and in Riemann's geometry no such line could be drawn, the new geometries were no less consistent than Euclid's.[15] Hence, the structure of these systems differed significantly from that which Kant had asserted to be a synthetic a priori condition for knowledge.

Nevertheless, these development did not necessarily form a threat to Kant's ideas. What Lobachevsky, Bolyai and Riemann had developed were merely mathematical systems that were not used to describe the empirical world. A careful reading of Kant's *Critique* shows that Kant would not have objected to such developments. In the *Critique* he explicitly made clear that he believed it was logically possible to construct non-Euclidean geometries as consistent systems.

> There is no contradiction in the concept of a figure which is enclosed within two straight lines[16]

The enclosure of a figure by two straight lines is impossible in Euclidean geometry where two straight lines, intersect only once or, if they are parallel, not at all. In Riemann's non-Euclidean geometry however, there were, on a point outside a given straight line, no other straight lines that would not intersect with the first. Indeed, they may intersect twice with it, thereby potentially enclosing a figure. Although Kant thus did not reject the possibility of Riemann's geometrical developments in the nineteenth century (and consequently there seems no reason why he would reject the geometry of Bolyai and Lobachevsky), he believed it was Euclidean geometry alone that was a precondition of experience. No other geometry would be of use in gaining knowledge of the world. Indeed,

[14] (Euclid, 1956, 202)
[15] Riemann's geometry as it is referred to here should not be confused with Riemannian geometry, understood as the extension of Gauss's analytic theory of surfaces.
[16] A220/B268; (Palmquist, 1990, 109)

it was due to their logical possibility and their impossibility to be applicable to the world, that the geometrical statements owed their synthetic character.

Kant's argument remained tenable until the end of the century. Only when Einstein developed his general theory of relativity by relying on non-Euclidean geometry, it had been proved that not only Euclidean geometry can be used to describe the world. The great variety of responses from neo-Kantian philosophers is discussed in more detail in chapters 2 and 3. Before this can be done, Cassirer's pre-relativistic philosophy and its neo-Kantian roots must be further explored.

1.2 Marburg School Neo-Kantianism

1.2.1 Cohen and Late Nineteenth-century Neo-Kantianism

The development of Kant's ideas in the decades following his death in 1804 are of little importance when compared to those found in the second half of the century. Works such as the *Critique of Pure Reason*[17] and *Prolegomena to Any Future Metaphysics*[18] were dusted off by those including von Helmholtz, Liebmann and Trendelenburg. By the time the German empire was founded in 1871 these philosophers, who we in retrospect refer to as the first neo-Kantians, had each developed their own interpretations of the Kantian doctrine, each emphasizing different aspects of it. It was in the midst of variety of these interpretations that Hermann Cohen joined the debate and presented his own version that would be of crucial influence on Cassirer's philosophy of science. In this section I shall evaluate the interpretation of Kant that was developed by Cohen, Cassirer and Natorp.

In 1868 Hermann von Helmholtz and Bernhard Riemann published results of their research on the foundations of geometry. Both men concluded that Euclidean geometry, which Kant had explicitly considered an a priori intuition, was not the only possible foundation for physical theory. When in 1868 von Helmholtz and Riemann published their aforementioned results on non-Euclidean geometries, an contradiction between the possibilities of actual scientific practice and Kant's theory had become reality. This meant that the first of the neo-Kantians had to come up with an accommodating response. If they wished to stay true to their doctrine whilst not dismissing the new scientific developments, either new interpretations of the texts had to be given or accommodating adjustments had to be made. Either one could argue that it was a misinterpretation of Kant to claim that he proposed the universal validity of Euclidean geometry for all scientific theories or that his theory might slightly be adjusted in order to account for he new geometries developed.

Hermann Cohen, born in 1848, was a neo-Kantian scholar at Marburg University. His concern was with staying true to the Kantian method whilst not dismissing new scientific developments. In his view, other neo-Kantians would

[17](Kant, 1998)
[18](Kant, 1977)

either interpret the Kantian doctrine in a way that he considered to be at odds with its original intentions, or read Kant's texts in such a way that modern science would make it non-viable. Cohen considered the work of Adolf Trendelenburg quintessential for the former reaction. In Trendelenburg's reading, synthetic a priori principles, were understood to represent physical processes in the human mind.[19] Epistemology, subsequently, then was considered to be an empirical research in which psychology played a central role. Cohen explicitly rejected such an interpretation of Kant, which he considered too psychological. This rejection would become one of the focal points of Cohen's neo-Kantianism and is further discussed in the next section.

Kuno Fischer advocated a second interpretation that could not count on Cohen's appraisal. His view corresponded to Kant's traditional ideas and it encompassed space and time as pure intuitions whose application must precede that of the application of the concepts.[20] Alongside his aversion of psychological implications of the Kantian doctrine, Cohen rejected a reading in which experience had a strong subjective component. The traditional understanding of Kant's theses, which Fischer too advocated and according to which intuitions and concepts were strictly separated, was argued to be the source of this unfortunate subjectivity. Cohen, in contrast, claimed that what Kant had called intuitions did not fundamentally differ from concepts and that if this was seen, the objectivity of experience could be guaranteed. Section 1.2.4 discusses the details of this view.

The two most central figures who would share Cohen's views on the above points were Paul Natorp and Ernst Cassirer. Natorp had moved from Strasbourg to Marburg to join Cohen and finished his *habitilation* under Cohen in 1881. Cassirer was only seven years old at that time, and still thirteen years away from studying in Berlin. There, Georg Simmel informed him of Cohen, whose books he regarded to be "undoubtedly the best books on Kant".[21]. In 1896 Cassirer joined Cohen and Natorp in Marburg and he would soon be considered the third central figure of the Marburg School. This school, one of the most prominent philosophical schools in early twentieth century Germany, was characterised by three focal points. Along the two aforementioned points, an anti-psychological neo-Kantianism and a problematisation of the distinction between concepts and intuitions, there was a central place for the natural sciences. These three points form the topic of the following three sections and shall function as an explanation of Cassirer's most fundamental epistemological ideas and their origin.

1.2.2 Anti-psychologism

Psychologism is the philosophical doctrine claiming that the grounds for our cognition must be explained in psychological terms. The laws of logic, describing the rules of our thought, are argued to be nothing more than descriptions of the patterns by which our brains function. This implies that logic is a subjective

[19] (Patton, 2005, 112)
[20] (Patton, 2005, 111)
[21] (Gawronsky, 1949, 6)

matter, arising from the structures of the subject's reasoning rather than from relations external to him and not accessible only to the particular individual. Psychologism in German philosophy was not uncommon in the 1870's and 1880's and criticism against it was barely existent until at least 1890.[22]

Hermann Von Helmholtz, a contributor to the fields of physics, psychology and philosophy, combined psychologistic views with the Kantian doctrine. Similar to the thoughts of Eduard Zeller, for example, Von Helmholt's idea was that the Kantian doctrine required a psychological underpinning. Like Kant, Von Helmholtz believed there must be a priori principles that organise the bare sense data and make it comprehensible. The psychological twist Von Helmholtz gave to this view was that these principles were understood as psychological structures. The a priori intuitions and concepts were thus believed to be reducible to the organisation of the human mind. Whereas this conclusion was not found in Kant's own writing, Von Helmholtz argued it was a valid addition nevertheless.

Indeed, it was this addition that would soon be under philosophical fire. The Marburg School was not alone in articulating its objections to a psychological reading of Kant. The South West School, the second large neo-Kantian school in Germany, although deviating from Cohen's interpretation on several points, agreed that Von Helmoholtz was mistaken. Which of the two voiced its objections first and what was the actual historical order of anti-psychologistic ideas is of little importance to the discussion here. What is of interest is the anti-psychologism practiced by the Marburg School. Cohen presented his problems with psycologistic interpretations of Kant already in 1871 in "Kants Theorie der Erfahrung"[23]. Natorp too, sixteen years later would present his objections to psychologism in detail and by use of clear argumentation in "Über objektive und subjektive Begründung der Erkenntnis".[24]

In this article Natorp expressed his disagreement with psychologist interpretations of Kant by offering an argument that is twofold[25] Natorp's first argument is that Von Helmholtz's crucial role for psychology can only be achieved at the expense of the validity of logic as a grounding of truth. If the truth of our judgements is ultimately described by psychology, then obviously there exists at least one branch of science, psychology, whose judgements cannot be described by logic. Either we maintain our understanding of logic as a universal theory of truth and therefore as a study more fundamental than psychology or we claim that logic is ultimately founded in psychology and give up this understanding. The latter option was not a viable one in Natorp's view. If logic ceases to be a universal study of validity, it ceases to be logic at all.

Although Natorp considered this to be a valid argument by itself, he continued and claimed that losing the universal character of logic is undesirable for a second reason. A logic that is not valid for all sciences, is a logic that cannot be used to judge any scientific field. It loses its authority and therefore cannot

[22](Edgar, 2008, 54)
[23](Cohen, 1871)
[24](Natorp, 1887) English translation: (Natorp, 1981)
[25]For a detailed discussion of the argument found in the article, see (Edgar, 2008)

function as an evaluator of the truth of any statement claiming the truth. This loss implies a loss of authority to judge any such claim to be objective and consequently knowledge would become a subjective state of affairs.

> One not only destroys logic, as the independent theory of the objective validity of knowledge, one also cancels out objective validity itself and changes it into purely subjective validity, if one attempts to support it on subjective grounds and to deduce it from subjective factors.[26]

Both Cohen and Natorp, the two most important figures of the Marburg School before the arrival of Cassirer, emphasised the subjectivity of knowledge as a serious objection against a psychological interpretation of the Kantian doctrine. Psychology is concerned with subjective structures. Both Cohen and Natorp stressed that knowledge, in their eyes, could not be subjective and that it was therefore impossible to ground it in psychology. Cassirer, a student of both Cohen and Natorp, undoubtedly was influenced by anti-psychologistic arguments such as the above. In his own epistemological works the rejection of psychologism feeded his own arguments. These arguments, in their own turn, formed the foundation of his interpretation of the theories of relativity.

1.2.3 The Transcendental Method

The Marburg School considered psychological interpretations to be a reading of Kant that was not necessary and moreover distracting from what was truly valuable in the Kantian doctrine. Rather than deforming it in unnatural ways, the doctrine must be stripped of such modern distracting points of view. Instead, they argued, we must pay attention to one of Kant's greatest achievements, which was understood to be his methodology. The first and foremost characteristic of the Marburg Schoolers as neo-Kantians was the presupposition of the philosophical method Kant had used and which they called the 'transcendental method'.[27] Indeed, the method was raised to the level of a fundamental principle and any implications of its use that would conflict with any other assertion by Kant, had to be accepted in the favour of the method. In the hierarchy of Kant's ideas, the transcendental method was found above any other statements or arguments. Cohen believed that by such a re-evaluation of Kant's works, one was able to read Kant and "understand him better than he had understood himself."[28]

The role the transcendental method played in Cassirer's philosophy, including his remarks on the theories of relativity, can hardly be underestimated. It therefore deserves some further commentary and explnation. Epistemology, according to the transcendental method, does not start with a psychological investigation of the human mind, nor with metaphysical assumptions but instead accepts the natural sciences as representatives for our most accurate knowledge.

[26](Natorp, 1981, 251)
[27](Natorp, 1912)
[28](Kaufmann, 1949)

The most advanced theories of these sciences are regarded as our best approximations of describing the experienced world accurately. Scientific facts are not doubted and the modes of their discoveries are not questioned on any grounds. The Marburg School presumed that scientists throughout history developed reliable methods to form their theories and did not consider it the philosopher's task to comment on these methods. Rather, it was understood to be the philosopher's task to take the scientist's theories for granted and analyses them logically. This means that the goal of this analysis is a reduction of the given scientific facts to their ultimate preconditions i.e. the most fundamental assumptions that are prerequisite in the arguments the scientist gives for his theory. Indeed these assumptions were identical to Kant's synthetic a priori concepts and principles. The transcendental method was first emphasised by Cohen but became one of the key characteristics of the neo-Kantianism practiced by all members of the Marburg School.[29]

It was argued by the members of the Marburg School that the transcendental method formed the core of Kant's *Critique of Pure Reason*. Whereas others may have believed this book to use the synthetic a priori principles as a justification for the fundamental principles of Newtonian physics, Cohen argued that the correct understanding of Kant's argument runs in reverse order. Kant, by applying the transcendental method, took Newtonian science as given facts and used it to justify the principles.[30]

Late nineteenth century science had developed considerable from Newtonian physics which had contained the most advanced theories in Kant's days. An important respect in which the Marburg School members differed from Kant was that they did not think that science was a static enterprise. What they believed was a serious error made by Kant was his high opinion of Newtonian physics. He had considered its theories to be perfect and therefore argued the principles he had derived from them to be permanent and apodictic. The preconditions of Newtonian science were, for Kant, the preconditions for all science and for knowledge in general. Not only Newton and his contemporaries, but all scientists, including those whose theories were not yet developed, would have to presuppose these principles in order to comprehend the world. All physical theories of the future would use the same categories as those fundamental to Newtonian theory including those of space, time and causation. Cohen explicitly rejected this idea by presenting science as an ever-developing set of theories.[31]

Cassirer wholeheartedly accepted the transcendental method and the corresponding criticism of Kant by Cohen. He praised Cohen for raising awareness of the role the transcendental method played in the Kantian doctrine.[32] Moreover, he applied it in his early epistemological work and strongly relied on it in developing his interpretation of the theories of relativity.

[29](Krois, 1987, 38)
[30](Heis, 2007, 160)
[31](Cohen, 1914, 585)
[32](Cassirer, 1920b)

1.2.4 Rejection of Intuitions

The Marburg rejection of subjective grounds for knowledge did not only lead to philosophical debates with their contemporaries, it was also of crucial influence on their interpretation of the original Kantian epistemology. In the previous section we have seen that Kant made a distinction between two faculties of the mind which he both considered necessary for the establishment of knowledge. Intuitions supply the objects in a spatio-temporal representation which subsequently is made understandable by the application of concepts. One of the characteristics by which intuitions distinguish themselves from concepts is that they are given to the mind without mediation. The neo-Kantians of the Marburg school considered intuitions, as immediately given representations, a problem for the justification of the objectivity of science. A representation that is given to the subject's mind without external reference would taint knowledge with subjectivity. They thus argued that in the constitution of knowledge intuitions, at least in the way they were broadly understood and as distinct from concepts, did not play any role.[33]

Depriving Kant's epistemology from intuitions implies that the principles of the possibility of the objects of our thoughts reside in concepts alone. As we have seen earlier, in Kant's theory concepts relate to the objects of thought only indirectly and only by reliance on intuitions. The removal intuition from the theory thus seems to be tantamount to the undesirable but complete removal of the objects from our thought. According to Cohen, this certainly was not the case. Cohen pointed out that analysis of scientific methodology showed that the objects of judgements made by scientists are not the things that we perceive, these judgements are not about the things that Kant argued were given to us by our senses. As will be explained later, Cohen believed that epistemological investigation started with the presumption of the truth of the facts established by modern science. The objects of such facts are not sensible objects but the laws of nature. Cohen clarified this idea by giving a basic example illustrating what the object of astronomy is.

> Not the stars in the heavens are the objects which [the transcendental] method teaches us to contemplate in order to know them; rather, it is the astronomical calculations, those facts of scientific reality which are the "actuality" that needs to be explained... What is the foundation of the reality which is given in such facts? What are the conditions of that certainty from which visible actuality takes its reality? The laws are the facts, and [hence] the objects [of our investigation]; not the star-things.[34]

The objects of judgements in astronomy are not the objects that we empirically experience, such as the stars and the planets, but they are the laws that this branch of science has produced. The representations of intuitions do not play a role in the constitution of the object. If we wish to maintain the notion of these representations, we must conclude that they play a secondary role in the sense that they only exist as derivations from the scientific laws. These laws are

[33](Cohen, 1914, 24)
[34](Cohen, 1910)

statements of which universal validity is claimed and which do not come to the mind in a direct, unmediated way. Hence, they are concepts and not intuitions. The rejection of intuition, a notion that is central in Kant's original theory, thus is a direct result of both an objection against psychologism and a dedication to the transcendental method.

However, Cohen emphasised that the removal of intuition, that was verified in scientific practice, was in accord with the Kantian thesis that in experience, objects are not given but posed (*nicht gegeben, sondern aufgegeben*).[114] Like Kant, scientists placed their objects in the constituted and concept-mediated laws, rather than believing that allegedly unmediated objects such as the stars were its true objects. The removal of intuition was understood as the mos determinate belief that we have no access to the noumenal world. Hence it was a way of understanding Kant better than he had understood himself.

For Cohen, the objects of scientific theory are dependent on the laws of particular theories. Along with the aforementioned conception of ever-evolving scientific knowledge, the removal of intuition as a stage in the constitution of knowledge thus meant that the Marburg School considered the object of scientific knowledge to be under the influence of scientific progress too. Cohen, Natorp and Cassirer all argued that this was indeed the case.[35] The object of science is a description of our experience but it can never be a perfect description of it. Nevertheless, throughout its development, the theories of science will come closer to such a perfect description. The object of science evolves and converges towards the ideal of that this description is. How exactly it was understood was not always made clear and differed between the particular authors. Cassirer's particular interpretation of the 'never completed "X"'.[36] will be discussed in further detail in section 1.3.2. The object of thought thus no longer is considered a thing, but has become an ideal. A shift which Kaufman has recognised to border on anti-Kantianism.[37] A more detailed description of how this convergence was understood by Cassirer will follow in the next section.

These ideas were fundamental in the way the representatives of the Marburg School were able to deal with the problems for Kantian theory posed be recent developments in geometry. The dynamic view of science and the objects of scientific knowledge made a variety of geometries as possible scientific foundations unproblematic. As scientific theory develops and changes its geometrical foundation, so will our understanding of the geometrical properties of actual space. If physical theory develops and its contents converge to the ideal description of reality, it is quite possible that in doing so geometrical foundations may be changed. The Marburg school thus dealt with the aforementioned objections against the Kantian notions of space. For its members space was not longer understood as Euclidean, indeed it did not have any definite structure at all and therefore its absolute status was not presumed either. Cassirer's thoughts in relation to this subject too shall be elaborated on in the following section as

[114](Friedman, 2000)
[35](Cohen, 1914), (Natorp, 1910)
[36](Friedman, 2000, 31)
[37](Kaufmann, 1949, 812)

well as in the next chapter.

1.3 Cassirer's Pre-relativistic Philosophy of Science

After studying philosophy in Marburg for three years, Cassirer promoted under Cohen and Natorp in 1899 with a thesis on Descartes's analysis of mathematical and scientific knowledge.[38] After moving back to Berlin, he wrote his *Habilitationsschrift*, based on his analysis of the development of science and philosophy from the Renaissance to Kant, in 1906.[39] Although this work was largely historical, his Marburg heritage would clearly be revealed four years later. In *Substanzbegriff und Funktionsbegriff*, Cassirer analysed the developments of scientific theories in the past centuries in an attempt to describe the underlying principles that make possible these theories.[40] *Substanzbegriff und Funktionsbegriff* thus was a historical as well as a philosophical work. As a philosophical work, it moreover is the most systematic presentation of Cassirer's epistemological ideas. Our wish to understand the role played by Cassirer in the philosophical debate on the relativity theories, requires an understanding of Cassirer's pre-relativistic philosophy,[41] clarifying which ideas Cassirer held before the news of a new 'epochmaking' physical theory reached him.[42] An analysis of the central ideas found in *Substanzbegriff und Funktionsbegriff*, which follows, will provide such an understanding.

1.3.1 Substance-concepts and Function-concepts

Substanzbegriff und Funktionsbegriff clearly is a work in the Kantian tradition, strongly relying on the characteristics described in the first section. It assumes the truth of Kant's Copernican revolution and recognises the epistemological object as constituted by the human mind. The goal of philosophy according to Cassirer, was that of Kant, understood as the investigation of the synthetic a priori concepts and principles, which are necessary for human beings to experience and to have knowledge.[43] Cassirer thus took this investigation as the ultimate object of philosophy. *Substanzbegriff und Funktionsbegriff* paid special attention to the way in which these concepts and principles are formed and

[38] The dissertation was later published. (Cassirer, 1902)
[39] (Cassirer, 1906)
[40] (Cassirer, 1910) The full title of the book was Substanzbegriff und Funktionsbegriff: Untersuchungen über die Grundfragen der Erkenntniskritik. The first translation appeared in 1923.(Cassirer, 1923)
[41] Although one may recognise elements of philosophical relativism in Cassirer's thought,(Freudenthal, 1996) the terms 'pre-relativistic' and 'post-relativistic' as used in this text, will be used exclusively to express a temporal relation with respect to the general theory of relativity and the brief period of time in which it gained worldwide publicity in and around 1919.
[42] New York Times, November 9, 1919
[43] (Cassirer, 1923, 268-269)

the major part of its contents focusses on the character of concepts by which we understand the world. Cassirer's analysis of this character is clearly influenced by the aforementioned neo-Kantian interpretations of Cohen and Natorp. These representatives of the Marburg School considered the notion of intuitions a threat to the objectivity that they demanded of knowledge. Therefore they argued that these types of representations did not play any role in the constitution of knowledge and that it was dependent on concepts alone. In *Substanzbegriff und Funktionsbegriff* Cassirer contributed to the exposition of the argument that this is indeed the case. Rather than considering Kant himself to be the single one responsible for the important role played by intuitions in the *Critique*, Cassirer argued that the rejection of this notion must rely on methods still unavailable in Kant's time.[44]

To simply remove subjectivity-tainted intuitions from Kant's methodology might initially sound attractive to a neo-Kantian who wants to guarantee the objectivity of human knowledge. The solution is not that simple however. Concepts, according to Kant's traditional doctrine, are formed by recognition of similarities and differences of received intuitions, without these intuitions they cannot possibly come into being. The utility of the notion of concepts in an epistemological theory is completely dependent on the assumption of intuitions. One of the central claims in *Substanzbegriff und Funktionsbegriff* is that the recent developments in logic and the foundations of mathematics had shown a way out of this apparent necessity of intuition for the formation of concepts. Indeed, recent developments in logic pointed out the way to a process of concept formation that differed from the Kantian interpretation which relied on traditional logic. Whereas logic in the days of Kant lead to concepts of a type that Cassirer called substance-concepts (*Substanzbegriffe*), he argued that modern mathematics employed a new type of concepts, which he called the function-concept (*Funktionsbegriff*). Unlike the former, the latter can be formed without the need for intuitions. The book thus revealed the Marburgian heritage of its author in two ways. First, *Substanzbegriff und Funktionsbegriff* was a defence of the possibility of an epistemology that, by its supposition that a priori principles are required for knowledge, was Kantian but, in contrast to the traditional theory, removed the requirement of intuition. Second, it achieved this by a reliance on the methods of modern science as the foundation of a philosophical argument and it thus was an example of the application of the transcendental method.

In the preface of the book Cassirer explicitly pointed out the conflict between modern mathematics and the logic upon which the substance-function was founded:

> ... Traditional logic of the concept, in its well-known features, proved inadequate even to *characterize* completely the problems to which the theory of mathematics led.[45]

[44] Moreover, Cassirer appeared to have been of the opinion that Kant himself not necessarily understood intuitions in the way they have been described in the first section of this chapter and as they were generally understood by non-Marburg neo-Kantians. (Cassirer, 1923, 418)

[45] (Cassirer, 1923, iii)

In what follows after this citation Cassirer remarked that certain recent developments in mathematical theory no longer relied on substance-concepts in the determination of their epistemological object. More precisely, he argued that the logic that grounds the formation of these types of concepts had not been applied by modern mathematicians who recently developed new theories. This logic, which Cassirer labelled 'traditional', is the system of formal logic that can be traced back to Aristotle. This system, which was uncontested from the day of its development in ancient Greece until the early twentieth century, and thus also in Kant's days, is based on Aristotle's metaphysics. Aristotle's logic organised the categorisation of objects in the world by their properties. This means that each individual object is categorised by its similarities and differences with other objects. When it is recognised to share a particular amount of properties with a certain group of other objects, it can be considered a member of this group. Thus, for instance, by a comparison between Socrates's characteristics and those of other men, he is recognised to have the necessary and sufficient properties it takes to be considered a man. We then can attribute to Socrates the predicate 'man'. This process may be continued, further 'down', specifying what type of man Socrates is, or in the other direction, determining in what larger group the group of men can be placed. In doing so Socrates is given a unique place within the entirety of existing objects. The judgements yielded by this logic are always of the form: '$M(s)$', representing the statement that Socrates is a man.

Since these judgements are made possible by a comparison of properties, the similarity with Kant's use of the term 'concept', as explained in section 1.1.2 is evident. Kant, like Aristotle, used a comparison based on similarities and differences in order to determine which concept can be applied to a certain intuition. The concept 'man', according to traditional Kantian concept formation, would be formed by comparing Aristotle to many other men and recognizing a number of differences and similarities in characteristics. Since the abstraction of these characteristics from the individual has a key role in this process, the corresponding theory of concept formation is also known as the 'abstractionist theory'. Kantian concept formation took place according to this theory and thus relied on traditional Aristotelian logic. The hegemony of this logic was unchallenged in the late eighteenth century when Kant first published his *Critique*.

In *Substanzbegriff und Funktionsbegriff* Cassirer remarked that at the close of the nineteenth century things had changed. For the first time in more than twenty centuries developments in logic had offered alternatives to Aristotelean logic as the foundation of concept-formation. In particular, Cassirer referred to the work of Bertrand Russell.[46] Russel had worked on the development of a relational logic, which he argued gave an explanation of the foundations of mathematics and hence challenged the traditional logic as the solely applicable formal logical system. Reading Cassirer's brief appreciation of the relational logic it becomes clear that he places its value and core characteristics in the fact

[46](Cassirer, 1923, 37)

that it is a second-order logic. Whereas the minimal proposition in a first-order logic, such as Aristotle's, expresses a subject having a certain property (as in the above example: 'Socrates is a man'), that of Russell's relational logic expresses a relation between two predicates. An example of the latter would be '$(a)R(b)$', expressing the statement 'a stands in relation to b'. These relations can than be further clarified by recognizing particular qualities such as symmetry (iff $(a)R(b) \rightarrow (b)R(a)$, as is the case with the relation 'is a brother of', but not with 'is taller than') or transitivity (iff $(a)R(b) \wedge (b)R(c) \rightarrow (a)R(c)$, as is the case with the two aforementioned relations but not with 'is a mother of'). Cassirer believed that if this logic of relations, rather than traditional Aristotelian logic, was used to describe the formation of concepts, it could do so without reliance on intuition and hence guarantee the objectivity of knowledge.

A concept whose structure is best explained by relational logic is a concept which Cassirer called a function-concept. As Jeremy Heis has noted correctly, Cassirer failed to give explicit definitions of some of the most central terms in *Substanzbegriff und Funktionsbegriff*, including clear explanations of what exactly must be understood by the central notions of substance-concepts and function-concepts.[47] Instead, the reader must deduce the meaning of the terms from the differences between these terms and a vast array of examples drawn from the history of science. Besides the foundation on a different logic, the independence from intuitions has already been mentioned as a characteristic of the function-concept. Below, the latter will be discussed in more detail, further revealing the distinction between the two types of concepts. First however, being unable to give the definitions that Cassirer himself could not give either, I shall follow his strategy and hope to make clear the meaning of the function concept by a simple example.[48]

The function concept can be well illustrated by the mathematical formula of a geometrical curve. A substance-function in this case would be that of a point, a thing-like entity, describable by its properties (e.g. its value on the y-axis) and could be classified accordingly. A function-concept is that of the formula, which, being a relation between the points, is a more abstract entity. Like the function concept, the formula gives the relations of each point to all other points that it describes. Indeed, the function-concept defines each point only by the relation it has to the other points in a larger structure, which is the curve. It thus becomes clear why Cassirer believed a logic based on relations, rather than one on abstracted properties, could explain such concepts.

An argument from the transcendental method

Although the particular example above serves as a model for Cassirer's notion of the function-concept, it is further illustrated and made clear by opposing it to the substance-concept on the basis of a large number of other examples

[47] Heis also recognises a variety of meanings of the term 'function' used by Cassirer.(Heis, forthcoming.a, 3,15-18)

[48] Cassirer borrowed the argument from Lotze, a German logician and philosopher.(Cassirer, 1923, 7,19-23)

too. From the history of physics and mathematics, a vast array of theories are analysed in order to determine the character of the fundamental notions found in them. One of the central theses of *Substanzbegriff und Funktionsbegriff* is that the preference of function-concept to substance-concepts in our epistemological theories is based on the observation that the history of science reveals a development according to which these notions more and more take the form of the former type. This thesis, in combination with the Marburgian idea that the natural sciences represent our knowledge most clearly, implies that the function-concept is the type of concept best used to explain the character of our knowledge.

The development of the notion of the ether exemplifies the tendency found in many other developments in a brief but clear manner. In the early theories in which the ether is found, it was understood as a thing to which properties such as that of fluidity and elasticity were assigned.[49] These properties yielded anomalies which were solved in subsequent theories. In these more modern theories observational properties are relinquished from the notion of the ether. Instead, in these theories, represents the totality of the relations between particular empirical phenomena. The equality of the ether used to explain the propagation of light with the ether used to explain electromagnetic phenomena is established by the equality of the formulas and the constants found in the formulas that are used to describe these phenomena. The ether, understood in this functional way, "cannot be understood as an isolated, individual thing of perception, but only as a unification and concentration of objectively valid, measurable relations."[50] In *Substanzbegriff und Funktionsbegriff* many more developments of scientific concepts, all describing a transformation from substance-concepts to function-concepts are given. The concept of the atom[51], of energy[52] and of the natural number[53] among others are argued to have developed in similar ways. Cassirer inferred from these examples that the development from substantive to functional concepts is a 'logical tendency of thought'.[54] The brief analyses of an impressive amount of scientific theories thus served as an important argument for the new type of concept. The transcendental method dictated that the most advanced theories best represented the our knowledge. Since in these theories scientists express their concepts in a functional way, we therefore have to understand the foundations of our knowledge to rely on functional concepts too.

Before turning to the next argument, it must be noted that Cassirer did not consider the notions of substantivity and functionality to be absolute terms. Both are initially relative terms, used to express a comparison between two concepts. When we say that a substantive concept is replaced by a functional

[49] Cassirer most probably referred to the ether theories of Faraday and Maxwell, who described the ether as an elastic and as a fluid medium respectively.
[50] (Cassirer, 1923, 163)
[51] (Cassirer, 1924, 156-162)
[52] (Cassirer, 1924, 187-203)
[53] (Cassirer, 1924, 44ff.)
[54] (Cassirer, 1924, 57)

one, we mean that the latter is functional in respect to the former, which in that light is considered substantive. The development of scientific concepts, however, is one that never stops. Instead, the functional concept itself may be replaced by a new concept, in the light of which it becomes substantive. The replacement of a concept by a more functional one is always possible and the most functional concept is an ideal which is essentially unachievable. Nevertheless, scientist always strive for more functional concepts and in doing so strive for this ideal when developing new theories.[55]

An argument on the basis of a rejection of intuitions

Cassirer used analyses of scientific practice in a second argument. In this two-step argument he claimed first that scientific practice verifies the Marburg rejection of intuition and subsequently argued that intuition-free concepts can only be function-concepts. The first step relied on a Duhemian argument. Along the well-known lines of Duhem's thesis,[56] Cassirer argued that scientific measurements, the empirical foundation of any theory, can never be made in isolation. All measurements, even the most elementary ones, require interpretation of the used apparatuses and thereby are possible only by the assumption of concepts and principles. The measurement of the intensity of an electrical current by using a galvanometer for instance, requires the acceptance of methods by which this apparatus works and thus presupposes a number of physical and mathematical laws, such as geometrical principles and laws of motion.[57] Every determines measurement thus is meaningful only when these principles and concepts are accepted and hence only can be properly explained as an element within a larger theoretical structure. In other words, no measurement is meaningful when it is taken in isolation and Cassirer thus argued that an analysis of scientific practice shows that it is impossible to found our theories on notions that are independent of other notions.

Such independent notions however, are exactly what the traditional Kantian intuition represents and hence what the classical concept makes use of. Recall that intuition was understood as an unmediated part of our knowledge, grasped directly and serving as the foundation of concepts. The scientific practice of measurements have shown however that we cannot have such a part in our knowledge and thus verifies the Marburgian theses that in knowledge, nothing is given directly. It therefore supports the rejection of intuition, which, Cassirer argued subsequently, allowed only the new functional-concept.

The abstraction theory defines concepts on the basis of their shared properties and thereby yields substance concepts. Thus the ether is defined as an object that belongs to the class of elastic objects. This method assumes that we can recognise the property of elasticity directly and without the use of con-

[55](Cassirer, 1923, 269)

[56]Cassirer explicitly referred to Duhem's *La Th'eorie Physique, son Object et sa Structure*, originally published in 1906.(Cassirer, 1923, 269) For a detailed discussion of the main argument, see (Ariew, 1984)

[57](Cassirer, 1923, 144)

cepts. But as both Cohen had argued, Cassirer argued, no property can be recognised as similar to another one without the prior assumption of certain concepts. The notion of elasticity itself is dependent on many more concepts and therefore neither this notion, nor the recognition of the similarity between to objects that possess it, can function in the way dictated by the abstractionist theory. The concept of the ether thus can only be established by relating it to other concepts. Only as such a functional concept it can be free of unmediated parts in knowledge such as intuition.

It must be noted that this argument does not make the traditional theory of concept formation a completely impossible one. It is still possible to form concepts on the basis of the recognition of similarity of properties. What Cassirer argued, however, is that this recognition already requires concepts and that hence not all our concepts can be formed in this way. The most fundamental concepts, the ones that would be required for the formation of substance-concepts need to be free of intuitions. Function-concepts thus play a role in our knowledge at the most fundamental level. In order to recognise any properties or similarities in the world, indeed, in order to have any experience, certain concepts, which necessarily are functional, must be accepted. As such preconditions of knowledge, their synthetic a priori character is easily recognised.[58] As with the notion of the concept however, the notion of the a priori must not be equated with the traditional Kantian one. The next section explains the similarities and the differences between the two.

The last pages have shown how Cassirer's reinterpretation of the Kantian concept was supported by two arguments that were based on typical Marburgian ideas. By adhering to the transcendental method as well as rejecting the notion of intuition, Cassirer concluded that the concepts on which our knowledge is based is are not substantive, but rather relational. Indeed, the revised Kantianism, in which intuition is dispensed of, supported the same type of concept as the one to which scientists always strive in their development of new theories.

1.3.2 Cassirer's a Priori

It is clear from the text in *Substanzbegriff und Funktionsbegriff* that Cassirer followed Kant and understood cognitions to be a priori not because they are prior to experience, but only if they are necessary requirements for the constitution of knowledge.[59] Nevertheless, like many other terms in *Substanzbegriff und Funktionsbegriff*, the notion of *a priori* is not explicitly defined and the readers must deduce its precise meaning from the context and given examples. That this has lead to ambiguity is clear from the variety of interpretations of Cassirer's use of the term in a number of recent publications. Michael Friedman has claimed that Cassirer's a priori principles must be understood only in the strict sense

[58] Cassirer explicitly defended their synthetic nature and refused to accept them as definitions in discussion with Schlick and Reichenbach. This discussion is outlined in chapter 3.1.

[59] "A cognition is called a priori not in any sense as if it were prior to experience, but because and in so far as it is contained as a necessary premise in every valid judgment concerning facts." (Cassirer, 1923, 269)

of preconditions for any experience.[60] In this strict sense of the term Cassirer's a priori principles are similar to Kant's original conception of synthetic a priori principles as apodictic rules that govern our thought. These rules are a priori in an absolute sense because they are definitive and are required for thought at any place or time and in all circumstances.

Several commentators have disagreed with Friedman and have argued that Cassirer's a priori must not only be understood in this strict sense and that we may recognise in his philosophy principles that are a priori in a relative sense only. Like the absolute a priori principles they are understood as preconditions for the possibility of knowledge but in contrast to them, they are not principles whose requirement is absolutely necessary. Instead, they are relative to the scientific theory that presupposes them. Whereas absolute a priori principles thus are considered to be necessary requirements for experience in general, relative a priori principles are required only by particular scientific theories and therefore are not apodictically valid. Since science is not static and its theories change over time, presumptions on which these theories are dependent may be revised and replaced. Both Thomas Ryckman[61] and Jeremy Heis[62] have defended the view that *Substanzbegriff und Funktionsbegriff* contains a relative a priori. Heis's account in particular is illuminating and shows successfully how Cassirer maintained both an absolute and a relative a priori and that moreover the former was necessitated by his rejection of the substance-concept. In what follows I accept his argument that numerous references in *Substanzbegriff und Funktionsbegriff* rule out the possibility that in Cassirer's epistemology there was no relative a priori.

Both Ryckman and Heis consider Cassirer's relative a priori to be a consequence of the Marburg School's claim that Kant had been mistaken in his belief that the development of science had finished with the publication of Newton's *Principia*. Like Cohen and Natorp, Cassirer emphasised that science is always progressing and is never complete. It was their opinion that Kant was highly impressed by the achievements of Newton and considered the principles that made possible its theories, such as Euclidean geometry, for human experience and knowledge in general. The Marburg School, however, replaced the notion of Newtonian science as the definite description of the world by that of merely a stage in the history of ever-evolving science. Therefore the idea that the preconditions for Newtonian physics were those of human thought in general had become debatable too. In *Substanzbegriff und Funktionsbegriff* Cassirer explicitly criticises Kant's absoluteness of the a priori principles found in Newtonian physics:

> Such principles as, for example, those on which Newton founds his mechanics, do not need to be taken as absolutely unchanging dogmas; they can rather be regarded as the temporarily simplest intellectual "hypotheses".[63]

[60] (Friedman, 2001, 65ff.)
[61] (Ryckman, 2005)
[62] (Heis, forthcoming.b)
[63] (Cassirer, 1923, 268)

Although Euclidean geometry, for instance, was one of the most fundamental assumptions and moreover a necessary requirement for the construction of Newtonian physics, for Cassirer there was no reason why it had to be presupposed by future theories too. To understand this, it needs to be recalled that, for Cassirer, the progress of scientific theories and their concepts towards more and more functional ones was a never-ending development. The principles of Euclidean geometry, which Kant had held to be apodictically valid, were considered to be subject to this development too. Cassirer therefore could not exclude the possibility that one day they would be replaced by concepts that are more functional. Hence they cannot be said to be apodictically true and they differ in status from the original Kantian a priori principles. Their role as presuppositions of knowledge only makes sense if this knowledge is understood to be represented by classical mechanics. Nevertheless, the impossibility to have any unmediated experience, demanded that such constitutive principles were required for experience and that every physical theory had to presuppose at least some (relaative a priori) constitutive principles.[64] Hence the principles that Kant had considered to be absolute a priori, Cassirer considered relative a priori principles.

Although Heis defends the notion of a relative a priori in Cassirer's theory, he does not claim that there is no room left for an absolute a priori. Indeed, Heis shows that Cassirer could not completely replace Kant's notion of an absolute a priori with a relative one without either giving up his objections against intuition or ending up with a theory that would be unable to account for objective science.[65] Without such objectivity, there would be no guarantee for the coherence between scientific theories throughout history and the idea that scientific theories today have any relation to older theories would become debatable. To understand this argument, Cassirer's notion of objectivity needs further clarification. Objectivity, in Cassirer's theory is given by two qualities, unity and permanence.[66] The stronger these qualities are in a theory, the more objective it is. The first quality, unity, demands logical coherence between the laws of a theory themselves and between these laws and experimental measurements. The second quality is that of permanence, which demands an objective theory to describe that part of our experience which is constant.[67] Thus, the position of a moving object is subjective relative to the law that describes this motion, since the former changes over time whereas the latter remains constant.[68] It is the quality of permanence that, Heis argues, becomes problematic for Cassirer if his theory would not contain absolute a priori principles.

In the substance theory of knowledge, which Cassirer rejected, intuitions guarantee permanence and hence play a fundamental role in supplying theories

[64](Cassirer, 1923, 267)
[65](Heis, 2007)
[66](Cassirer, 1923, 322)
[67](Cassirer, 1923, 273)
[68]Cassirer remarked that objectivity and subjectivity are not absolute terms, but used only to express relations between multiple theories or judgements. The particular law given in the above example would be subjective relative to a higher order law that describes the first law as dependent on variable aspects.

with objectivity. Intuitions are the sole and ultimate source of the concepts found in scientific theory. Moreover, they are characterised as being direct and unmediated. Since intuitions precede concepts and with them the mediated stage of our knowledge, they are not tainted with subjective interpretation. Intuitions thus supply the mind with a part of our knowledge that is constant. Explanations of concepts in scientific theories by reference to intuitions, therefore can account for permanence and hence can claim to explain the objectivity of science. Different scientific theories, using different concepts, should all refer to the same intuitions. Since intuitions precede concepts, they are independent of particular scientific theory. In the substance theory of knowledge, intuitions thus function as elements of our knowledge that are theory-neutral and objective.

The previous section discussed Cassirer's argument that intuitions cannot precede every concept and that therefore the reception of every intuition depends on the application of at least some concepts already. In Cassirer's function theory of knowledge that replaces the substance theory, concepts are formed solely by their relation to other concepts, not by reference to intuitions. But this implies that the role that intuitions play in the substance theory as guaranteeing a shared manifold of theory-neutral representations has also been removed. This obviously leads to the undesirable conclusion that a science that adopts Cassirer's intuition-free function theory of concept formation, can no longer be considered objective. Science would be reduced to an arbitrary set of theories and concepts that describe the world. There would be no theory-independent elements of our cognition to which these laws should relate. Without any intuitions that must be presumed in all theories, the meanings of our concepts lose an origin that must be accepted by all scientists, independent of subjective interpretation. Without such a common ground to even compare different theories, the history of science would become a series of theories that whimsically substitute each other. To maintain that scientific evolution is objective and evolving towards an ideal science, Cassirer thus was necessitated to find a new way in which the role of intuitions could be fulfilled.

Cassirer's way of securing the objectivity of science, was a preservation of the notion of absolute a priori principles. Although most of the a priori principles originally proposed by Kant were, in Cassirer's eyes only relative a priori principles, he thus did not away with the idea of apodictically valid principles entirely. These principles are constant throughout history and independent of particular theory and hence can supply the constancy demanded by objectivity. Indeed, Cassirer considered it the ultimate task of his philosophy to identify these principles.[69] Since the method of striving for this philosophical goal is a study of scientific theory, the never-attainable ideal of the natural sciences entails that we can never have certain knowledge of the absolute a priori principles. We cannot possibly know what future theories will look like and in which ways they may replace the principles of current theories. What we may find as principles of all scientific theories in history and thus hold to be absolute a priori

[69](Cassirer, 1923, 269)

principles today, may be replaced by more abstract principles and be contained in it only as an approximation tomorrow. The task of Cassirer's philosophy thus is, along with that of science, principally unattainable.

Although, Cassirer admitted that he could not possibly give a definite list of the absolute a priori principles, throughout *Substanzbegriff und Funktionsbegriff* a variety of candidates are advanced. Reflecting on these candidates, we can identify four different types of absolute a priori elements of our knowledge.[70] First, it is necessary that all our scientific theories apply mathematical concepts and principles.[71] The particular concepts and principles that are used may vary from theory to theory, but no theory can be formed without the application of any of these concepts and principles. Among the principles and concepts of Newtonian mechanics, on which Kant based himself, we find the the axioms of Euclidean geometry, but also fundamental arithmetical propositions. Cassirer held that alternative mechanics may replace these, but that they cannot simply eliminate them since every theory must employ at least some mathematical principles and concepts. Second, every theory must contain a number of 'ultimate invariant' concepts such as those of space, time, magnitude and cause.[72] Again, although no account of our experience can leave these concepts untouched, the exact interpretation of these concepts may change and are made intelligible by the relative a priori laws of particular theories. The concepts of space and time are thus considered to be absolute a priori requirements by Cassirer, but unlike Kant's intuitions of space and time, their structures are not given independently of their relation to particular scientific theory. Third, every theory must take into account some principles of theory selection. Examples that Cassirer believed had guided this selection process throughout history, were the principles that 'theories should be as simple, general and fruitful as possible'.[73] The fourth and final type of a priori elements is that of the unity of nature. Every theory must be constructed by the idea that all empirical events can be described by, preferably simple, physical laws.[74]

In contrast to the laws of a particular theory which are only a priori in a relative sense, the demands expressed by these four elements are argued to be preconditions for all descriptions of our experience. As mentioned earlier, Cassirer acknowledged that the absoluteness of absolute a priori principles could not be stated with certainty. If we accept them as tentative descriptions of absolute a priori principles, however, we see that they are not adapted over time, even if the contents of our theories change fundamentally, they remain constant. Hence they are able to supply the permanence and guarantee an objective science. These absolute a priori concepts and principles therefore serve as regulative ideals. Any possible theory that would not rely on any notion of space or would describe our experiences in an enormously complex way, would not be considered to express objective knowledge at all. The ideal theory,

[70](Heis, forthcoming.b, 13)
[71](Cassirer, 1923, 257,322-3)
[72](Cassirer, 1923, 269, 309)
[73](Heis, forthcoming.b, 13),(Cassirer, 1923, 260)
[74](Cassirer, 1923, 248, 304)

towards which science always strives, is one in which the principles are achieved in the best possible way and where the concepts used have reached ultimate functionality. It is important to distinguish this regulative feature from the constitutive character of the relative a priori principles. The constitutive a priori principles are required to make possible experience and interpret measurements. They are revisable however and hence cannot guarantee objective science. Every relative a priori principle is however, the realisation of a regulative ideal. The absolute a priori demand that every description must be given by the use of some notion of space and that it be formulated in a way that expresses the highest possible degree of expressing the unity of nature' can be given particular content by the presupposition of the constitutive principles of Euclidean geometry and the qualitative separation of space from time. The latter are required in order to 'constitute' a theory, they are revisable but any replacement must adhere to certain regulative and absolute a priori principles.

Understood as ideal principles, it becomes clear how Cassirer's absolute a priori principles take over the function of intuitions as warrantors for objectivity. Like these intuitions, the absolute a priori rules are independent of particular theory and supply scientists with a shared basis of concepts and principles that their theories must adhere to. Physicists throughout the entire history of science can refer to these concepts and principles. Indeed, the absolute a priori concepts and principles make it possible that we can speak of science as a single enterprise that hosts both the theories of Ptolemy, those of Copernicus and, as will be seen in the next chapter, would include those of Einstein too.[75]

The notion of a priori found in *Substanzbegriff und Funktionsbegriff* thus has two distinctive meanings. On the one hand we find principles that are constitutive and a priori only in a relative sense. This relativity is a result of a typical Marburgian view on the development of science as an ever-developing enterprise. On the other hand, to combine the proclaimed objectivity of this development with the objections against the notion of intuition, which was equally typical for the Marburg School, Cassirer was forced to adopt a notion of regulative, absolute a priori principles alongside the relative ones.

[75](Cassirer, 1923, 321)

Chapter 2

Cassirer and the Theory of Relativity

2.1 "*Zur Einsteinschen Relativitätstheorie*"

2.1.1 Before the publication

In the previous chapter we have examined Cassirer's philosophy of science and his theory as found in *Substanzbegriff und Funktionsbegriff*. Since it was published in 1910 and thus written in a time when the field equations of general relativity were still unknown, we have referred to it as 'pre-relativistic' philosophy. Consequently, it is unsurprising that Einstein and his physics are not mentioned in "Substance and Function". Cassirer's first publication that reveals an awareness of the general theory of relativity is an article published in 1920 in *Die neue Rundschau*, entitled "*Philosophische Probleme der Relativitätstheorie*".[1] In this article, the title of which translates to "Philsophical problems of the theory of relativity", Cassirer briefly described a similarity between the special and general theories of relativity and his own theory of substance formation which he expressed in 1910 in "Substanzbegriff und Funktionsbegriff".

Although only published in early 1920, a more detailed version of this analysis had already been sent to print by Cassirer before the article in *die Neue Rundschau* appeared. Even so, "*Zur Einsteinschen Relativitätstheorie*"[2] was was among the first books to philosophically reflect on the general theory of relativity. Initially the contents of the book were not written with the aim of being published, but rather with Cassirer's idea of helping himself to understand the physics and mathematics of the relativity theories.[3] It is for the same reason that Cassirer contacted the creator of the theories. In 1920 he sent a draft version of the text he was evaluating to Einstein and asked him whether

[1] (Cassirer, 1920c)
[2] (Cassirer, 1921)
[3] Cassirer to Einstein, 10 May 1920, (Cassirer, 2009, 44-45)

he thought it displayed the theories correctly and to ask him for his criticism and corrections. Einstein responded a month later in a letter in which he remarked Cassirer's comprehension of the theory and its physics. Einstein was not entirely uncritical but his criticism was directed towards the epistemological consequences of the relativity theories drawn by Cassirer more than towards his presentation of the theory itself.[4] Although Einstein himself had noted that he had made these epistemological criticisms as a non-philosopher, Cassirer took them serious and used them to adapt his text. Most importantly, in the revised version of his draft, he emphasised the empirical foundation of the relativity theory stronger than he had in his earlier version, in which it had appeared less significant than its theoretical foundations.[5] Correspondence with Natorp reveals that Cassirer was more than happy to learn from Einstein himself that he had understood the physics of the relativity theory and that hence to that extent his aim of writing the text as a method of gaining knowledge of modern physics had succeeded.[6] Indeed, Einstein's approval of Cassirer's depiction of the theory had encouraged him to think about publication. During the months leading up to the publication of "*Zur Einsteinschen Relativitätstheorie*", in January 1921, Cassirer, then a professor at the University of Hamburg had given a course on the philosophical problems of the theories of relativity.[7]

2.1.2 Mutual understanding of physicists and philosophers

As with the acceptance of the criticism of a non-philosopher, Cassirer did not wish to express with his a publication any ideas of authority on the interpretation of the relativity theory. Instead, he believed that a correct interpretation could only be realised after intensive discussion and throughout a series of articles exposing different interpretations, of which his own text would be one of the first.[8] Cassirer hoped that his book would awaken the debate in which he thought philosophers as well as physicists should join and in which a mutual understanding between the two groups could be realised.[9] From his correspondence with Einstein it is clear that Cassirer expected objections to his interpretation from the latter group.[10] Indeed, this expectation was not ungrounded. Cassirer was known to be a philosopher in the tradition of Kant and he had used Kantian ideas as the underpinning of his interpretation on the theory of relativity. The theory of relativity, as we have seen in the previous chapter, conflicted with Kantian philosophy. Most importantly the notions of space and time as

[4] Einstein to Cassirer, 5 June 1920, (Cassirer, 2009, 45-46) For a more detailed discussion on the relation between Cassirer and Einstein, see section 3.4.2

[5] Cassirer to Einstein, 16 June 1920, (Cassirer, 2009, 47)

[6] Cassirer to Natorp, 15 October 1920, document 294 on the DVD accompanying (Cassirer, 2009)

[7] (Cassirer, 2010, 31-49)

[8] (Cassirer, 1923, 349)

[9] See also: Cassirer to Cohn, 23 November 1920, document 299 on the DVD accompanying (Cassirer, 2009)

[10] "Ich selbst hoffe aus der Diskussion gescehen, diesen Fragen zu lernen - besonders auch von den Einwänden, die etwa von Seiten Physiker gegen meine Schlussfolgerungen erhoben werden sollten." Cassirer to Einstein, 16 June 1920, (Cassirer, 2009, 47)

they are described by the general theory of relativity did not correspond with Kant's expressions of space as being necessarily understood as Euclidean and distinct from time.[11] Adherents of the relativity theory, with a growing number of physicists among them,[12] thus naturally were drawn to the idea that the Kantian doctrine had to be given up. Cassirer, however, did not think the tension between the relativity theory and Kant was fatal for the latter. An adaption of traditional Kantianism in such a way that it would not harm those elements of the doctrine that Cassirer considered fundamental, would, he claimed, give an epistemological theory that could perfectly account for the theory of relativity. Cassirer's expectation of criticism from the scientific community was moreover fed by the responses they had given to earlier philosophical commentaries on the theories of relativity. Neo-Kantians as well as other philosophical scholars had recently published views that had not fared well with many physicists. Authors such as Kraus[13] and Drill[14] had rejected the theory of relativity theory without paying attention to its physical content. Both had thereby invoked the wrath of notable physicists such as Einstein, Born and Ehrenfest.[15] Other philosophers, such as Bauch[16] and Hönigswald[17] had expressed their thoughts that physical theory and philosophy were distinct fields that make statements on unrelated topics and that hence the theory of relativity could not refute any philosophical positions. Cassirer considered both these view harmful and instead expressed his hope for a cooperation between physicists and philosophers.

The rapprochement to scientists is evident from two further letters written to Einstein in the summer of 1920. Einstein was invited by the University of Hamburg to hold a lecture on the foundations of relativity theory on July 17 that year. Cassirer, living in Hamburg with his wife at the time, and working as a professor in philosophy at its University, wrote a letter to Einstein, not only to tell him that he was looking forward to the lecture, but also to invite him over to his own house to stay over.[18] When a month later, on August 24, the Philharmonic Hall in Berlin had hosted a large rally against the theory of relativity, largely fed by anti-Semetic feelings[19], Cassirer again wrote Einstein. Only four days after the event, Cassirer, like Einstein born in a Jewish family himself, expressed his sympathy towards Einstein. More particularly, he pitied the fact that the years of research and hard work done by Einstein had been objected on personal and political grounds rather than on sound argumentation.[20] That Cassirer did not believe in a strict distinction between philosophy and science is clear from the continuation of the letter. He emphasised that

[11] See section 2.2.1 for a more detailed discussion of the problems the general theory of relativity posed for Kant's philosophy.
[12] (Pyenson, 1987)
[13] (Kraus, 1919)
[14] (Drill, 1919)
[15] (Hentschel, 1990, 168-170, 554)
[16] (Bauch, 1911)
[17] (Hönigswald, 1912)
[18] Cassirer to Einstein, 15 July 1920, (Cassirer, 2009, 48)
[19] (van Dongen, 2007)
[20] Cassirer Einstein, 28 August 1920, (Cassirer, 2009, 49)

the non-scientific source of objection to the theory of relativity must not set the tone for the debate on the theory of relativity. In the letter he claimed that the stronger the unscientific objections and "the worse the conditions for us, the more we need men who guide us back to critical discretion and calm, factual work."[21] In Cassirer's eyes, the rally in Berlin, had not only harmed the physicist's work, but had interfered with its philosophical counterpart just as much. Indeed, according to Cassirer, physicists and philosophers were not working in different fields, but their topics overlapped in such a way that the attack on Einstein was an attack on the same academical field that he himself was working in. The calm, factual work that was needed was a job that was shared by philosophers and scientists alike.

Cassirer hoped that his own work on the theory of relativity would be one of the examples of such factual interpretation and that it would lead the way to further philosophical thought on the theory. As one of the first philosophical comments on the new physical theory that was moreover proofread and approved by the author of that theory, the book drew attention within philosophical circles. Well-known contemporary philosophers of science, including Eduard Hartmann[22], Ilse Schneider[23], Hans Reichenbach[24] and Moritz Schlick[25], commented on the publication or corresponded with Cassirer about its contents. Although none of these would share Cassirer's views completely and some even rejected its philosophical foundations explicitly, they all praised him for his work and considered it a valuable contribution to the philosophical debate on the theory of relativity.[26]

2.1.3 "Einstein's Theory of Relativity"

The first English translation of "*Zur Einsteinschen Relativitätstheorie*" appeared two year after the original edition, in 1923, together with a translation of "*Substanzbegriff und Funktionsbegriff*"[27]. The two were combined in a single volume in which the newer work was presented as a supplement to the older. The English version, bearing the title "Substance and Function and Einstein's Theory of Relativity", thus combined two books whose original versions appeared independently and were separated by more than a decade. Moreover, in the intermediate years Cassirer had continued to publish a variety of articles and books on fundamental topics found in "*Substanzbegriff und Funktionsbegiff*" such as epistemology, science and modern day interpretations of Kant.[28] The

[21] Own translation. Originally: "Je schlimmer die Verhältnisse bei uns werden, um so mehr bedürfen wir der Männer die uns wieder zur kritischen Besonnenheit und zur ruhigen sachlichen Arbeit erziehen." Cassirer to Einstein, 28 August 1920, (Cassirer, 2009, 49)
[22] (Hartmann, 1924)
[23] (Schneider, 1921a)
[24] (Reichenbach, 1922)
[25] (Schlick, 1979)
[26] e.g. Schlick recognised in "Zur Einsteinschen Relativiätstheorie a " *brilliant use of the finest historical and philosophical scholarship"* (Schlick, 1979, 327)
[27] (Cassirer, 1923)
[28] See for instance (Cassirer, 1913), (Cassirer, 1914), (Cassirer, 1918) and (Cassirer, 1920a).

original editions of "Substance and Function" and "Einstein's Theory of Relativity" thus were not only separated by more than a decade but also by a number of other publications and hence the combination of both works in a single volume might not be evident from the face of it. Nevertheless, the relation between his 1910 book and his treatment of relativity was recognisably stronger than that with any of the other texts Cassirer had published since. Most importantly, in "*Zur Einsteinschen Relativitätstheorie*" Cassirer had presented Einstein's physical theory as a confirmation of his own philosophical theory proposed in "Substance and Function".

Although the influence of the Marburg School on Cassirer's work had started to weaken by 1921,[29] Cassirer was still affiliated with its neo-Kantian tradition. This included a strong emphasis on the transcendental method, predicating the idea that the facts of modern science should not be doubted, but instead taken for granted and that investigating them will inform us about the most fundamental rules that govern our thinking. The previous chapter has shown that this method played an important role in developing Cassirer's philosophy found in "*Substanzbegriff und Funktionsbegriff*". Like his colleagues Cohen and Natorp, he had considered the most advanced scientific theories as a source of epistemological investigation. The publications of the theories of relativity, the special theory in 1905 and the general theory in 1915, supplied the physicist with a set of brand new theories that differed from their predecessors fundamentally. Naturally, these theories were of interest for the adherents of the transcendental method too. As the most advanced descriptions of our experience, an analysis of their foundations would not only tell us something about the laws by which we may describe nature, but would also give us a better understanding of how we can have knowledge at all. For Cassirer and the Marburg School, a radically new physical theory was essentially a worthwhile topic from the standpoint of epistemology.[30]

Moreover, "*Substanzbegriff und Funktionsbegriff*" contained philosophical and historical analyses of physical theories since the Renaissance. The appearance of a new, revolutionary theory only a few years after the publication of this book, challenged Cassirer to investigate whether or not these analyses and general tendencies of scientific development which he had described, were still defensible. Cassirer accepted this challenge and his interpretation of the theories of relativity may well be understood as the thesis that both of the central ideas of his pre-relativistic philosophy, as discussed in section 1.2.4, a reinterpretation of the notion of the a priori and the discovery of a historical tendency in the development of concept formation, had been verified by Einstein's physics.

Cassirer's reinterpretation of the a priori considered claim that in scientific theories way can distinguish between relative a priori requirements and absolute a priori requirements. Whereas both are understood as fundamental

[29](Skidelsky, 2009, 47 ff.)

[30]The opening pages of "*Zur Einsteinschen Relativitätstheorie* reveal this attitude of Cassirer clearly. 'Thus, the theory of relativity, as opposed to the classical system of mechanics, offers a new scientific problem by which the critical philosophy must be tested anew.' (Cassirer, 1923, 355)

assumptions made in scientific theories, the latter are necessarily required by all theories and the former are replaceable. In contrast to the traditional Kantian doctrine which held the Euclidean structure of space to be an absolute a priori requirement, Cassirer's neo-Kantian interpretation held that this requirement was dependent on particular scientific theory and that it may be superseded by a new requirement. Reflecting on the history of science, Cassirer argued that such a replacement always took place in a way whereby the old principle was contained in its successor in such a manner that the latter could make the former comprehensible as an approximation or as a valid rule only in limited cases. If Cassirer was correct, he had to be able to give an account of the general theory of relativity and in particular of its new notions of space and time in accordance with this proclaimed development of science. The replacement of the Newtonian notions of space and time by relativistic ones should be expressible as the replacement of relative a priori principles in which the former are understood as special cases of the latter. Cassirer, in "*Zur Einsteinschen Relativitätstheorie*", thus treated the relativistic notions of space and time as relative a priori concepts. Moreover, in "*Substanzbegriff und Funktionsbegriff*" he had considered the concepts of space and time, unrelated to particular structure, to be absolute a priori requirements. He had claimed that no scientific theory could do without some embodiment of these concepts.[31] He thus was also challenged to give an account of relativistic space and time as expressions of these absolute a priori concepts. The outlines of Cassirer's arguments that defend this view are given in section 2.5

The second claim found in "*Substanzbegriff und Funktionsbegriff*" and discussed in the previous chapter was Cassirer's theory that throughout the development of science the general concepts found in its theories relied more and more on a modern method of concept formation. Rather than applying the 'copy theory of knowledge' that yielded substance concepts, directly visible things as objects of knowledge, modern theories relied on the function concepts, relations and dependencies between phenomena, as their objects. If Cassirer wished to maintain this theory, whilst accepting the theories of relativity, he had to argue that this new theory too accorded with this generalisation. Indeed, besides a defence of relativistic space and time as a priori principles, this argument is made by Cassirer. It is one of the central claims of the book that the principle of general covariance was the realisation of an advanced stage in the replacement of substance concepts by function concepts in science. Section 2.4 discusses this argument in detail.

The choice to treat Cassirer's "Einstein's Theory of Relativity" as a supplement to "Substance and Function" thus is not an arbitrary one. The contents of Cassirer's discussion of the theory of relativity greatly overlap with that of his publication of 1910. The arguments found in the earlier work had been supported by examples taken from the history of science. The general theory of relativity was understood as a new development in this history and thus was a theory that begged to be evaluated in a similar manner. The transcendental

[31] (Cassirer, 1910, 269, 309) See also section 1.3.2

method challenged Cassirer to reassess his earlier theories and hence to write a text that can easily be understood as an appendix to "Substance and Function".

2.2 Kantianism and the Theory of Relativity

2.2.1 Problems for Kant

Cassirer's epistemology had developed as a neo-Kantian theory and the development and growing acceptance of the special as well as the general theory of relativity had posed some serious problems for Kant's original doctrine.[32] The core of Kant's theory that conflicted with the relativity theories were his notions of space and time, which, as Cassirer's colleague Cohen had emphasised correctly, were fundamentally Newtonian.[33] Kant had, for instance adopted Newton's distinctions between absolute and relative space and time.[34] Whereas relative space and time, in his eyes, were useful notions for calculation, they were not the frames in which physical events should be thought to take place. Absolute space and time, required by Newton to give meaning to his notion of absolute rest as it is found in the first of his laws, were the unique frames of reference in which all physical events necessarily should be thought. Kant had not only copied these Newtonian principles as descriptions of nature, but applied them in his philosophy as requirements of human cognition. In his critical philosophy, Kant had identified Newtonian physics with the ultimate science and he had drawn the conclusion that the presuppositions of its laws were presuppositions of human thought in general. This meant that in the traditional Kantian doctrine, several aspects of space found in Newtonian theory were considered to be a priori. In at least three of these aspects the conflict with the notion of space as found in theories of relativity was more than evident. According to Kant, space and time were necessarily thought to possess absolute existence, they were presupposed to exist independently from each other and third, space was thought to be necessarily three-dimensional and only describable by Euclidean geometry.

3 maal

Mathematicians had already made this last assumption problematic by the construction of non-Euclidean geometries in the nineteenth century. These however, could still be dismissed as irrelevant material for neo-Kantians since it considered only formal, mathematical systems that were argued to be unrelated to the world around us. Indeed, the non-Euclidean geometries as merely mathematical constructions gained little attention by neo-Kantian philosophers. The general theory of relativity, however, had proved the possibility to apply non-Euclidean geometry to a description of the empirical world. Evidently Kant had been wrong in claiming that Euclidean geometry was a fundamental assumption in all thought.

But it was not only the non-Euclidean character of space in the general

[32] See also subsection 1.1.4
[33] (Cohen, 1871)
[34] (Kant, 1900, 15)

theory of relativity, and not even only the general theory that conflicted with Kant's words. The other two aforementioned Newtonian characters of space and time that had been implemented in Kant's philosophy, their independence and their absolute existence, were considered false in the light of either one or both of the relativity theories too. The independent existence of space and time did not correspond to Einstein's treatment of space and time as mere coordinates of a single space-time unity in the special theory. In the general theory this unity was maintained and emphasised even stronger by the fact that the coordinates that refer to space cannot be distinguished from those that refer to time and that thus the two cannot be said to be distinct from each other. The absoluteness of space and time which Kant had explicitly considered apodictically valid, conflicted directly with the equality of reference frames for the laws of the relativity theories and that of the perceptions of simultaneity in these different frames.

In the years immediately after 1905, when only the special theory had been developed, little attention was paid to Einstein's work by neo-Kantians[35]. The general theory, in contrast, had initiated a rise of interest for the relativity theories by laymen and experts alike. Consequently, philosophers who claimed to work in the spirit of Kant were challenged to respond to the aforementioned anomalies. They were forced to take a position towards both Kant and the relativity theories. Generally, one may recognise and distinguish two types of responses chosen by neo-Kantians reflecting on Einstein's theories. One the one hand there were 'conservatists', who clung to the original Kantian doctrine and tried to explain how it was not fatally harmed by the recent developments in physics. On the other there were 'revisionists' who attempted to show how modern-day adaptations of the original doctrine would be able to overcome the purported anomalies. Amongst the variety of neo-Kantians in the early twentieth century and the variety of interpretations of Kant, both paths were followed. Although others proved it was possible to deny the relation between the relativity theories and Kant's original theses or even reject some fundamental aspects of the theory,[36] Cassirer straightforwardly admitted that the traditional Kantian teaching could not be squared with Einstein's physics. Nevertheless, he maintained that if it would be stripped of its contemporary character, and if one focused purely on its methodological character, it would not conflict with either one of the relativity theories.[37] Expressing these views as early as 1920, they were some of the first that clearly revisionist option. The most important arguments found in "*Zur Einsteinschen Relativiätstheorie*" are based on the idea that neither of the relativity theories contradicted the Marburgian interpretation of Kant, which allowed certain deviations from the traditional doctrine.

[35](Hentschel, 1990, 224)
[36]The neo-Kantian Ripke-Kühn, for instance, rejected general covariance as a valid demand of physical theory.(Hentschel, 1990, 218)
[37](Cassirer, 1923, 415)

2.2.2 Cassirer's Attitude towards Kant

Cassirer's willingness to revise the traditional Kantian doctrine was not initiated by the relativity theories. The previous chapter has shown that already before 1910 Cassirer had joined his fellow Marburgians in rejecting the distinction between intuitions and concepts which many Kantian scholars had interpreted as a strict distinction of a direct and unmediated part of experience on the one hand and a conceptual part mediated by the understanding on the other hand. Cassirer's colleagues in Marburg had opposed the role of the former part already in the late nineteenth century, before Einstein had moved to Bern where he would develop the special theory of relativity. Kant had argued that space and time were intuitions and by most Kantian interpreters this was understood to imply that they were directly perceived by the human mind. The Marburg scholars however, claimed that space and time only contributed to knowledge in the form of concepts; constructs created by the mind to relate different parts of experience. In "*Substanzbegriff und Funktionsbegriff*" Cassirer had applied the Marburgian rejection of intuition as a theoretical foundation of the historical development of the use of concepts in science. In "*Zur Einsteinschen Relativitätstheorie*" Cassirer returned to this argument and argued that in the light of this development relativistic space and time are not as incompatible with Marburg School neo-Kantianism as they are with Kantian interpretations that are not aware of this development.

But it was not only a particular interpretation of Kant that the Marburgians held responsible for the incompatibility between Kant's theses and modern science, Kant himself had made mistakes that had become visible in the light of modern science, and now required correction. Kant had lived in the heydays of Newtonian mechanics and it had been his mistake to consider these mechanics as definite descriptions of experience. In Cassirer's discussion of relativity theory, this dependence of Kant on Newton was explicitly recognised[38] and Cassirer argued that it was no longer tenable.[39] The strong relation of Kant's philosophy to Newtonian physics had caused Kant to confuse the presumptions of a particular physical theory with the presumptions for all possible human knowledge. Cassirer instead maintained that Newton's presumptions were only relative a priori principles that were constitutive for his theory, but could be revised in the course of scientific development. An important reason why Cassirer did not completely betray his intellectual ancestor and why he still was considered a Kantian, is that he did not reject the existence of some fundamental requirements for all possible knowledge. Although principally impossible to state with certainty, Cassirer had attempted to define these unchangeable, absolute a priori principles already in 1905. An awareness of this revised notion of the a priori helped Cassirer in demonstrating the unproblematic relation between the

[38] *"[H]e [Kant] shaped his "Analogies of Experience" essentially on the three fundamental Newtonian laws: the law of inertia, the law of the proportionality of force and acceleration, and the law of the equality of action and reaction."*(Cassirer, 1923, 415)

[39] "That a step is thereby taken beyond Kant is incontestable; for he shaped his "Analogies of Experience" essentially on the three fundamental Newtonian laws(Cassirer, 1923, 415)

relativity theories and Marburgian neo-Kantianism.

In Kant's epistemology the strong connection with classical mechanics had lead to wrong ideas on concept formation and a misapprehension of the content of absolute a priori principles. If this connection would be destroyed and the Newtonian contents, which now had been proved false, would be separated from its philosophical methodology, a refutation of the former by the relativity theories might not be harmful for the latter. For Cassirer, as a true Marburgian, the fundamental Kantian methodology was understood to consist in his critical philosophy, the search for the requirements of knowledge through the investigation of contemporary science. With the relativity theories at hand, this task could be attended to anew. An important aspect of Cassirer's monograph on the relativity theories was thus to identify the relative a priori structures, the principles that made possible these theories. A second important task was to prove that these principles abided to the requirements of the aforementioned absolute a priori demands, that the absolute a priori requirements listed by Cassirer were not falsified.

Cassirer's rejection of pure intuition, his recognition of Kant as a Newtonian and his allowance of relative a priori principles all played a role in his defence of what he considered truly valuable in Kant, his critical philosophy. Indeed these particular features of Cassirer's Marburgian neo-Kantianism were all referred to when addressing the issues of space and time in the relativity theories. Cassirer's theory of concept formation formed the basis of his explanation of the rejection of absolute space in the relativity theories and likewise Cassirer's ideas of the a priori were used to account for the application of non-Euclidean geometry in these theories. The problem of the union of space and time in the relativity theories was, however, dealt with in a more conservative manner. Before turning to the other two problems of space and time for Kantian theory, Cassirer's use of this more traditional strategy is discussed. Cassirer's response to the problem of relative space and non-Euclidean geometry are the topics of sections 2.4 and 2.5 respectively.

2.3 A Natorpian Argument and the Union of Space and Time

Although Cassirer was not reluctant to adapt particular elements of Kant's theory, his treatment of the problems of space and time raised by the theories of relativity did not only exist in proving that an updated Kantianism could cope with these problems. Indeed, some of the most relevant passages of "*Zur Einsteinschen Relativitätstheorie*" that deal with these problems relied on a strategy that had been used in earlier neo-Kantian discussions of the special theory of relativity. Rather than relying on a revised form of Kantian theory, these discussions had attempted to point out that the notions of space and time as they had originally been employed by Kant differ in character from those

employed by physicists.[40] Whereas the Kantian notions refer to the a priori conditions for experience, the notions of the physicist concern the (a posteriori) contents of these empirical phenomena. The precise specifications of the latter may vary from theory to theory, but they will necessarily all depend on the (Kantian) preconditions for all experience. Natorp had developed this argument as early as 1910 in his discussion on the notions of space and time as used by Kant and as found in the special theory of relativity. He had concluded that the applications of a Minkowskian space-time structure by the special theory of relativity could not prove false the qualitative distinction between space and time as purported by Kant.[41]

Cassirer recognised the use of this argument by Natorp as well as by other neo-Kantian authors and subsequently employed it in his own discussion. Of the three problems for the original Kantian doctrine posed by the relativity theories that have been emphasised earlier; the union of space and time, the relativity of space and the use of non-Euclidean geometry, it is the first that Cassirer treats by reference to the Natorpian argument. Like Natorp, Cassirer underlined the distinction between 'pure space and pure time' of critical philosophy on the one hand and 'empirical space and empirical time' of the relativity theories on the other.[42] The employment of this distinction by others to argue for the impossibility of physical theories to refute philosophical theses, ruled out the idea of an overlap between philosophy and physics and therefore conflicted with Cassirer's commitment to unite philosophers and physicists in the development of an understanding of the theories of relativity. Although Cassirer recognised the distinction between the empirical and the ideal notions of space and time, his argument therefore went further and did not lead to a distinction between the subject matter of physicists and philosophers.

Indeed, the application of the transcendental method to discover ideal notions demanded Cassirer to conclude that the ideal notions of space and time must be retrievable from physical theories. Cassirer's strategy thus was to show that even though physics may refute Kantian theses, this was not the case for the separation of ideal space and time. A second, additional argument made by Cassirer as that not only do the theories of relativity not refute this separation, Kant's philosophy indeed anticipated the union of the empirical notions of space and time. To understand both of these arguments, Cassirer briefly explained the unity of space and time in both relativity theories. In the special theory of relativity the notions of space and time are less distinguishable than in the equations of classical mechanics. If an event is observed to take place at location (x, y, z) and time t in reference frame S, then the determinations of the location and of the time in reference frame S', which moves along the x-axis relative to S, both involve x as well as t. Determination of the location along the x-axis at which the event is found in reference frame S' involves the spatial and temporal locations of the event in S, and likewise, determination

[40] For a more detailed discussion of this argument, see (Hentschel, 1990, 212-217)
[41] (Natorp, 1910, 398)
[42] "[T]he doctrine of space and time developed by the theory of relativity is a doctrine of empirical space and empirical time, not of pure space and pure time."(Cassirer, 1923, 409)

of the time of the event in S requires both these locations too. The equations of the Lorentz-transformations between reference frames reveal this mutual dependency of spatial and temporal coordinates. Minkowski's representation of the theory further illustrated the unity of space and time by representing the events in a single four-dimensional stage which he aptly called space-time.

By the creation of the general theory of relativity the developed unity of space and time as represented by Minkowski was furthered and in this theory there no longer is any qualitative distinction between the four coordinates of spacetime. None of the coordinates used to describe the location of an event represent solely its temporal aspect and no set of three coordinates can be considered to describe its spatial aspect. Indeed, general relativity assumed a spacetime in which space and time are no longer represented as different qualities but each only aspects of a single spacetime. It was only in this theory that "[forced] us to move from the older conception of space-through-time to the more profound notion of spacetime, and from places and instants as the basic spatiotemporal constituents of the world to event locations as the irreducible basic entities of spacetime."[43]

The first part of Cassirer's argument was the assertion that despite the unity of space and time expressed in the mathematical formulations of the relativity theories, neither of the theories conflict with the distinction between ideal space and time as suggested by Kant. This is the most evident in the case of the special theory. The light postulate, a fundamental principle of the theory, reveals the fundamental assumption of a distinct space and time. The constant velocity must, Cassirer argued, be understood as a derivation of the occurrence of light at different places and at different times. The formulation of the light postulate, which again plays a constitutive role in the special theory of relativity, thus is only possible by assuming a 'definitely distinguished "'now" in a definitely distinguished "here"".[44] In the case of the general theory, the verdict is the same. In this theory arbitrary reference frames can be chosen in which the same laws of nature are valid. What is ultimately different in these frames are the measured orders of events. Similarly to the case of the light postulate, these events can only be understood as taking place at a certain time and in a certain place. The actual content of the physical laws tell us that no observer may hold his own frame with its particular arrangements of space and time as the only valid frame and hence in their physical description, space and time may not be distinguishable. Within each frame, however, and for each possible standpoint, the observer will distinguish "from his standpoint of measurement a continuum, which he calls "space", from another, which he calls "time"."[45] Both the special theory of relativity and the general theory thus express a unified space-time as a description of the a posteriori object of space, but the theories can only be constructed by a priori assumptions that rely on the separation of space and time. The empirical unity, Cassirer concluded, thus does not contradict their ideal separation as a priori presumptions necessary for the constitution of

[43](Sklar, 1977, 297)
[44](Cassirer, 1923, 423)
[45](Cassirer, 1923, 425)

knowledge.

The accordance of the relativity theories with the ideal distinction of space and time is only one aspect of Cassirer's argument. In the continuation of this argument Cassirer claimed that critical philosophy, although suggesting an ideal separation of space and time, indeed anticipates a science in which the empirical description of space and time is given as a union of the two. To make this point, Cassirer again relied on the difference between the ideal and the empirical concepts of space and time. The ideal concepts are the requirements for the possibility of the constitution of knowledge and experience. In our experience, all these ideal concepts are necessarily employed. But none of these concepts refer exactly to one element in the experience, but instead are experienced only in their unity. All absolute a priori principles work together to construct an experience. According to *critical philosophy*, space and time thus always are found together in our experience and the fact that the relativity theories express this unity thus "not only permits but demands precisely their empirical "union."[46]

The above arguments were based on Natorp's earlier used argumentation to wave off the purported incompatibility between Kantian philosophy and the theories of relativity, especially the general theory, based on distinctive concepts of space and time in the former and their complete unity in the latter. Others too had used the Natorpian argument to defend Kant in the light of the relativity theories. By recognition of the distinction between the empirical and the ideal notions of space and time without labelling either of these notions purely physical or purely philosophical, Cassirer's version of the argument transcended the naivety found in many of those put forward by more conservative neo-Kantians, which were heavily criticised.[47] Moreover, the debate over the unity or separation of space and time was merely one aspect of Cassirer's relativity interpretation. And although Kant was not believed to be in need of too much revision with respect to this particular issue, reinterpretation was thought to be inevitable in the cases of the problems of geometry and the relativity of space. The subsequent two sections deal with Cassirer's views on these two issues.

2.4 Rejecting Intuition and Relative Space

2.4.1 Non-intuitable constants of measurement

The previous section has shown that Cassirer made use of an earlier articulated argument that aims to show that at least one of the difficulties between general relativity and Kantian thought is merely a misconception and a confusion of the character of space and time used in physics and in philosophy. Cassirer is however better known for his revisionist strategy with respect to the frictions between Kant and Einstein and there are two cases in which we find the appli-

[46](Cassirer, 1923, 426)
[47]See Section 3.2

cation of this strategy the clearest. Below, Cassirer's response to the problem of relative space is discussed. Section 2.5 focusses on his treatment of the problem of non-Euclidean geometry.

Cassirer saw a relation between the problem of the relativity of space and another aspect of the relativity theories, and of the general theory in particular, which had drawn interest from philosophers who had preceded Cassirer on publishing their views on the theories. Popular expositions of the general theory of relativity, but also also serious philosophical attempts at interpreting it, had criticised it for its strong reliance on formal criteria and its use of non-intuitable constants of measurement.[48] Cassirer recognised this non-intuitive element of the theory and opposed it to the invariant elements of classical theories. That what remains constant in the general theory of relativity is no longer based on fixed and observable things in the way the Sun had functioned for Copernicus's system and the fixed stars for that of Newton. Instead, what remains invariant in the general theory of relativity are not a 'given things' but only 'certain fundamental relations and functional dependencies retained in the symbolic language of our mathematics and physics, in certain equations'[49] In contrast to the criticism of this characteristic of Einstein's theory, Cassirer welcomed it and even considered it to be a perfect example of his epistemological theory on concept formation which he developed in "*Substanzbegriff und Funktionsbegriff*".

Indeed, several times throughout "*Zur Einsteinschen Relativitätstheorie*" it is mentioned how well the relativity theories correspond to Cassirer's views expressed in 1910. The trend of scientific development that he had described in these views is one in which theories, as they succeed and replace each other, increasingly rely on concepts that do not represent things that are direct copies of observable entities, but instead purely represent relations between the phenomena observed. Awareness of this trend will make the formal aspects of the theories of relativity not objectionable but will make them be 'regarded as [a] natural logical conclusion of an intellectual tendency characteristic of all the philosophical and scientific thought of modern age.'[50] The exposition of this argument is given in a style similar to that found in "*Substanzbegriff und Funktionsbegriff*". As in this earlier work, Cassirer applied a philosophical as well as a historical method to develop his argument. Cassirer's philosophical method is a Marburgian one, it is a critical analysis of physical theories and an investigation in their, often tacit, preconditions. These preconditions determine the concepts of the theory and thus are the relative a priori elements of physical theory. They are a priori in the sense that they are presupposed by the theory and have a constitutive function. Meanwhile, they are relative in the sense that they are replaceable and may differ from theory to theory. Besides containing a philosophical investigation of the theories of relativity and a determination of their a priori elements, Cassirer's "*Zur Einsteinschen Relativitätstheorie*" contains a historical analysis too. The first four chapters contain examinations of the transitions in physical theory that have taken place in the constitution of

[48] (Cassirer, 1923, 380)
[49] (Cassirer, 1923, 379)
[50] (Cassirer, 1923, 379)

the theories of relativity. Reconstructions of the shift from classical theory to the special theory of relativity as well as that from the latter to the general theory are found in the first four Chapters of Cassirer's book.

Physics, by the end of the nineteenth century, had great difficulty to combine the Galilean principle of relativity, which was known to be true for classical mechanics, with the constancy of the velocity of light in a vacuum, which had been observed. Einstein's resolution, the special theory of relativity, maintained both these principles. It could, however, only do so by replacing the concepts of simultaneity and distance as they were found in the classical theories by new ones. Whereas in preceding theories, both these concepts were fixed magnitudes that were independent of the state of motion of the reference body, the special theory of relativity introduced a dependence. Ultimately, and through reconsideration of the methods by which measurements are made, this implied that other magnitudes which were held to be independent of this state of motion, such as a body's volume, energy and temperature, lost their invariability in the new theory too. Cassirer remarked that this aspect had made other philosophers wary of the theory of relativity. The loss of such invariants and the dependence of a description of nature on particular reference frames appeared to imply a loss of the unity of nature and the notion that any depiction of its phenomena was arbitrary.

2.4.2 Special Relativity and the tendency of scientific development

Although Cassirer did not specify names of philosophers who held this view, he argued that it was 'remarkable' that the rejection of the non-intuitive character of general relativity and its rejection of 'old invariants' had been raised not only in popular articles on the interpretation of relativity theory, but also in philosophical investigations.[51] Cassirer claimed that it should rather be embraced. The abandonment of the old invariants was not a simple removal of constancy in physical theory since it was compensated by the introduction of new invariants, most importantly the invariance of the 'general form of natural law'. The same natural laws, in the special theory of relativity, are valid in all reference frames that are in uniform motion in a straight line with respect to each other. The new unity of nature is found in the fact that no longer a distinction is made between all these frames but that instead the special theory of relativity unites them all by giving a formulation of the rules of conversion from measurable magnitudes of one frame to those of another. What has become static in this theory of relativity thus is a function that gives the old invariants as expressions of itself. The former, fixed, concept of distance which was held to be a directly and absolutely measurable quantity had, in Cassirer's eyes, become a derivative of a new concept. This transition is of the same type as that of the ancient Greek concept of 'up' which was considered an independent entity of nature influencing the behaviour of other objects, to that of the unity of space

[51] (Cassirer, 1923, 380)

in which 'up' has become a mere relational aspect.[52] The Grecian concept is a clear example of substantive thought. A constancy of the observed phenomena, a part of space towards which smoke moves, is recognised, and applied in the understanding of our experience. In our theories it is considered to be an invariant element with properties, a 'thing'. The concepts of distance and simultaneity in classical mechanics, although not considered to be a 'thing' to the same extent, is considered in a similar manner, when compared to those of the relativity theories. Like the ancient concept 'up', they are intuitively recognised as elements of our experience that are invariant and subsequently are interpreted as things, whose particular properties do not change. As with the case of the concept of 'up', and likewise in correspondence with the general tendency of scientific development, the old concepts of distance and simultaneity are replaced by functional concepts which are more abstract and represent the varieties of possible measurements that all belong to a complete description of an object. The new permanence is not placed in the notions of distance and simultaneity itself, but in the law that describes them as appearances in different reference frames. In respect to thee new theory, the old, Newtonian, notions had become substance-concepts.

The new invariant in the special theory of relativity, the form of law in inertial reference frames, comes forth from the relativity principle which functions as a constitutive principle in the theory. Whereas in the years preceding 1905 this principle had appeared as a problem, Einstein took it as a postulate of his theory. He made it a presupposition of his theory that in both classical mechanical phenomena, as well as in electrodynamical ones, respective inertial reference frames were equal. As such, the relativity principle functions as an a priori requirement for the special theory of relativity and consequentially it plays a role in the determination of objectivity in scientific theory and measurements. Only laws that maintain their form in all inertial reference frames are considered objective and, similarly, measurements of a specific length which are made in only a single reference frame, cannot be called objective. The objective length of an object is that which is represented by the function that gives all possible measurements.

2.4.3 General relativity and the tendency of scientific development

In the general theory of relativity, developed a decade after the special theory, Cassirer saw another realisation of the natural tendency of scientific development. In the special theory the difference between the laws valid in inertial reference frames is overcome, but not all possible reference frames are equalised. The laws of the special theory are valid only in those systems that move in uniform motion in a straight line with respect to each other. In the general theory these restrictions are overcome and its laws are valid in all reference frames, no matter what their relative motions to other frames are. Cassirer understood

[52](Cassirer, 1923, 361-2)

the development from the special to the general theory as another change in scientific theory in which substantivity is further replaced by functionality.

> Only with this result do we reach the real center of the general theory of relativity. Now we know where lie its truly ultimate constants, its cardinal points, around which it causes phenomena to revolve. These constants are not to be sought in particular given things, which are selected as chosen systems of reference from all others, such systems as the sun was to Copernicus and as the fixed stars were for Galilei and Newton. No sort of things are truly invariant, but always only certain fundamental relations and functional dependencies retained in the symbolic language of our mathematics and physics, in certain equations. This result of the general theory of relativity, however, is so little a paradox from the standpoint of the criticism of knowledge, that it can rather be regarded as the natural logical conclusion of an intellectual tendency characteristic of all the philosophical and scientific thought of the modern age.[53]

Once again, something that used to be taken as a fixed thing, the reference bodies to which the laws of the special theory of relativity were valid, was replaced by a relation. The frames in which these reference objects were considered fixed now only become meaningful when they are understood as particular derivations of a function that describes nature in all possible reference frames. The concept of a reference frame of the special theory of relativity is a substantive concept with respect to the field equations of the general theory of relativity and hence the expression of nature as found in scientific theories has undergone a further progression.

The fact that Einstein developed a theory in which these laws hold, results from his demand that indeed the same laws should be formulatable for all reference frames, that is, all Gaussian coordinate systems. This demand, known as general covariance, did not follow from experience but instead was an a priori demand used to give a description of nature. It was foundational for the theory and served as a rule of investigation in the sense that any found laws that did not abide this requirement would not be considered objective descriptions of nature. That Einstein himself considered it to be of such nature is evident from his reflections on the theory, written in 1916, in which he writes:

> The general laws of nature are to be expressed by equations which hold good for all the systems of coordinates, that is, are covariant with respect to any substitutions whatever (generally covariant).[54]

The rejection of absolute space as a result of general covariance is emphasised in contemporary literature. A modern variation of Einstein's 'hole argument'[55] shows that an adherence to absolute space leads to strict indeterminism.[56] It is generally agreed upon that a belief in absolute space with respect to the general theory of relativity means a belief in the physical reality and independence of the manifold since it is this part of the theory that represents the container

[53](Cassirer, 1923, 379)
[54](Einstein, 1952, 117)
[55]Einstein developed the *Lochbetrachtung* in 1913 to argue against the use of general covariant theories. When in 1915 he succeeded in developing a general covariant theory of relativity, he later corrected his own interpretation of the argument.(Einstein, 1923)
[56](Earman & Norton, 1987)

of physical events.[57] The demand of general covariance implies that since the laws of nature are uninfluenced by the chosen coordinate system, one is free to choose any spreading of the metric over the manifold. The metric supplies the information of physical properties such as distances and simultaneities. The hole argument then follows from two possible spreadings of the metric over the manifold, differing only in a particular area called the 'hole'.[58] The two spreadings thus yield different values for coordinates at which, say the simultaneity of two particular events, is found. To the proponents of relative space only the relations between the simultaneity with other events is real, these relations are given by the laws of nature and hence uninfluenced by the coordinate system. The proponent of absolute space, however, claims that the coordinates too represent a part of reality. Since these laws render both spreadings valid, the proponent of absolute space needs to accept that our laws cannot inform us which of the two possible physical realities is accurate. This indeterminism, resulting only from the assumption of absolute space, as proposed by Kant, is one which Earman and Norton consider a price 'far too heavy a price to pay'.[59]

Not only does the general theory replace substances of the special theory by functional concepts, the development from the special theory to the general is recognisable as a normal scientific development in a second way. The general theory does not make the special theory invalid, but that the latter is contained in it as a limited case. In general relativity a large variety of metrics can be considered. If we reduce this number by limiting ourselves to those metrics in which the curvature of spacetime is negligible, the laws of the general theory are equivalent to those of the special theory.

Both the special and the general theory of relativity thus let go of a substantive concept of an absolute space. Kant had originally held this to be an a priori demand for all thought, but this view was based on an outdated model of concept formation. A proper analysis of Kant's doctrine cannot maintain a strict difference between intuitions and concepts. Cassirer recognised this to be in agreement with the development of scientific concepts which have more and more become functional rather than substantive. Awareness of this development thus makes it unsurprising that the concept of place too would undergo such a transformation.

2.5 Relative a Priori and Euclidean Geometry

As has been emphasised before, Kant's belief that Newtonian physics were the ultimate descriptions of our observations lead him to believe that their foundations were necessary requirements for all human thought. The space of Newtonian mechanics was described by Euclidean geometry and hence Kant claimed that the propositions of Euclid's *Elements* 'were a priori principles for all de-

[57] (Earman & Norton, 1987, 518)
[58] The name origins in the original argument made by Einstein, where the hole represented a matter free area.
[59] (Earman & Norton, 1987, 524)

scriptions of nature.[60] In contrast to Newtonian physics the general theory of relativity is a theory that relies on a space that is described by non-Euclidean geometry. The general theory of relativity thus clearly falsifies at least one thesis of the original Kantian doctrine.

Cassirer's neo-Kantianism contained a notion of a priori principles that was more subtle than that found in the original Kantian thesis. In the previous chapter we have seen that Cassirer had already plead for a distinction of absolute a priori concepts and principles on the one hand and relative a priori concepts and principles on the other hand. Now that Einstein had falsified the idea of Euclidean geometry as an absolute a priori requirement, this distinction was an evident source for an argument to show that a revised Kantianism would be able to take account of even the most modern physical theories in which traditional geometry had been replaced.

Cassirer's relative a priori principles were understood as particular instances of absolute a priori principles. Cassirer did not deny that, in accordance with Kant's ideas, the latter existed, but he explicitly recognised that Kant's own purported a priori principles were no longer tenable.[61] Already in "*Substanzbegriff und Funktionsbegriff*" Cassirer had suggested more abstract principles that he thought were ultimately invariant and found in all thought. In contrast to Kant, Cassirer had not considered the postulates of Euclidean geometry to be among them. Instead, these postulates were considered to be a priori only in the relative sense, they represented mathematical propositions that played a foundational role in the physical theory. Moreover they gave particular content to the absolute requirement of the application of the concept of 'space'. The non-Euclidean geometry used in the general theory of relativity was, according to Cassirer, a different implementation of that same requirement. Riemannian geometry plays a constitutive role for the theory of relativity in the same way Euclidean geometry is foundational for classical mechanics. Both are constitutive and hence a priori, but only relatively to a particular physical theory. From the standpoint of this revised Kantianism, the replacement of a theory that relied on Euclidean geometry by one that relied on non-Euclidean geometry thus is unproblematic. The incompatibility of the absolute requirement of Euclid's propositions with the use of Riemannian geometry in Einstein's theory was overcome simply by stating that the requirement is not absolute in the first place.

Besides creating an allowance for the use of non-Euclidean geometry, Cassirer's revised interpretation of 'a priori' had two further important consequences. First, it meant that the a priori concepts and principles used in the general theory of relativity were no less relative than those of Newtonian physics. Riemannian geometry, as well as the demand of general covariance discussed above have a constitutive function in relativity theory. In future theories these may be thrown overboard and be replaced by new mathematical and theoretical principles.[62] Unlike Kant's firm belief that Newton's laws were the ultimate

[60] (Itzkoff, 1971, 70)
[61] (Cassirer, 1923, 431)
[62] (Heis, forthcoming.b, 10)

embodiment of physical theory, Cassirer thus was careful to fall into the same trap and did not think that Einstein's laws were infallible.

Second, Cassirer maintained that besides these relative a priori principles, absolute requirements existed too. Indeed, he had attempted to formulate them in "*Substanzbegriff und Funktionsbegriff*" in 1911, when general relativity was still unknown to him. Most importantly for the discussion raised by general relativity, Cassirer had argued that the concept of space was one of these absolute a priori concepts.[63] Although Cassirer had noted that it would be impossible to give a definite list of all absolute a priori concepts and principles, the general theory of relativity had shaped a case study to test this suggested concept. The precise physical properties we assign to space may vary from theory to theory but none of these theories can be written without a reliance on some notion of spatiality. In "*Zur Einsteinschen Relativitätstheorie*" Cassirer was thus challenged to defend this thesis and hence to argue that the concept of space found in the general theory of relativity could be understood as being of the same type as that found in other theories. Cassirer briefly argued for this identity only in an argument that we have come across earlier in our discussion on Cassirer's treatment of the unity of space and time. He claimed that the fundamental notion of an event in the theory can only be understood as taking place in space. The general theory of relativity thus relies on the ideal requirement of space. It presupposes it in order to give meaning to the notion of an event. Cassirer thus fell back to the use of his conservative argument in order to find the absolute demand of the concept of space to be verified by the most modern physics. It is this argument from which he concludes that the concept of space remains *"to constitute the real a priori for any physics and the presupposition of its possibility as a science."*[64]

2.6 Conclusion

The above sections have shown that Cassirer's "*Zur Einsteinschen Relativitätstheorie*" attempted to defend the idea that an updated version of Kant's theory could withstand the criticism raised after the rise of Einstein's relativity theories. Although Cassirer was one of the first to argue that a revision of Kant's original doctrine was needed to explain the relativity theories, he used a more conservative strategy in his treatment of the union of space and time. Following Natorp, Cassirer argued that there is a difference between the empirical and the a priori notions of space and time and that the union of the two found in a physical theory is of no influence on the latter notion. Nevertheless, Cassirer argued that, to be able to deal with the relativity of space and the reliance on non-Euclidean geometry in the relativity theories, Kant's own philosophy could not suffice. A revised theory of concept formation and a non-standard notion of a priori principles, both of which Cassirer had developed in his earlier works, were needed to protect critical philosophy against the new findings of Einstein's

[63] (Cassirer, 1923, 269, 309, 321)
[64] (Cassirer, 1923, 394)

physical theories. On the one hand Cassirer observed that his notion of the a priori did not lead to any problems with respect to Einstein's reliance on non-Euclidean geometry, since it is understood as a relative, revisable principle. Moreover, the notion of space as it is found in the relativity theories confirms the development of physical concepts from substantive concepts towards functional ones. Therefore, Cassirer claimed, the modern version of Kantianism whose Marburgian blueprint had been developed before the rise of the relativity theories, had been verified by Einstein's physics. Despite his belief in this confirmation, Cassirer had adopted a modest attitude and he explicitly remarked that he did not wish to suggest that he had given a definite interpretation of the theories of relativity. One of the main goals of the book had been to open up the conversation between philosophers and physicists. How each of these responded to Cassirer's views and how they compared to those of others is explored in the next chapter.

Chapter 3

Cassirer's Theory in Perspective

3.1 Interpretations of Relativity in the Early 1920's

3.1.1 Philosophers on General Relativity

The previous chapter has illustrated Cassirer's philosophical interpretation of the theories of relativity. Set forth in a single book, published in early 1921, his view held that, despite some discrepancies between Kant's words and Einstein's theories, the relativity theories did not pose any fundamental problems for critical philosophy. Indeed, they verified an amended version of the traditional Kantian doctrine which Cassirer had proposed already a decade earlier. The great achievement of the general theory of relativity was its application of the demand of general covariance which, Cassirer argued, verified Kantian epistemology, corrected by new ideas of the apodicticity of the a priori, the conception of pure intuition and concept formation according to the views of the Marburg School.

Cassirer had not written his essay on relativity theory, "*Zur Einsteinschen Relativitätstheorie*", with the intent of presenting a definitive understanding of the relativity theories, but aimed at a stimulation of the discussion on the correct interpretation and moreover hoped that it would help to bring together both philosophers and physicists in this discussion. The former of these goals, stimulation of the debate, appeared an unnecessary one that Cassirer had set himself. It would have been a noble pursuit a decade and a half earlier, when the publication of the special theory of relativity had taken place almost unnoticed in philosophical circles. Especially compared to its successor, the general theory, it had caused only a small amount of articles reflecting on its philosophical implications.[1]

[1]Noteworthy exceptions were works by Natorp(Natorp, 1912) and Schlick (Schlick, 1915)

That the situation was different in the case of the general theory is an understatement. This theory had shaken the foundations of classical mechanics and had destroyed some of the most fundamental Newtonian ideas of nature widely taught at schools for the past centuries. Most notably it made use of a different geometry than the intuitively attractive one developed by Euclid and it no longer made use of separate notions of space and time, which too was an aspect of classical mechanics that had satisfied commonsensical ideas. Its severe deviation from these ideas and from physicaal theories so widely taught had captured the imagination of many. Scientific journals quickly picked up the theory and during the early 1920's the theory and its consequences were enthusiastically discussed by both experts in the field and laymen. An article in an edition of Nature in 1921 that was completely dedicated to the relativity theories, and published almost simultaneously with Cassirer's monograph, mentions one thousand articles and books dealing with these theories.[2] Three years later another inventory claims that this number had more than tripled.[3] A significant portion of these books and articles had been written by philosophers.[4] The destruction of classical concepts had captured the imagination of many and had awakened the interest of both scientists and philosophers. Among the latter were many that previously had not shown interest in with physical theories.[5]

When reflecting on the variety of philosophical positions towards relativity in 1926, Russell concluded that

> There has been a tendency, not uncommon in the case of a new scientific theory, for every philosopher to interpret the work of Einstein in accordance with his own metaphysical system, and to suggest that the outcome is a great accession of strength to the views which the philosopher in question previously held. This cannot be true in all cases; and it may be hoped that it is true in none. It would be disappointing if so fundamental a change as Einstein has introduced involved no philosophical novelty.[6]

The general theory of relativity differed form earlier physics in numerous aspects. Not only did some of its predictions deviated from earlier physics, the ways it understood central concepts of nature such as space, time and matter were different from the ways in which they had been understood for centuries. Russell noted that it appeared that every philosopher could rely on at least one of these new aspects or on one of the new insights of the theory to vindicate the positions they had been proposing even before they had first heard of Einstein. Although containing some truth, and perhaps entertaining, the above citation is wrong in at least one important perspective. Not all philosophers considered the relativity to be a vindication of their own position. A non-negligible group of philosophers from different schools and traditions recognised one of the many new aspects of the theory to conflict with some presuppositions of their own philosophical positions and chose to reject Einstein's new physics on the basis

[2] *Nature* 106 (1921)
[3] (Lecat & Lecat-Pierlot, 1924)
[4] (Hentschel, 1990, 70)
[5] (Ferrari, 2003, 99)
[6] (Russell, 1926, 331)

of this opposition. Most notable were the proponents of the *Als-Ob* philosophy who argued that, based on their doctrine, the relativity theories could be proved to be the results of poor physics.

3.1.2 Some Interpretations

These *Als-Ob* philosophers were putting forward merely one of the possible viewpoints possible and, as Russell has remarked correctly, a substantial number of philosophers with deviating views presented their arguments in the early 1920's. Some of the most visible and debated interpretations of relativity theory in this period included the following positions:[7]

- **Neo-Kantianism** Like Cassirer, a great number of neo-Kantians felt the need to respond to the recognition of a physical theory that defied the necessity of the application of Euclidean geometry, which Kant had held to be a priori. The great variety of neo-Kantian interpretations each emphasizing different aspects of Kant's philosophy, led to a similar variety of responses to Einstein's theories. Cassirer's position, arguing for the necessity to revise particular elements of Kant's doctrine, was different from that of many others who claimed there did not exist such a necessity. Notable advocates of this latter idea were Hönigswald[8], Sellien[9] and Schneider[10]. Some of those who shared Cassirer's willingness for revision and proposed similar expositions were Bollert[11], Elsbach[12] and Reichenbach.[13]

- ***Als-Ob* Philosophy** Oskar Kraus was undoubtedly the best known proponent of the *Als-Ob* (as-if) philosophy in the philosophical debate on relativity theory and subsequently one of the strongest philosophical voices against Einstein's theories. Basing himself on a philosophical theory originally developed by Vaihinger, Kraus argued that the theories of relativity contain fictions, mental structures that do not correspond to reality. A clear example is found in special relativity which, Kraus argued, determined the Lorentz contraction based on a method of measurement which has never been performed.[14] Einstein's method of measurement thus is qualified as a fiction, an element for which there should be no place in physical theory.

[7] Many philosophical articles have been written that may not be grouped among the following views. Nevertheless, the four interpretations briefly described here were those drawing the most attention. Books that given reflections on the entire debate between proponents of different interpretations, such as (Reichenbach, 1922),(Hartmann, 1924) and (Wenzl, 1924) express the relevance of these views by treating them most extensively.
[8] (Hönigswald, 1912)
[9] (Sellien, 1919)
[10] (Schneider, 1921a)
[11] (Bollert, 1923)
[12] (Elsbach, 1924)
[13] (Reichenbach, 1920)
[14] (Kraus, 1920)

- **Mach's followers** Einstein explicitly mentioned Ernst Mach as an inspiration who played an important role in the development of the relativity theories.[15] The equality between inertial mass and gravitational mass, fundamental in the general theory of relativity, indeed was originally posed by Mach in the late nineteenth century who claimed that if a difference between them cannot be observed it should have no place in our theories.[16] Remarkably however, at an old age, Mach explicitly spoke out against the special theory of relativity.[17] This dubious discrepancy between Mach's philosophy and Einstein's physics continued in the 1920's in the relativity debate when followers of Mach both embraced (e.g. Petzold) and opposed (e.g. Dingler[18]) the theories of relativity. Of these, Petzold gained the most attention. In the general theory of relativity he saw the vindication of a strong positivism according to which all our theoretical knowledge should be based on and reducible to simple facts of experience. In the general theory of relativity then, the only reality described is that of sensible coincidences.

- **Logical Empiricism** Schlick was one of the first philosophers to entirely embrace the relativity theories. His view was different from the three briefly discussed above. Arguing explicitly against both Machian and Kantian interpretations, he based himself on Poincaré 's conventionalism. Schlick's work of 1917[19] inspired other philosophers who too would defend this conventionalism by reference to Einsteinian physics. All claimed that the neo-Kantian notion of the a priori should be replaced by that of a convention. Most notably Carnap,[20] who would become one of the central figures of Schlick's Vienna Circle and Reichenbach who, after his 1920 monograph on the relativity theories, would grow closer to Schlick and further from his neo-Kantiant roots, suggested this argument. One of the clearest examples of an argument in the defence of conventionalism by reliance on relativity theory is from Reichenbach's hand, although initially mentioned by Einstein in his 1905 article on relativity.[21][22] The concept of simultaneity, which was defined by Einstein in his special theory of relativity, is required to link theory to observation. Einstein defined two separated events, E_a and E_b to be simultaneous if E_a is the event where a light ray transmitted at t_1 has travelled a certain distance and is reflected and E_b is given by $t_1 + t_2 \times \frac{1}{2}$, where t_2 is the moment at which the light ray arrives at the spot where it was emitted at t_1. But, as the explicitness

[15] (Einstein, 1916)
[16] Indeed, this is identical to Leibniz's principle of the identity of indiscernibles, discussed in chapter 1.
[17] (Mach, 1953, foreword), Gereon Wolters has argued that the authenticity of these texts must be doubted and that likely the opinions displayed were those of Mach's son Ludwig. (Wolters, 1987)
[18] (Dingler, 1919)
[19] (Schlick, 1917)
[20] (Carnap, 1922)
[21] (Einstein, 1905)
[22] (Reichenbach, 1958)

of the definition reveals, it is not a logically necessary one. Indeed, the logical empiricists emphasised, it is conventionally chosen. Logically one may, for instance, have opted for a definition identical to Einstein's but define E_b by $t_1 + t_2 \times \frac{1}{2}$ is replaced by $\frac{1}{3}$, yielding a new definition that can be used as the cornerstone of physical theory.

3.1.3 Difficulties for Philosophers

Few philosophers, Schlick, who studied under Max Planck, among them, enjoyed an advanced scientific education. Moreover, Einstein's theories were less intuitive and required different mathematical skills than the Newtonian theories and hence much harder to comprehend than the physical theories most of the philosophers were acquainted with. As a result, many of the early articles presenting philosophical interpretations were heavily criticised and retrospectively are dismissed as 'silliness'[23] written by normally respectable, but this time 'self-overestimated'[24] philosophers. Indeed, overviewing the array of interpretations brought forward by philosophers in 1922, Reichenbach noted that

> the number of obvious misunderstandings is so large, and it is futile for some philosophers to attack the theory, simply because they do not fully understand its physical content.[25]

The attention of philosophers with no physical training for the general theory of relativity meant that during the first, tumultuous years of the decade, there was a sprawl of philosophical articles on the relativity theories where the well-evaluated viewpoints were not yet filtered from unjustified conclusions.

Despite this lack of clear oversight of which viewpoints reflected proper understanding and which did not, Cassirer's work was quickly recognised as that of a well-trained scholar. Initially not meant to be published, "*Zur Einsteinschen Relativitätstheorie*" had been taken up as a task to personally get acquainted with the relativity theories. Thus, unlike Kraus, for instance, who refused to do so,[26] Cassirer had carefully informed himself on the technical parts of the theories. Consequentially, many, including Einstein and philosophers both agreeing and disagreeing with Cassirer's philosophical thesis, had praised his book for its technical insight. Einstein's appraisal has been mentioned in the previous chapter, but it is noteworthy that also philosophers from various backgrounds such as the empiricist Schlick,[27] the neo-Kantian Schneider, who held a much more conservatist view than Cassirer,[28] and the critical realist Hartmann[29] recognised Cassirer's affinity with the physical theory.

Despite this appraisal, "*Zur Einsteinschen Relativitätstheorie*" could not produce a remaining influence on the dominant philosophical interpretation of

[23](Coffa, 1991, 198)
[24](Hentschel, 1990, 556)
[25](Reichenbach, 1978, 4), translated from (Reichenbach, 1922)
[26](Hentschel, 1990, 554)
[27](Schlick, 1979)
[28](Schneider, 1921b)
[29](Hartmann, 1924)

relativity theory. It is commonly accepted that by the end of the decade Schlick's views had become the most popular and that subsequently the logical positivists had gained a monopoly on making philosophical remarks on relativity theory.[30] Schlick's criticism on the possibility to save Kantianism after Einstein's theories had appeared convincing in the view of most and Cassirer's attempt to reconcile critical philosophy with relativity had failed in the eyes of most.

The remainder of this chapter is an attempt to gain further understanding of Cassirer's position in the philosophical debate on relativity theory. An analysis of responses to "*Zur Einsteinschen Relativitätstheorie*", thoughts and correspondences between its author and those who praised or criticised him will reveal Cassirer's status as a philosophical commentator on the relativity theories. The role of Cassirer in the debate and the final succumbing to a deviating interpretation shall be discussed in the following sections. Whereas the subsequent section focusses on Cassirer's position among philosophers, the section thereafter deals with the relation between Cassirer and some of the most renown physicists of his age.

3.2 Cassirer and Other Neo-Kantians

3.2.1 The Status of Neo-Kantianism

In the previous section a number of different philosophical viewpoints from which the theories of relativity were evaluated were mentioned. The neo-Kantian position was merely one of these and indeed philosophers from various traditions were eager to join the debate. Neo-Kantianism was one of the most prominent, if not the most dominant of all philosophical movements in the early twentieth century, especially in Germany, where the centres of particular neo-Kantian schools were found, each maintaining a different interpretation of Kant's philosophy and considering a different aspect of the theory as expressing its essence.[31] What united the neo-Kantians was the belief that the main goal of philosophy should be the determination of the demands for experience and that these are supplied to us by our reason in the form of a priori principles. Indeed it was with the second of these aspects, that friction with the relativity theories arose[32] and hence the entire neo-Kantian community was confronted with the relativity theories. Moreover, due to the prominence of neo-Kantianism, non-Kantians were quick to notice this friction and challenge the large group of neo-Kantians to come forward and offer a response. Hardly any of the non-Kantian protagonists in the philosophical debate on relativity failed to pay attention to the discrepancy between Kant and Einstein. Schlick had already questioned the legitimacy of Natorp's and Hönigswald's attempts to defend Kant in the light of

[30] (Ryckman, 2005, 6), (Ferrari, 2003, 123)

[31] The best known of these are the Marburg School in Marburg focussing on Kant's epistemology and logic and the Baden School, located in south-west Germany, concentrating on cultural issues.

[32] See section 2.2 for more information on the conflict between Kant's a priori principles and the theory of relativity

the special relativity theory,[33] and in the discussion on the general theory many other non-Kantian philosophers would do so too. Among others, the Als-Ob philosopher Wenzl,[34] the empiricist Carnap,[35] the positivist Petzold[36] and the creator of the theory, Einstein himself,[37] paid attention to the tenability of the neo-Kantianism position in the light of modern physics.

petz en carn

Due to the variety within neo-Kantianism itself however, the community of neo-Kantian scholars did not respond to Einstein's theories with a single voice. Since Hentschel's elaborate discussion on neo-Kantian interpretations of the relativity theories, a distinction between two types of reactions is recognised by many.[38] On the one side stood the conservative neo-Kantians who aim at immunizing Kant against its contradiction with the relativity theories. Although particular elaborations of this strategy differ, the fundamental argument is that the purported contradiction is merely apparent because physics and philosophy have two distinctive domains of discourse and that hence no physical theory can possibly refute any philosophical thesis. The strongest voices on this side of the neo-Kantian camp during the debate on the general theory of relativity were Ilse Schneider and Ewald Sellien. The second road taken by neo-Kantians was that of revision. Besides Cassirer, Hans Reichenbach, Josef Winternitz and Alfred Elsbach were the voices of the more liberal neo-Kantians who accepted the opposition between the traditional Kantian doctrine and the theories of relativity but who believed that the former could be revised in such a way that it would give a correct interpretation of the relativity theories whilst maintaining the methodology proposed by Kant. In order to understand where in the debate Cassirer must be placed and how his arguments corresponded to and differed from those of other neo-Kantians, both strategies shall now be discussed.

3.2.2 Two neo-Kantian positions

Immunisation

The distinction between the ideal a priori notions of space and time, found in Kantian theory, and those of empirical space and time in physical theory was emphasised clearly first by Natorp in 1910. On the final pages of (Natorp, 1910) Natorp discussed the relation between Minkowskian spacetime and critical philosophy. Although he did not continue to deem philosophy irrefutable by science (rather, he saw Minkowskian spacetime as a verification of Kant), others took the distinction to imply a strict distinction between the arenas of philosophy and science. In the discussion on general relativity this implication was drawn by a number of neo-Kantians in order to defy the purported refutation of Kantianism by Einstein's theories and to argue that Kant's critical philosophy remained

[33](Schlick, 1917)
[34](Wenzl, 1924, 87-128)
[35](Carnap, 1922)
[36](Petzold, 1921)
[37]e.g. (Einstein, 1924a) and (Einstein, 1924b)
[38](Hentschel, 1990, 209 ff.) This distinction is accepted in other recent discussions such as (Ryckman, 2014b) and (Ferrari, 2003, 101).

untouched by them.

Just before the joint meeting of the Royal Society and the Royal Astronomical Society on November 6 1919 where the deflection of light, predicted by the general theory of relativity, was confirmed, Ewald Sellien published his *Habilitationsschrift*[39] One of the arguments presented in this work is that the general theory of relativity is a theory that concerns only empirical space and time and hence it cannot have any implications for the ideal notions of space and time that were applied by Kant.[40] Sellien thus argued that nothing of what Kant had said needed to be changed. By arguing that Kant's and Einstein's theories spoke of different notions of space and time, he 'immunised' the former theory against the latter. It appears hard to find any appraisals of the book, but *Die erkenntnistheoretische Bedeutung der Relativitätstheorie* deserves mentioning here nevertheless, merely for the fact that it had drawn the interest of Einstein, who commented on it in at least two letters. In neither of the letters he failed to express his discontent of the ideas expressed by Sellien, calling it 'rather foolish' in a letter to Schlick[41] and drawing an analogy of Sellien's interpretation of Kant as an attempt to save the doctrine from relativity with 'Anderson's tale about the emperor's new clothes' in a letter to Schneider.[42] Einstein believed that Sellien had given an interpretation of Kant that made his philosophy look ridiculous rather than protect it against the threats posed by relativity.

Ilse Schneider,[43] the latter of the two correspondents to whom Einstein complained about Sellien's attempt to immunise Kant, was a student at the university of Berlin, where Einstein was a professor at the time. In 1920 she finished her doctoral thesis under the supervision of Wilhelm Heinrich Riehl and Max von Laue, a renown physicist and personal friend of Einstein.[44] Although von Laue considered the thesis exceptional and praised it for its 'complete comprehension of Einstein's theory',[45] there exists no evidence of Einstein's opinion on the work. This is unfortunate, since Schneider shared with Sellien the view that Kant's philosophy was in no need of revision[46] and to someone like Schneider, with whom Einstein wished to discuss Sellien's work,[47] Einstein might have

[39](Sellien, 1919)
[40](Sellien, 1919, 56)
[41] "Haben Sie die ziemlich thörichte Dissertation von Sellien gesehen?" Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)
[42] "Mich erinnert die gepriesene Kantsche Ansicht über die Zeit and Andersens Märchen vom Kleid des Königs, nur dass es sich um Kleid des Königs, um die Form der Anschauung handelt!" Einstein to Schneider, 15 September 1919, (Einstein, 2004, 155-156)
[43]After her marriage in 1922 to Hans Rosenthal she was known by and published under the name Ilse Rosenthal-Schneider.
[44]It was this thesis that was published as a book in 1921 under the title *Das Raum-Zeit Problem bei Kant und Einstein*(Schneider, 1921a).
[45](von Laue, 1920)
[46] "Kants transzendentaler Idealismus steht, wenn er richtig gedeutet wird, zur Einsteinschen Physik und auch deren erkenntnistheoretischen Ergebnissen in keinerlei Widerspruch."(Schneider, 1921a, 64)
[47]Through von Laue, Schneider came into close contact with Einstein and developed a friendship that would last until Einstein's death.

been more elaborate in the formulation of his criticism. Although Schneider's account is undoubtedly more refined than Sellien's and it relies on different arguments too, it does not fail to refer to the distinction between ideal and empirical notions of space and time as a method of proving the irrefutability of Kant by Einstein.[48] Although we may not know Einstein's views on the book, others have reviewed it. Many of these reviewers criticised the philosophical arguments put forward by Schneider. Especially her claim that the compatibility of Kant and Einstein can be deduced if one understood Kantian space as a purely idealistic concept was heavily criticised.[49]

Although no other applications of the immunisation strategy shall be discussed here, Schneider and Sellien were far from unique in defending this position. Hentschel has claimed that indeed the majority of neo-Kantians chose for a protection of a traditional, unrevised version of the Kantian doctrine in dealing with relativity theory.[50] Other notable advocates of this view in the debate on general relativity included, among many others, Lenore Ripke-Kühn,[51] Hermann Kranichfeld[52] and Julius Schultz[53]. As with the books by Sellien and Schneider, the treatises of these philosophers on relativity were not received with much enthusiasm.[54] Moreover, modern literature too often reflects upon the works of such 'immunizing' neo-Kantians as 'forgettable' misinterpretations.[55]

Revision

In direct contrast with Hentschel's remark that Immunisation of Kant was the most chosen strategy, Ryckman claims that most neo-Kantians did not believe Kant's philosophy could remain unrevised after the publication of the general theory of relativity.[56] In the previous chapter it has been shown that Cassirer

[48] "Je weniger "physikalische Gegenständlichkeit" den Begriffen von Raum und Zeit an sich genommen zukommt, desto mehr gleichen sie sich den kantischen formalen Prinzipien an, desto mehr entfernen sie sich gleichzeitig von dem "wirklichen" absoluten Raum und der "wirklichen" absoluten Zei, den physikalisch nachweisbahrer Gegebenheiten". (Schneider, 1921a, 65)

[49] Hartmann, for instance, argued that Schneider was wrong in deducing Kant's own awareness of the relative character of space from the purely idealistic notion of space. (Hartmann, 1924, 53-54). Schlick's rejection of Schneider was similar (Schlick, 1979, 329) and Reichenbach argued that in order to make this deduction, Schneider had to take quotes by Kant out of their original context.(Reichenbach, 1978, 25-26)

[50] (Hentschel, 1990, 212)

[51] (Ripke-Kühn, 1920)

[52] (Kranichfeld, 1922)

[53] (Schultz, 1935)

[54] "L. Ripke Kühn does not understand very much of the theory of relativity" in (Reichenbach, 1978, 43)

[55] Howard (Howard, 1994, 52) calls Schneider's book forgettable. Hentschel considers all the interpretations relying on 'immunisation' as misinterpretations.(Hentschel, 1990, 567)

[56] (Ryckman, 2014b) Whether Hentschel or Ryckman is correct, is difficult to determine. Not in the last place because the distinction between the strategies of revision and of immunisation is not always black and white. As our actual case of Cassirer has shown in the previous chapter, it was possible for philosophers to propose a revision of Kant but nevertheless make use of arguments which are typical for immunisation of Kant. Whether in fact there were more immunisating neo-Kantians or revisionists is not the issue here. What is important, is that

took this position and claimed that the original Kantian doctrine was contaminated with Newtonian thought and that hence its notion of the a priori must be reconsidered. Notable other philosophers that were influenced by Cassirer's work on relativity theory and that followed his approach of adapting Kant's a priori were Karl Bollert, Josef Winternitz and Alfred Elsbach. Reichenbach too must be grouped among these revisionists but his relation to Cassirer and the development of his own thought are complex enough to be discussed in a separate section.[57]

As was the case with the individual interpretations of imunnisation, the particular versions of the revision strategy of each of the above revisionists differed slightly from those of the others. All agreed, however, that Kant's apodicticity assigned to the Newtonian-based a priori was undoubtedly falsified by the relativity theories but that the essence of his philosophy was not harmed and remained valuable. Like Cassirer, they made a distinction between Kant's critical method on the one hand and the actual results thereof, found in Kant's books, on the other.[58] The essence of Kant's thought, they claimed, was to be found in the postulation of the requirements of experience and could be maintained if new a priori demands, valid in relativity theory too, were recognised. Wherein exactly these new demands were found, was a point in which the opinions differed, although little discussion between these revisionists ever took place on this topic.

Bollert argued that a demand always present in scientific theory is that of the presupposition of the lawfulness of nature and that this should be considered a new a priori demand.[59] Winternitz recognised that in all scientific theories causality, spatiality and temporality are used in the same manner as which Kant had believed the presupposition of Euclidean space had functioned. [60] Elsbach, a professor at the University of Utrecht, deviated stronger from traditional Kantianism. He based his theory on that of Cassirer and argued that the search of apodictic a priori principles had to be given up entirely and had to be replaced by the aim of justifying historically held true principles.

If the responses these revisionist received are compared to the criticism towards the treatises by the conservative neo-Kantians, we may spot a clear difference on the one hand and a remarkable similarity on the other. Although their reviews were more positive, their theories too were accused of being non-Kantian. In opposition to the bad analyses Schneider, Sellien and Ripke-Kühn

neither position was unique and that at least a rough distinction between the two standpoints can be made and that, as will be shown, these standpoints correspond to views on the relation between science and philosophy.

[57] See section 3.3

[58] e.g. "Man hat [...] bei den verschieden Problemen immer zu untersuchen, einerseits welche Antwort Kant hier tatsächlich gegeben hat, andererseist welche Antwort aus den allgemeinen Philosophie folgt." (Winternitz, 1923, 199); "Surely, one would perform a better service to Kant if, in the face of modern physics, one were to abandon the content of his assertions and, follow the great plan of his system, search for the conditions of experience on new paths instead of clinging dogmatically to his specific statements." (Reichenbach, 1978, 26)

[59] (Bollert, 1923, 126)

[60] (Winternitz, 1923, 204, 217)

were accused of, Cassirer, Reichenbach, Winternitz, Bollert and Elsbach were widely praised for their technical and philosophical insight. Hartmann, who had criticised Schneider's book on relativity theory, in the same article called Bollert's book an "excellent introduction to the central ideas of relativity theory"[61] and considered Winternitz's work "one of the most informative books on relativity theory".[62]

Einstein too was generally positive in his reflections on the revisionists' accounts. As opposed to the harsh language towards Sellien, in his review of Winternitz's book, he praised the author for his physical and philosophical understanding[63] and presented their differences of opinion on the character of the a priori as a matter of debate in which both positions were tenable.[64] Elsbach's book too was recommended in a review by Einstein [65] although this time his criticism was more elaborate. By alteration of the character of the a priori, Elsbach had deviated from Kant to such an extent, Einstein claimed, that one could wonder if the interpretation may still be considered Kantian at all.[66]

This point of criticism was one made not only by Einstein and not only towards Elsbach. Schlick, for instance, opened his scathing review of *Zur Einsteinschen Relativitätstheorie* by a detailed account of what Kantianism meant, a description which, as the next section will make clear, was hardly applicable to Cassirer.[67] But also conservative neo-Kantians were happy to cite the above comment made by Einstein[68] and accuse the revisionist neo-Kantians of not being Kantians at all. Schneider, for instance, made the same accusation Einstein made against Elsbach, having lost touch with Kant by having severely changed the a priori, to Reichenbach.[69] It was common for conservative neo-Kantians to argue that the modification of the a priori resulted from looking at the relation between Kant and science with blinkers. Schultz, for example, argued that by compulsively focussing on a single aspect of Kant, his reliance on Newtonian mechanics, philosophers such as Winternitz and Cassirer lost sight of the true intention of Kant's metaphysics and were forced to radically change the original notion of the a priori.[70] The accusation of having interpreted Kant

[61] "[...] eine vortreffliche Einführung in die Grundgedanken der Relativitätstheorie." (Hartmann, 1924, 49)

[62] "Eines der lehhreichsten Bücher, die über die Relativitätstheorie geschrieben worden sind." (Hartmann, 1924, 54)

[63] "[...]eine gründliche Kenntnis des Gegenstandes vom physikalischen und philosophischen Gesichtspunkte" (Einstein, 1924b, 49)

[64] "W. neigt zu der ersteren Auffassung, Ich zu der letzeren"(Einstein, 1924b, 22)

[65] "Das Elsbachsche Buch bietet viel saubere und ehrliche Denkarbeit und verdient das Studium derer, die sich für die Beziehung der Philosophie zur Naturwissenschaft interessieren."(Einstein, 1924a, 1692)

[66] "[...] so sollte man sich wohl nicht "Kantianer" nennen." (Einstein, 1924a, 1688)

[67] (Schlick, 1979)

[68] e.g. Marcus(Marcus, 1925)

[69] "Die Kantauffassung, von welcher Dr. Hans Reichenbach [...] ausgeht, entspricht nicht dem von Kant nachdrücklich betonten Sinn der Transzendentalphilosophie." (Schneider, 1921b, 73)

[70] "Die Anhänger des Meisters [Kant] nun, die aus seinen Schriften einseitig die epistemologische Seite herauslesen, die Marburger voran. dürfen jede beliebige Phase jeder beliebigen Wissenschaft mit den Sätzen der Vernunftkritik vereinigen. Denn irgendeinen 'Zusammenhang

in an un-Kantian way was not only made by conservative neo-Kantians against revisionists but, perhaps surprisingly, was made in reverse direction too. Most illustrative is Reichenbach's direct response to Schneider's accusation in a letter to Arnold Berliner. Not only did he call Schneider's book 'quite weak', but indeed, he argued that the relation between Kant's philosophy and science is indispensable and postulated that if Kant were still alive he would rather have followed Schlick than Kantians such as Schneider and Sellien.[71] In his evaluation of various interpretations on relativity he explained why he believed Schneider was wrong in accusing him of misinterpreting Kant and why instead it is she who wrongly understands what Kant really had to say. Schneider, Reichenbach argued, overemphasises the apodicticity of the a priori, whilst its true value is found in its constitutive character.[72]

With both camps blaming each other of misinterpreting Kant, it is easy to see that each tried to present their own interpretation as the solely true Kantianism. The central issue in the debate between these two camps was not so much the correct interpretation of relativity theory as it was the authority on Kantian scholarship. The conservatives saw the true value of Kant in what was written in work such as 'Kritik der reinen Vernunft' and, in Einstein's words, they did their best to 'cram relativity theory into the theses of these books'.[73] They argued that physicists and philosophers work with different, unrelated concepts and that hence there was no problem for Kant's eighteenth-century theories. The revisionists however considered the relation between science and philosophy as an essential part of these theories. In their opinion, Kant had attempted to give an account of the a priori assumptions of science. The ones he had come up with were valid for physics in his days but could not be reconciled with modern physics. To accomplish the Kantian task anew thus inevitably meant giving up on some of the theses found in Kant's books. The texts expressing this latter view were generally received better by the wider philosophical community as well as by Einstein.

---

mit dein Denkprozeß' wird ja selbst die verstiegenste physikalische Lehrmeinung behaupten. [...] Nur freilich, auf das stolze Vorrecht, das Kant für seine Metaphysik in Anspruch nahm: zwischen Wissenschaften zu richten. verzichten Denker wie Cassirer oder Winternitz; aus dem Tribunal wird eine Registratur." (Schultz, 1935) quoted from (Hentschel, 1990, 233)

[71] "Ich habe jetzt übrigens Ilse Schneiders Buch gelesen. Es ist doch recht schwach. [...] Ich glaube, Kant ginge heute lieber zu seinem grossen Gegner Schlick als zu Ilse Schneider und Riehl und Sellien und zur Kantgesellschaft." Reichenbach to Berliner, 22 April 1921, quoted from (Hentschel, 1990, 509)

[72] Ilse Schneider has also overlooked this meaning of the transcendental philosophy. She charges that my criticism of the Kantian a priori does not "correspond to the meaning of the transcendental philosophy emphasised by Kant"; but if one searches for this meaning in her writings, one finds the claim that the "general laws and the concepts of the a priori are immutable".I will admit that this is an assertion of the transcendental philosophy, but this assertion does not exhaust its significance; this is precisely the reason why I have Objected to the transcendental philosophy. Kant does not want to say merely that the general a priori laws are logically correct — this would be trivial — but rather that empirical knowledge cannot dispense with them. (Reichenbach, 1978, 24)

[73] Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)

3.2.3 Cassirer's Neo-Kantian Position

Cassirer as a revisionist Cassirer's "*Zur Einsteinschen Relativitätstheorie*" is one of the best known examples of revisionist interpretations of the relativity theories. In the book we find abundant passages that illustrate its revisionist character. Kant's philosophy is explicitly linked to Newtonian mechanics and hence as incompatible with modern physics. The true essence of this philosophy is recognised in revealing the a priori assumptions made in scientific theories. And most importantly, it is argued that in the light of the relativity theories, this essence is maintainable only if the original a priori is revised.[74] It therefore is understandable that the criticism Cassirer received was often of the same type as the criticisms given to other revisionist neo-Kantians. Like Bollert and Winternitz, Cassirer's understanding of the relativity theories and for his correct representation thereof made it a 'brilliant and excellent work' and an 'intelligent and thoughtful book' in the view of others.[75] However, like Reichenbach and Elsbach, Cassirer too was accused of having lost touch with the true essence of Kant. Julius Schultz and Henrich Scholz, the latter a teacher of Sellien, both argued that Cassirer had taken the Kantian intuitions of space and time and turned them into schemata whose extremely abstract characters differed so strongly from the traditional ones that they no longer had anything in common. [76]. These accusations must not be pushed aside too quickly. Indeed it is hard to deny the difference between the pure intuitions of space and time of Kant and the functional concepts of these notions in Cassirer's theory. For Cassirer, however, as we have seen, the notion of pure intuition conflicted with scientific practice. If the core of Kant's methodology, the transcendental method is followed, Kantian epistemology must be deprived of pure intuition and the character of space must necessarily be adapted. Ultimately, therefore, such criticisms boiled down to a difference of opinion on where the core of Kantian theory had to be placed and to which extent the original doctrine should be followed. That Cassirer was aware of these accusations becomes clear when reading the opening pages of *Determinismus und Indeterminismus*, where he reflected on the reactions his work on relativity evoked:

> When my essay "Einstein's Theory of Relativity' appeared, there were many critics who agreed with the conclusions I had drawn from the development of the new physics but who supplemented their agreement with the question whether as a 'neo-Kantian' I was permitted to draw such conclusions.[77]

[74] "Thus, the theory of relativity, as opposed to the classical system of mechanics, offers a new scientific problem by which *the critical philosophy must be tested anew.* If Kant — as Hermann Cohen's works on Kant urged repeatedly — and proved from all angles — intended to be *the philosophical systematiser of the Newtonian natural science*, is not his doctrine necessarily entangled in the fate of the Newtonian physics, and must not all changes in the latter react directly on the form of the fundamental doctrines of the critical philosophy? [...]. If it is shown that the modern physical views of space and time lead in the end as far beyond Kant as they do beyond Newton, then *the time would have come when, on the basis of Kant's presuppositions, we would have to advance beyond Kant."*(Cassirer, 1923, 355) My emphasis.
[75](Reichenbach, 1978, 29) and (Schlick, 1979, 332)
[76](Schultz, 1935, 10-12) (Scholz, 1924, 1-2)
[77]Quoted from (Cassirer, 1966)

Cassirer did not respond to these accusations and personal views on his own relation to neo-Kantianism were only expressed in a later period.[78]

In the previous chapter we have seen that despite the above, Cassirer made use of an argument very similar to that of Schneider and Sellien. In order to explain the unity of space and time in the general theory of relativity, Cassirer argued that they are only found united empirically, but that their ideal separation is unharmed by these new scientific findings and that the general theory of relativity, as an empirical theory, cannot escape the necessity of a critical demand of reason, which he believed the separation of space and time to be. It is remarkable that Cassirer made use of this argument since the issue could have been solved by dissociation of the traditional a priori principles, as he had done too with the a priori status of Euclidean geometry, for example. That Cassirer nevertheless opted for 'imunnisation' in this particular case, can be explained by the pressure exerted by the neo-Kantian community, where the use of this argument was widespread and which hence made it an easy one to adopt in one's own writings. This argument has been proposed by Hentschel[79] and it seems the most plausible explanation one can think of. Nevertheless, it may be repeated that Cassirer's version of the argument deviated from that of many others by maintaining a shared basis of concepts in the fields of physics and philosophy. Moreover, in the period after *Zur Einsteinschen Relativitätstheorie*, the distinction between empirical and ideal concepts would fade away. Despite the novel twist, Cassirer gave to the imunnisation argument was generally ignored by those commenting on *Zur Einsteinschen Relativitätstheorie*. Reviews such as those by Hartmann, Kranichfeld and Reichenbach did not mention it and instead paid attention to Cassirer's revisionist argumentation only.[80]

Cassirer's revisionism compared Although *Zur Einsteinschen Relativitätstheorie* was compared to the works of others, it differed from every other interpretation in particular respects. Its time of publication was one of the ways in which Cassirer's book positively distinguished itself from other revisionist interpretations. Being published in January 1921, it was one of the first to propose the idea that the original Kantian theory needed to be revised in the light of relativity. Sellien and Ripke-Kühn had published books in which they had defended the Kantian position in 1919 and 1920 respectively but they aimed at 'immunizing' Kant, rather than revising him. At the time Cassirer's book was published, in January 1921, the proposition of revision had only been made by Reichenbach whose first work on relativity appeared in November 1920. Cassirer's book had, however gone to press already by then and he therefore could not used Reichenbach's publication as an inspiration. Both the fact that Cassirer and Reichenbach had written their books independently and that nevertheless the similarity of their arguments was evident is illustrated in Cassirer's

[78] Cassirer reflects on his relation to neo-Kantianism in (Cassirer, 1939).
[79] (Hentschel, 1990, 210-212, 229)
[80] Wenzl remarked that Cassirer used this argument which he recognised in Sellien and Schneider too, but nevertheless was much more elaborate on Cassirer's revisionist arguments.(Wenzl, 1924, 104 ff.)

letter to Reichenbach written on 7 July 1920 after he read an early version of Reichenbach's book.

> Nehmen Sie vielen Dank für Ihren brief: wann Ihr Arbeit im etwa 4-6 Wochen erscheint werde ich dann wenigstens am Schluß der meinigen noch auf sie hinweisen können. Meine Arbeit wollt gleichfalls in nächsten Zeit und zwar als besondere Schrift unter dem Titel „Zur Einsteinschen Relativitätstheorie. Erkenntnisstheoretische Betrachtungen" bei Bruno Cassirer in Berlin erscheinen [...] Unsere Gesichtspunkte sind in manchen verwandt.[81]

Being one of the first revisionist interpretations, *Zur Einsteinschen Relativitätstheorie* inspired others and indeed, one may find explicit references to Cassirer's arguments in later publications.[82] Elsbach explicitly recognised the influence by giving a detailed, ninety pages long account of Cassirer's epistemology in '*Kant und Einstein*', which moreover was dedicated to Cassirer.[83]

Cassirer's work also distinguished itself by its focus on the change of concept formation throughout the history of science. Cassirer relied on *Substanzbegriff und Funktionsbegriff* when developing his views on the relativity theories and their explanation as theories that fit in a historical development of science he also used to explain other replacements of theories. The development of the character of scientific concepts towards functional relations was understood as a tendency always prevalent in the development of science and the creation of the relativity theories formed no exception. This idea is comparable only to Elsbach's account. As has been mentioned before, Elsbach explicitly mentioned Cassirer as the originator of this idea. This idea of Cassirer had an important consequence for the character of his revisionist interpretation. For Cassirer, not only the traditional content of the synthetic a priori had to be abandoned, but the recognition of the development of concept formation meant, as we have seen in chapter 1, that also the form in which the a priori was normally understood required reinterpretation. Along only with Reichenbach and Elsbach, and in contrast to other revisionists, Cassirer understood the a priori to be something different from what most philosophers held it to be. Cassirer's absolute a priori, distinct from the relative a priori which he also recognised, came closest to the standard interpretation. But even here, its regulative character and the principal unattainability were elements that were unique to Cassirer's epistemology and hence his treatment of the theories of relativity

Third, the representation of the physical theory in *Zur Einsteinschen Relativitätstheorie* was praised more widely than that in any of the other neo-Kantian works on the relativity theories. Not only by Cassirer's contemporaries, but modern commentators too recognise these qualities and in modern literature is presented as one of the most important books on relativity theory of the early 1920's. Howard's statement that it was 'the best of the neo-Kantian reactions to relativity'[84] illustrates a regard for the text that is shared by other modern

[81] Cassirer to Reichenbach, 7 July 1920, document 285 on the DVD accompanying (Cassirer, 2009)
[82] (Winternitz, 1923, 207-209)
[83] (Elsbach, 1924, III, 279-368)
[84] (Howard, 1994, 53)

commentators.[85] To a large extent, the same opinion, albeit less explicit, was expressed quickly after its publication. Einstein referred to Cassirer's interpretation as the prototype of a tenable Kantian response to his theories[86] and Schlick picked the views of *Zur Einsteinschen Relativitätstheorie* as his subject to argue against neo-Kantian philosophy in general.[87] That Schlick's 1921 article in retrospect is seen as the final blow to neo-Kantianism,[88] underlines the fact that Cassirer's treatise was not seen as an irrelevant attempt to Kant with relativity theory, but as one of the most promising of these attempts. Schlick's argument was so strong exactly because it was aimed at Cassirer's interpretation, rather than at one of the poorer ones.

Cassirer's revisionism explained That Cassirer chose to allow a revised Kantianism and opted for a different approach to deal with relativity than other neo-Kantians who preceded him had done is not surprising. And although Cassirer was one of the first to propose a revised Kantianism in the debate on relativity, it did not appear out of the blue. In *Das Erkenntnisproblem*, first published in 1906, as well as in his 1910 *Substanzbegriff and Funktionsbegriff* Cassirer already questioned the tenability of a dogmatic interpretation of Kant's categories. Even before Einstein had finished developing the general theory of relativity, Cassirer had suggested that the Kantian principles are probably not apodictic but instead should 'rather be regarded as the temporarily simplest intellectual "hypotheses," by which we establish the unity of experience.' [89]

There are three explanations that can be given for the revisionist approach of Cassirer. First is Cassirer's Marburg training in philosophy and the accompanying emphasis on the transcendental method which he had learned from Cohen and Natorp. Taking scientific theories, the most recent ones in particular, for granted and accepting them as expressions of our knowledge was the very essence of this method, which Cassirer had applied in his earlier work too. Rather than dictating the standards for adequate science, philosophy is understood to follow science and trust scientist in being the best at establishing new knowledge.[90] The task of philosophy then, is to reveal the tacit presumptions made in the creation of scientific theories. This means that if modern day scientist believe that the physical laws of Kant's days no longer represent accurate knowledge, the presumptions of these laws might no longer be those of our current knowledge either. The idea that philosophy follows science stood in stark contrast with the idea that philosophy could dictate science. It is the latter idea that follows easily from a belief that the a priori principles determined by Kant

[85] For example (Ryckman, 2005), (Ferrari, 2003, 135) and (Hentschel, 1990, 551 ff.)
[86] (Einstein, 1924a, 1688)
[87] See the discussion in section 3.3.2
[88] (Ryckman, 2005, 50), (Hentschel, 1990)
[89] (Cassirer, 1920a, 16) and (Cassirer, 1923, 268)
[90] Cassirer's opening words of his 1920 article on relativity are illustrating: "Die philosophische Betrachtung einer physikalischen Theorie kan nicht darauf ausgehen, einen eigenen und selbständigen Maßstab dür die Beurteilung ihres Inhalts aufzustellen, der den Maßstäben über welche die Einzelwissenschaft selbst verfügt, gleichberechtigt zur Seite treten könnte."'(Cassirer, 1920c, 1337)

were fixed for eternity and therefore are rules that modern science too had to abide by. Cassirer's Marburg years can be considered to have rejected this idea and hence to have influenced his acceptance of the fact that not all of Kant's words were still valid after Einstein introduced the theories relativity.

Second, as is clear from his first letters to Einstein, Cassirer wished to unite philosophy and the natural sciences in a single discussion. He believed that the debate on relativity should not be left to philosophers alone, but needed to be held by both philosophers and scientists. The texts by Sellien and Ripke-Kühn, which were published before *Zur Einsteinschen Relativitätstheorie* had relied on the argument that Einstein's theories did not conflict with Kant's simply because the former were empirical and the latter concerned ideal requirements. The immunizing neo-Kantians had drawn the conclusion that the domains of philosophy and of science were separated and that science was essentially unable to refute a philosophical thesis for this very reason. This idea is diametrically opposed to Cassirer's desire to reduce the gap between philosophical and scientific discussions. Hence, the imunnisation strategy, at least in the form in which it had been used by others, was unavailable to Cassirer.

Third, it has been suggested that Cassirer's age influenced his willingness to adjust existing philosophical theses. Basing himself on a distinction between 'younger' and 'older' neo-Kantians made by Marck and Ollig[91], Hentschel raises the idea that of the younger generation one may simply expect a greater tendency to throw overboard existing theories. However, upon closer examination this idea appears implausible, simply because it seems impossible to find any correlation between the ages of neo-Kantian philosophers who responded to the theories of relativity and their willingness to revise the original Kantian doctrine. First of all, the distinction that Hentschel upholds is not the same as the distinction made by those he cites. Whereas Marck lined Cassirer indeed among the young neo-Kantians,[92] Ollig considered Cassirer and old neo-Kantian.[93] Hentschel's distinction thus only corresponds with that of Marck by considering Cassirer to be part of the young revolutionaries. Even if we follow Hentschel's distinction, according to which Cassirer, Bauch and Hönigswald are labelled 'young' and Natorp, Cohen and Rickert 'old', the conclusion that the former were more inclined to revision is hard to draw. Natorp, who used an 'immunizing' strategy appears to be the only old neo-Kantian to have joined the relativity debate. That the only old neo-Kantian in the debate was not a revisionist evidently is too little information to conclude that there existed a generation gap. I believe that if we wish to make a distinction between two generations of neo-Kantian philosophers in the relativity debate, we would have to consider those born in 1881 or earlier as old ones (Natorp, Cassirer, Hönigswald, Bauch, Ripke-Kühn, Bollert) and those born after 1890 as young ones (Schneider, Sellien, Reichenbach, Winternitz, Elsbach), leaving a gap of a decade in which few important contributors to the debate were born. It is clear that this distinction gives no reason to believe there existed any correlation between the

[91](Marck, 1949), (Ollig, 1979)
[92](Marck, 1949, 144)
[93](Ollig, 1979, V)

generation to which any of these philosophers belonged and their attitude towards a revision of the original Kantian texts. The distinction yields both old revisionists (Cassirer and Bollert) as well as young immunisation-neo-Kantians (Schneider, Sellien). I therefore do not think that Cassirer's age or an assignment of him to a specific generation of neo-Kantians is helpful to explain his willingness to revise Kant.

3.3 Reichenbach and Schlick

3.3.1 Reichenbach's *Relativitätstheorie und Erkenntnis a Priori*

In section 3.2 a distinction was made between two approaches used by neo-Kantian to deal with Einstein's relativity theories. Cassirer, as well as Winternitz, Bollert and Elsbach was recognised as a 'revisionist', who, unlike the 'imunnisationists', believed it was necessary to change the original Kantian philosophy. A fifth important advocate of this latter view was Hans Reichenbach, whose *Relativitätstheorie und Erkenntnis a priori*, published in 1920, represents a clear revisionist interpretation of Einstein's physics. Due to the developments of his views and his dissociation from neo-Kantianism in later years, as well as his close contact with Cassirer, Reichenbach's thoughts were not discussed in detail in the earlier section, but will receive their due attention on the following pages.

The relation between Reichenabch and Cassirer goes back to the time when Einstein had not yet completed the general theory of relativity. In 1913, Reichenbach, seventeen years younger than Cassirer and then in his early twenties, took courses with Cassirer at the University of Berlin.[94] The next year, Cassirer recommended the young student to Natorp, revealing an admiration which, despite the philosophical differences that would arise in the 1920's, never faded.[95] Not only did Cassirer and Reichenbach maintain a vivid correspondence in which they appraised each other's writings and which lasted until Cassirer's sudden death in 1945,[96] Cassirer had rejected personal and political motives in scientific and philosophical criticism[97] and he encouraged philosophical discussions in which participants were judged by the soundness of their arguments alone. Thus, when the philosophical views of Cassirer and Reichenbach grew apart, the tone of the letters remained friendly and respectful. Philosophical arguments were formulated formally and separated from expressions of personal interest. Also Cassirer's claim that the main goal of his treatise was to stimulate the discussion on relativity theory rather than to give a definite explanation was reflected in his attitude towards Reichenbach's views. When Reichenbach had

[94](Reichenbach, 2008, 149)
[95](Reichenbach, 2008, 2)
[96]Cassirer's last letter to Reichenbach was written on 10 April 1945, eleven days before Cassirer died of a heart failure in New York.
[97]See section 3.4.2

come to oppose neo-Kantian interpretations on physical theories, Cassirer still believed in Reichenbach's qualities as a philosopher, as is clear from Cassirer's attempts at helping Reichenbach to obtain a professorship.[98] [99]

Although Cassirer's *Zur Einsteinschen Relativitätstheorie* is recognised as one of the first texts to propose the idea that the relativity theories were incompatible with the traditional Kantian doctrine and that it needed to be revised, Reichenbach beat him to it by publishing this idea three months prior.[100] Indeed, the key argument of Reichenbach's *Relativitätstheorie und Erkenntnis a priori* is that the traditional notion of the a priori is untenable but that critical philosophy remains the most useful approach to interpete the theoeries of relativity.[101] According to Kant, the presupposition of absolute space and time, as well as that of Euclidean geometry, was apodictically necessary for the possibility of knowledge. If the general theory of relativity was correct, which Reichenbach did not doubt, this claim had been proved to be wrong and hence Kant and Einstein were indisputably incompatible.[102]

Like Cassirer, Reichenbach, in 1920, did not believe this incompatibility implied a refutation of Kant's critical philosophy. Whereas other revisionists attempted to find new principles to replace the falsified Kantian principles, Reichenbach's strategy differed. He believed it was not the content, but rather the character of the a priori that needed revision. In lucid language Reichenbach explained how the traditional a priori was understood and what he believed to be its deficiency.

> Kant's concept of a priori has two different meanings. First, it means "necessarily true" or "true for all times," and secondly, "constituting the concept of the object."[103]

Despite the fact that these two meanings of the a priori are logically independent, Kant had used them interchangeably. The general theory of relativity both clearly showed how the first one is untenable and that the second one is a indispensable element in scientific theories. Indeed Einstein's theories rely on

[98] (Heis, 2013, 6)

[99] Cassirer's relation with Schlick was not as close as that with Reichenbach. Nevertheless, when Philipp Witkop asked him to write an article on the theory of relativity, Cassirer, in his response, said that he did not have time to write such an article and instead suggested Witkop to contact Schlick or Reichenbach. In a subsequent letter he recommended the physicist (and teacher of Reichenbach) Arnold Sommerfeld, who indeed wrote an article on the theory of relativity for Witkop's *Deutsches Leben der Gegenwart*. See: Cassirer to Witkop, 16,17 December 1920, documents 300 and 301 on the DVD accompanying (Cassirer, 2009). Moreover, Cassirer helped Shlick and Carnap with the latter's publication of *Der logische Aufbau der Welt* without any reservation. (Cassirer, 2009, 98-99)

[100] Zur Einsteinschen Relativitätstheorie was published in January 1921, Relativitätstheorie und Erkenntnistheorie a priori was published in Novermber 1920. ((Ryckman, 2005, 252)) Citations of the latter book are taken from the English translation (Reichenbach, 1965).

[101] Indeed, Reichenbach agreed with Cassirer that Kantianism was verified by the theories of relativity and he repeatedly expressed his astonishment that the principle of relativity had not been asserted by Kantians a long time ago. (Reichenbach, 1920, 8), (Reichenbach, 1978, 27)

[102] (Reichenbach, 1965, 31)

[103] (Reichenbach, 1965, 48)

constitutive principles in the same way Newtonian mechanics relied on principles such as the assumption of Euclidean geometry and absolute space. Riemannian geometry, which replaced Euclidean geometry is a constitutive principle, not deducible from experience but nevertheless required to give meaning to the field equations of general relativity. Reichenbach considered this second meaning of the a priori the only proper one and the fact that it was manifest in relativity theory was the reason why Einstein's works supported critical philosophy.[104]

The first of the two meanings, the apodiciticty of the principles is one tacitly introduced by Kant, and Reichenbach argued that the relativity theory had shown that there could be given no justification for this introduction. The possibility to develop a physical theory without the use of some of Kant's a priori principles made us aware that no definite necessity can be guaranteed for any principle. Like Cassirer, Reichenbach therefore argued that it is essentially impossible to determine any apodictic principles.[105] A crucial difference between Reichenbach's and Cassirer's views is that Cassirer held these principles to be goals to ideally strive for, whereas Reichenbach drew the conclusion that the attempt to define absolute a priori principles was useless and rejected it without reservation.[106] What remained in Reichenbach's epistemology were principles which were constitutive, that is functioning to order bare impressions in such a way that they can be interpreted. They lack apodicticity and are replaceable by different principles in successor theories. In the previous chapter I have followed Heis's terminology and labelled such principles 'relative a priori'. In contrast to Friedman and in line with the views of Ryckman and Heis, I recognised that in Cassirer's philosophy we find such relative a priori principles. An important difference between Cassirer's and Reichenbach's notions of the relative a priori is that for the former they are additional to absolute a priori principles which are apodicitic whereas in Reichenbach's theory the absolute a priori is abandoned completely.

3.3.2 Schlick

Reichenbach's rejection of the absolute a priori was shared by Moritz Schlick. Before starting his studies in philosophy, Schlick had obtained a Ph.D. in physics under the supervision of Max Planck. Via Planck, he was brought into contact with Einstein, who, once Schlick started publishing his philosophical ideas, became one of his greatest admirers. When in 1915 Schlick criticised Natorp's and Hönigswald's neo-Kantian interpretations of the special theory of relativity, Einstein read it and responded with much enthusiasm.[107] Schlick's epistemology, which was an alternative to the neo-Kantianism which Cassirer advocated, was praised not only by Einstein, but indeed by the majority of the scientific commu-

[104] (Reichenbach, 1965, 77)
[105] For Cassirer's argument, see section 1.3.2.
[106] (Reichenbach, 1965, 79)
[107] (Schlick, 1915) and Einstein to Schlick, 14 December 1915 (Einstein, 1998, 220-221)

nity.[108] Cassirer himself was aware that Schlick's views were favoured by most physicists, but primarily drew the positive conclusion that Schlick could function as an intermediary between the scientific and philosophical communities.[109] As a result of this status, Schlick was widely believed to be the philosophical expert and authority on the theories of relativity. Even the neo-Kantian minded journal *Kant-Studien*, had no choice but to recognise Schlick's authority. In 1921 the editors therefore asked Schlick to review several philosophical interpretations of the theories of relativity, including Cassirer's. Schlick played a crucial role in the development of logical empiricism and remained a central figure in the philosophical community until his sudden murder in 1936.

Schlick's early epistemology

Most of Schlick's early epistemology is clearly expressed in *Allgemeine Erkenntnistheorie*, largely written in 1916, and first published in 1918. Although the ideas in this book formed the basis of Schlick's criticism of *Zur Einsteinschen Relativitätstheorie*, they were much closer to Cassirer's thoughts than to those of most other philosophers. First Schlick, like Cassirer, considered modern physics to be the necessary point of departure of philosophical thought and thereby share Cassirer's idea of philosophy as an analysis of science, rather than as its guide.[110] Second, Schlick also fully embraced Cassirer's ideas of concept formation, the core thesis of *Substanzbegriff und Funktionsbegriff*. Indeed, reflecting on a later edition of Schlick's book, Cassirer wrote that he recognised in it the thesis which he himself had "sought to develop and prove nearly two decades ago in [his] book "Substance and Function""[111]

Nevertheless, Schlick strongly disagreed with Cassirer, and with all neo-Kantians for that matter, on the character of knowledge by explicitly arguing against the need for synthetic a priori principles and concepts. Knowledge, according to Schlick, was nothing but the coordination of judgements to reality. When this coordination was unambiguous (*eindeutig*), it was understood as a true judgement. Schlick further distinguished between two types of judgements. Judgements are expressions asserting the existence of relations between concepts. If a judgement contains a concept that is not yet used in other judgements, it is a definition. If, on the other hand, a judgement contains a concept which already occurs in different judgements and hence is related to other concepts already, we have an empirical judgement. these two types of judgements correspond to a priori analytic judgements and empirical a posteriori ones. Schlick explicitly rejected that there was a third type. Thereby he denied the existence of synthetic a priori judgements, which the neo-Kantians argued,

[108] See for instance Weyl's remark that Schlick's book had found "great resonance among the leading theoretical physicists". Weyl to Husserl, 26-27 March 1921. (Ryckman, 2005, 113), as well as Einstein's remark in his letter to Schlick written on 17 October 1919. "Born also much loves your book." Quoted from (Howard, 1994, 94)

[109] Cassirer to Schlick, 23 October 1920, (Cassirer, 2009, 50)

[110] see section 3.2.3

[111] (Cassirer, 1927); Quoted from (Krois, 1987, 117)

was non-empirical but nevertheless was capable of relating already existing concepts, such as space a and time. Instead, Schlick argued, all a priori knowledge was definitional. The term 'convention' was not yet used by Schlick in 1918, but it would not be long before Schlick would start speaking of conventional definitions.[112]

Schlick, in 1918, claimed that the distinction between definitions and empirical judgements, and thereby that between analytical and synthetic judgements, was relative and dependent on the stage our science was in.[113] What is considered definitional in one phase, matter's property of mass for instance, may be considered an empirical judgement later on. Newly discovered properties can yield the matter's mass as a consequence, whereby the description of these properties becomes a definition and the property of mass an empirical claim.

Critical or empiricist interpretation?

Due to his reputation as a well informed scholar on the relativity theories and an early critic of neo-Kantianism, Schlick was asked by *Kant-Studien* to review both Cassirer's *Zur Einsteinschen Relativitätstheorie* and Reichenbach's *Relativitätstheotie und Erkenntnis a Priori* soon after these books were published.[114] Schlick obliged and in 1921 the journal published an article of seventeen pages, bearing the title "Kritizistische oder empiristiche Deutung der neuen Physik?"[115] More than merely a review of Cassirer's and Reichenbach's books, the article was an assessment and criticism of neo-Kantian interpretations of Einstein's theories of relativity. Reichenbach's book is found only on the last page of the article and by far the largest part of the text was an evaluation of Cassirer's book, which Schlick had taken as a point of departure from which to argue for the untenability of critical philosophy. Although the overall tone of this evaluation is nothing less than dismissive, the review is peppered with words of appreciation and agreement with many of Cassirer's findings. So, whereas Schlick strongly disagreed with Cassirer's claim of the verification of critical philosophy by the theories of relativity, he nevertheless considered the book to be 'intelligent and thoughtful'[116] and to contain 'a brilliant use of the finest historical and philosophical scholarship.'[117] Schlick explicitly contrasts Cassirer with conservative neo-Kantians such as Sellien and Schneider, who, he argued, had not correctly understood the notion of a priori principles.[118] It has been shown above, that some of Schlick's fundamental philosophical perspectives were shared by Cassirer and hence Schlick's preference of Casssirer's

[112] See Schlick's correspondence with Reichenbach in 1920 discussed below.
[113] (Schlick, 1918, 50)
[114] The third book which Schlick was asked to review was (Born, 1922), which he considered a "brilliant, comprehensive account of Einstein"s theory from the physicists' point of view."(Schlick, 1979, 332) However, since it has little relation to the issues discussed here, it shall not be elaborated upon.
[115] (Schlick, 1921). An English translation of this text is found in Schlick's "Philosophical Papers" (Schlick, 1979)
[116] (Schlick, 1979, 332)
[117] (Schlick, 1979, 327)
[118] (Schlick, 1979, 325)

neo-Kantianism to that of others is easily understood. The implicit strategy of Schlick's criticism is that by arguing that even the most thought-out critical philosophy could not give a correct account of the relativity theories, he would convincingly refute all neo-Kantian approaches and show that a different philosophy was required.

Schlick's argument was twofold. He argued that actual elaborations of neo-Kantianism in the light of the theories of relativity failed and that moreover their purported necessity by the rejection of strict positivism was a fallacy. Both these arguments, the first one in particular, relied on Schlick's understanding of neo-Kantianism which is found on the opening pages of the article. Its essence is the recognition of synthetic a priori principles, which have the two characteristics of playing a constitutive role in knowledge as well as being apodictic.[119]

The first argument, the failure of neo-Kantianism to explain the theories of relativity, starts with the observation of the conflict between Kant's theses and the theories of relativity. Schlick straightforwardly rejected the imunnisationist approaches and drew the conclusion that the only option left for critical philosophers is the revisionist approach: "Anyone who accepts Einstein's theory must reject Kant's theory in its original form."[120] Schlick, fairly uncontroversially, defined the essence of neo-Kantianism as the recognition of synthetic a priori principles. Its task then, after the recent discoveries in physics, had become to find synthetic a priori principles which are valid for the theories of relativity.[121] Schlick's argument was that even Cassirer's attempt at accomplishing this goal was unsatisfactory.

Cassirer's argument that despite its use of non-Euclidean geometry, the general theory of relativity relies, as all previous physical theories had done, on some notion of spatiality, was a claim of a new a priori principle, suggested in '*Zur Einsteinschen Relativitätstheorie*'.[122] Schlick rejected this claim by noting that, in great contrast to Kant's original a priori principles, the notion of 'spatiality' is too vague and is in need of a more specified formulation, which, he added, appears impossible to give.[123] Schlick had mentioned this point of criticism in a letter to Cassirer in which he also explicitly requested Cassirer to be more specific about what he believed to be new synthetic a priori principles. In his response, Cassirer wrote that the true a priori is only to be found in "the unity of nature', i.e. the lawfulness of experience.'[124] In his review, Schlick argued that this principle is no more satisfying than that of 'spatiality'. The assumption of the lawfulness of experience is a '*conditio sine qua non*; a demand that, by their very definition, all scientific theories satisfy. Again in great contrast with Kant's original a priori principles, this principle is much more general and lacks the specificity required to make critical philosophy valuable. Even empiricist would admit that a theory that doesn't describe nature as a

[119](Schlick, 1979, 323)
[120](Schlick, 1979, 324)
[121](Schlick, 1979, 325)
[122](Cassirer, 1923, 418,433)
[123](Schlick, 1979, 326)
[124]Cassirer to Schlick, 23 October 1920, (Cassirer, 2009, 51)

law-abiding system is not considered scientific. Cassirer had made a move that seemed inevitable if trying to reconcile Kant with Einstein, he stretched the notion of the a priori and as a result ended up with a theory that is no longer testable by science at all. The demand that philosophy should follow science, one advocated by both Schlick and Cassirer, thus is one that makes Cassirer's theory 'lose its philosophical value'.[125] Hence Schlick concluded with a rejection of Cassirer's ideas:

> Casirer's observations appear to me to provide no convincing evidence of how we may heal the wound dealt to the original Kantian viewpoint by the overthrow of Euclidean physics.[126]

As mentioned, Schlick's argument was twofold. The second argument Schlick gave against neo-Kantian interpretations of the relativity theories was that their necessity may not be deduced from the rejection of strict positivism. The simple dichotomy between critical philosophy and such extreme empiricism which Cassirer had sketched, was a fallacy in Schlick's opinion. He conceded that Cassirer had done an outstanding job in refuting Mach's and Petzold's positivism by showing the necessity of constitutive elements in knowledge.[127] To deduce from this rejection the truth of the critical position, is the result of the assumption that there is no third position. Schlick rejected this assumption and argued that his own views offered a viable alternative to both extreme positivism and neo-Kantianism. This new empiricism, which indeed was the epistemology he had outlined in 1918, contained constitutive elements but rejected their synthetic character. Whereas in 1918 Schlick had not yet applied the term convention, in his review of Cassirer, Schlick argued explicitly that the conventional principles should be understood as 'conventions or hypotheses'.[128]

The importance of Schlick in the development of logical empiricism is uncontested. If a closer look is taken at this development, the role of Schlick's review of Cassirer's book on relativity must not be underestimated. No other publication before had argued so strongly or in such a systematic manner against neo-Kantian interpretations of relativity. Coffa has claimed that "This remarkable article may well be regarded as the point of departure of a new direction for scientific philosophy."[129] A further contribution to the alleged relevance of the article is found in a letter Einstein sent to Schlick. Praising the article wholeheartedly, he wrote: "This morning I read your article about Cassirer with great enthusiasm. I have not read anything so clever and true in a long time."[130]

Schlick's criticism discussed

Despite Schlick's damning article, Cassirer, unlike Reichenbach, never became convinced that his views were tantamount to conventionalism.[131] The con-

[125](Schlick, 1979, 323)
[126](Schlick, 1979, 327)
[127](Schlick, 1979, 324, 330)
[128](Schlick, 1979, 324)
[129](Coffa, 1991, 199)
[130]Einstein to Schlick, 10 August 1920. Quoted from (Coffa, 1991, 189).
[131]Reichenbach's adoption of conventionalism is discussed in the next section.

clusion of his 1936 work on quantum mechanics was the same as that of his 1921 work on the theories of relativity: the Kantian doctrine is unaffected by the acceptance of scientific results that contrast with the classical Kantian principles. Unfortunately, a full discussion between Cassirer and Schlick never emerged. Cassirer's most noteworthy criticism of Schlick's philosophy is found in (Cassirer, 1927) in which the argument against critical philosophy, as found in (Schlick, 1925), is rejected. Cassirer argued that Schlick's account of conventionally determined definitions was incomplete as long as they were not guided and resticted by regulative principles.[132] Indeed, where Cassirer here was drawing attention to, was the role of the a priori as he had developed it in 1910 in *Substanzbegriff und Funktionsbegriff*.[133] Almost two decades after this development, Cassirer, in his criticism of Schlick, made clear that his notion of the a priori had never successfully been rebutted by Schlick, not in either of the editions of *Allgemeine Erkenntnislehre*, nor in *Kritizistische oder empiristiche Deutung der neuen Physik?*.

Looking back at Schlick's 1921 review of Cassirer's interpretation of relativity, it indeed appears that he had misunderstood a central notion of Cassirer's epistemology and that his rejection of it was founded on a misleading argument. Schlick's refutation of Cassirer's *tertium non datur* was unmistakably correct, Cassirer had been wrong in suggesting that the choice was merely one between strict positivism and critical philosophy. By its recognition of constitutive elements in knowledge, Schlick's empiricism differed from Mach's version to such an extent that if formed a serious alternative. This much one must grant Schlick. His other argument, however, the claim that no neo-Kantian had successfully shown his philosophy to be compatible with the theories of relativity, is one that strongly depends on Schlick's personal ideas on critical philosophy and the a priori. The subsequent attempt to force Cassirer's theory into this account may remind one of, and indeed is no less discreditable than, the neo-Kantian attempt to 'cram relativity theory into the Kantian system', a complaint made by Einstein in a letter to Schlick.[134]

Elucidating what his account of neo-Kantianism entailed, Schlick had explicitly mentioned that a critical philosopher is one that accepts synthetic a priori principles and added that these principles are to be understood as apodictic and constitutive principles.[135] Most interpreters of Kant would have happily agreed with this description. Indeed, Schlick's ideas on the notion of critical philosophy did not differ from the conservative neo-Kantians who wished to stay as close as possible to the traditional reading of Kant. Hence this interpretation of Schlick is one of the few, albeit crucial, respects in which he stood spiritually closer to the likes of Schneider and Sellien than to Cassirer, whose account of critical philosophy allowed much more flexibility. The traditional notion of the a priori in particular, was an element which Cassirer had long abandoned. Inspired by the Marburg rejection of the distinction between sensibility and understanding,

[132](Cassirer, 1927, 67-79)
[133]See chapter 1
[134]Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)
[135](Schlick, 1979, 323)

he had revised it, as outlined in section 1.3.2. It was this reinvented a priori that was used in Cassirer's interpretation of the relativity theories and hence it is no surprise that Schlick failed to find any acceptable versions of the classical a priori there.[136]

That Schlick had not in mind Cassirer's remodelled a priori, is clear from Schlick's criticisism of Cassirer's suggestion of spatiality as an a priori concept. He argued that it was too vague and inexact to be considered a satisfactory example of an a priori concept.[137] This remark only makes sense when it refers to the traditional Kantian a priori, where only clearly understood concepts and principles such as the rules of Euclidean geometry are allowed. For Cassirer however, the concept of spatiality did not need any such specification. In his view, spatiality was an absolute a priori concept which meant that it received particular implementation by relative a priori concepts. The relative a priori principles about which Cassirer wrote, general covariance and the equivalence of inertial and gravitational mass for instance, are not apodictic and therefore too would have been essentially unacceptable for Schlick.[138] For Schlick, the a priori could only be traditional, that is, apodictic and clearly defined. By his demand of specificity, Schlick moreover completely disregarded Cassirer's repeatedly emphasised argument that the apodictic a priori in his theory is to be understood as a regulative ideal whose exact content we can never determine with certainty.[139] This idea, as well as the claim that such principles, as well as their content, are incompatible with the arbitrariness of theory choice had already been recognised by Cassirer in 1910. Cassirer recognised Poincaré's purported multiplicity of possible constitutive principles and in his theory we find these principles as the relative a priori elements of our knowledge. In contrast to Poincaré, Cassirer argued that the choice between these principles is not unrestricted, but 'follows a certain law of progress'.[140] Indeed, this law is the result of the regulative, absolute a priori principles whose apodictic and ideal character make them impossible to be understood as conventions. Recently Jeremy Heis recently has put it very clearly:

> It simply makes no sense to talk of the very same conventions being laid down throughout the history of science, and it makes even less sense to say that there are conventions that we cannot in principle identify for certain.[141]

Indeed, it were these principles, restricting the variable principles, that Cassirer in 1927 argued Schlick could not do without either. We have seen earlier that Cassirer deemed them necessary in order to guarantee the objectivity of scientific progress. Without an element that gives a scientific theory permanence, the theory risks losing its relation to other scientific theories and the development

[136] Schlick's rejection of Reichenbach's theory as a neo-Kantian theory, discussed above is a result of the same unwillingness to allow much deviation from the original Kantian notion of the a priori.
[137] (Schlick, 1979, 326)
[138] (Cassirer, 1923, 428, 433)
[139] (Cassirer, 1923, 269)
[140] (Cassirer, 1923, 187)
[141] (Heis, 2013, 23)

of science into an arbitrary sequence of theories that cannot be guaranteed to even refer to a singe world of experiences. In Cassirer's view, Schlick's theory, yielded exactly such a subjective view of science.

Schlick's purported refutation of Cassirer;s suggestion that the 'lawfulness of experience' is an a priori demand, is based on a similar misinterpretation of Cassirer's notion of the a priori. This lawfulness is meant not as a relative a priori principle that can be refuted by our next physical theory, but serves as a regulative principle, used in determining these relative a priori principles. When Schlick marked that even empiricists would accept this principle, he, tactfully but unjustly, ignored the crucial difference between himself and Cassirer. That is, Cassirer could not accept this principle as a convention but instead considered it an expression of human reason.

Schlick only allowed a restricted Kantianism and correctly argued that this was incompatible with the results of modern physics. Due to his failure to see that Cassirer's theory could not be reduced to this form of Kantianism, however, he threw out the baby with the bath water. The purported role played by Schlick's review of Cassirer's interpretation of relativity therefore was one that resulted from erroneous argumentation. Likely, if not Schlick's authoritative status, his orderly and lucid style of writing was of more influence than philosophically sound argumentation. It is known that Einstein had called Cassirer a 'deceiver of the people' due to the eloquence of his writing.[142] We may, again, wonder if Einstein's accusing words were not equally applicable to Schlick. In a recent publication, Thomas Ryckman has taken this idea as a premise and argued that due appreciation of Cassirer's philosophy (as well as that of Hermann Weyl and Arthur S. Eddington) could have prevented some fundamental flaws in logical empiricism, such as those later pointed out by Quine. In section **XXX** we will see that Einstein too witnessed the change made by Schlick with sorrow.

3.3.3 Aftermath

Schlick convinced Reichenbach

The epistemological ideas of Schlick and Reichenbach outlined above show a number of points of overlap as well as some fundamental differences between them. Most important here is the shared rejection of absolute a piori principles on the one hand and a difference of opinion on the tenability of Kantianism on the other. Both philosophers agreed that the classical a priori, as it had been suggested by Kant, were to be rejected by those who believed that Einstein's theories had to be taken seriously. Reichenbach explicitly claimed that even though along with the traditional doctrine of Kant most neo-Kantian accounts were to be rejected, a modified notion of the a priori was fruitful. Schlick, in contrast, rejected all forms of neo-Kantianism and asserted that the concept of the a priori had to be replaced by the notion of convention.

[142] Schlick to Reichenbach, June 1924. Quoted from (Hentschel, 1990, 519)

Schlick had noticed the above similarity and difference and in late 1920 exchanged thoughts with Reichenbach. In September he sent a letter in which he expressed his hope that their differences could be resolved and two months later, in a second letter, he explained Reichenbach how he believed Reichenbach's notion of the a priori were tantamount to his idea of conventions.[143] Crucial were two remarks Schlick made in this letter. First is his notice that the apodicticity of the a priori could not simply be removed from its constitutive character, as Reichenbach had attempted. In Schlick's view this implied a deviation from Kant's traditional theses to such an extent that it no longer had any serious relation to it.[144] Second, and consequentially, having removed the apodicticity from the a priori, what remained of it did not fundamentally differ from the definitions which he himself had considered conventions. Indeed, Schlick wrote:

> In my opinion [...] - and it is the main point of this letter that I cannot see what is the real difference between your a priori statements and conventions. ... The decisive places where you describe the character of your a priori correspondence principles seem to me to be nothing short of accomplished definitions of the concept of convention.[145]

Reichenbach's initial response, found in a letter written a few days later, was twofold. With respect to the first point made by Schlick, he reacted indifferently. In remarkable contrast with the strong language on Kant's spirit made a few months later,[146] Reichenbach did not seem to care much about the Kantian label he was denied by Schlick. He even appeared inclined to agree with Schlick that this denial was appropriate.[147] On the other hand, he also expressed his objections to the notion of conventions, remarking that the choice of principles is not entirely arbitrary. Constitutive principles only get empirical meaning when taken in conjunction, singular principles are always void of empirical significance. However, if, in creating a system of principles which together describe experience, one principle has been chosen, the arbitrariness of the remainder needs to be equivalent with both our experience and this one principle and thus is thereby restricted. With this argument Reichenbach claimed that Schlick could not defend a conventionalism which assumed a complete arbitrariness of principles. A final letter by Schlick, however, waived this criticism. Reichenbach was cerainly correct and although the father of conventionalism, Poincaré, had perhaps not emphasised it, he had definitely been aware of it.[148] Schlick himself too, had taken the truth of Reichenbach's argument for granted and claimed that it did not stand in the way of application of the term 'convention'.

The thus reached consensus between Schlick and Reichenbach led Schlick to conclude that

[143] Schlick to Reichenbach, 25 September 1920. Quoted from (Hentschel, 1990, 519-520); Schlick to Reichenbach, 26 November 1920. Quoted from (Coffa, 1991, 201-202)

[144] The same remark was made by Schlick in (Schlick, 1979, 333).

[145] (Coffa, 1991, 201-202)

[146] See page 66

[147] "Aber ob man meine Ideeenrichtung dann noch Kantianismus nennen soll, ist nur noch eine terminologische Frage, und wohl besser zu verneinen." Reichenbach to Schlick 19 November 1920. Quoted from (Hentschel, 1990, 522)

[148] Schlick to Reichenbach, 11 December 1920. Quoted from (Howard, 1994, 62)

> [T]here is really no profound difference of opinion, as an elucidation of our positions by correspondence has subsequently disclosed.[149]

What followed, was Schlick's hoped-for rapprochement of the spirits of himself and Reichenbach. In the continuation of the 1920's and the 1930's, Reichenbach further and more explicitly departed from his neo-Kantian roots as the emphasis on the a priori's property of constitution was replaced by its conventional character. Although differences would remain between both philosophers, they were often grouped under the same 'logical empiricist' banner.

Although Cassirer's and Reichenbach's theories had shown great similarities, the former remained a dedicated critical philosopher and the latter, by the end of the 1920's, had become 'the most eloquent proponent of relativistic conventionalism'.[150] The minor difference between their ideas, addressed above, turned out to be decisive. Cassirer had held that besides a relative a priori, there are absolute a priori principles as well. Reichenbach, on the other hand, believed we only require relative a priori principles. In the previous section we have seen that it was exactly the invariant and regulative character of Cassirer's absolute a priori which had prevented it from being understood as a convention. Since Reichenbach's a priori lacked these properties, they indeed, as Schlick had claimed, could much more easily be understood as conventions. In the first chapter, we have seen that the ultimate ground for Cassirer's absolute a priori was an assurance of the objectivity of science and its progress. Reichenbach, as is clear from a text from 1924, attempted to give this assurance in a different way. Instead of absolute a priori principles, he claimed scientists relied on theory-neutral and immediately given elements of experience. All theories had to comply with such observational elements and hence they could serve as the foundation of all science.[151] Obviously, the same argument was not available for Cassirer since he had rejected the possibility of such elements from the outset. Accepting theory-neutral elements was the result of not recognizing that in all intuition concepts have already been applied.[152] Along with Cohen and Natorp, Cassirer claimed that such an interpretation of Kant was too psychological and would make our notion of knowledge too subjective. Indeed, this is Cassirer's best articulated point of criticism of Reichenbach's first interpretation on the theories of relativity.[153]

Schlick's adaptation

Not only Reichenbach changed his views due to the discussion that arose after the debates on the theories of relativity. In the early 1920's Schlick too modified his theories. In order to successfully counter neo-Kantianism, minor, albeit

[149] (Schlick, 1979, 333)
[150] (Coffa, 1991, 203)
[151] (Reichenbach, 1924)
[152] See section 1.2.4.
[153] "[...] der Kantischen Lehre, die Sie meiner Ansicht nach zu psychologisch nehmen [...]" Cassirer to Reichenbach, 7 July 1920, document 285 on the DVD accompanying (Cassirer, 2009)

consequential, adjustments were made to the epistemological theory outlined above. The changes become most visible when the 1918 edition of *Allgemeine Erkenntnislehre*, discussed above, is compared with the second edition of this book, published in 1925.

The second edition contained new sections in which ideas on the distinction between definitions and knowledge claims were advanced that differed from those expressed in 1918. Recall that for the Schlick of 1918 this distinction was relative and dependent on the stage of science from which it was considered. In 1925 Schlick abandoned this idea of relativity and instead emphasised the absoluteness of the distinction. In section 11, only to be found in the second edition, Schlick wrote:

> Every judgment we make is either definitional or cognitive. This distinction, as we noted above, has only a relative significance in the conceptual or "ideal" sciences. It emerges all the more sharply, however, in the empirical or "real" sciences. In these sciences it has a fundamental importance; and a prime task of epistemology is to make use of this distinction in order to clarify the kinds of validity possessed by various judgements.[154]

The difference with the first edition of the book, where the relativity of the distinction was claimed for both the natural as well as the 'ideal' sciences, is evident.[155]

Don Howard has clarified how this change was used in order to counter neo-Kantianism.[156] A distinction which is relative, means that no proposition can be considered purely empirical and that therefore empirical content is assigned only to the totality of empirical and analytical propositions. Duhem had shown how this holism leads to a multiplicity of possibilities of theories that are compatible with our experience. The neo-Kantians, Cassirer among them had happily agreed with Duhem and used this underdetermination to argue that there was a need for a third group of propositions. Indeed, the synthetic a priori was argued to be able to fulfil this role and solve the underdetermination by rejecting theories that did not correspond with their content.

By strictly separating definitions and empirical propositions, Schlick undermined the need for synthetic a priori principles. Once Schlick would choose his definitions, the remaining propositions would all be empirical and thus could each be verified or refuted by experience. With the ambiguity gone, the only a priori principles required are the definitions, which clearly are analytical, not synthetic. The strict distinction between empirical propositions and definitions thus was used as an argument against the need for synthetic a priori principles and hence neo-Kantianism. In the 1920's and the 1930's it developed into a central doctrine of logical empiricism. It is crucial to see that the conventionality of Schlick in 1925 no longer concerned the distinction between analytic and synthetic propositions, but was restricted to the choice of the definitional part.

This new conventionalism which was better able to counter the purported purpose of the synthetic a priori, was applied by both Schlick and Reichenbach

[154] (Schlick, 1985, 69)
[155] (Schlick, 1918, 46-47)
[156] (Howard, 1994, 71-73)

and caused them to even further abandon their neo-Kantian roots. For some however, this argument against neo-Kantianism was claimed to be untenable. Quine famously argued against the distinction, but, as will be shown in the next section, Einstein too, considered it untenable.

Demise of neo-Kantianism

It is generally agreed that the new thoughts Schlick and Reichenbach developed in the early 1920's marked both the beginning of the dominance of logical empiricism in the philosophy of science, as well as the end of the reign of neo-Kantianism in German philosophy. Although, as we have seen, during the first few years of the decade large numbers of publications on the theory of relativity from various neo-Kantian points of view appeared, a few years later this stream had dried up. No new Kantian scholars joined the debate with refreshing ideas and some, like Reichenbach, traded their Kantian backgrounds for conventionalism.[157] The role played by Schlick in this transition must not be underestimated. Although his understanding of the theory of relativity has been doubted in modern literature[158], he was praised by the scientific community of his days, including Einstein, who repeatedly declared himself in favour of Schlick's theories.

Schlick's criticism of Cassirer was one of the most crucial battles between neo-Kantianism and logical empiricism. It was the latter group that triumphed. The above has shown however that in doing so, it had relied on false arguments, supporting Ryckman's claim that it was Schlick's status that heavily contributed to the victory. Whilst Schlick and his cohorts established their monopoly on the philosophy of science, they further disassociated themselves from their neo-Kantian roots. Although in this process the seed was sown for most of the criticism that the logical empiricists would receive, most of it was only to be voiced several years later, a time in which Germany's situation was developing into one which did not contribute to the creation of much fruitful soil for debate.

The final convulsions of the persistent neo-Kantians, Cassirer included, received a further blow when the National Socialists seized power in Germany. Representatives of the logical empiricist as well as many neo-Kantians were forced to flee the country due to their Jewish heritage. Cassirer and Reichenbach emigrated in 1933, only a few months after Hitler was appointed *Reichskanzler*. Within a few years others, including Carnap, Hönigswald, Schneider and Winternitz, had left Germany. The adaptation to a foreign academic community did not prove easy for everyone and once abroad they experienced difficulties finding work and gaining the recognition they were accustomed to back home. The authority of the logical empiricists, which had developed in Germany, now strengthened its position as an established philosophical movement.

Among the first to escape the country, Ernst Cassirer and his wife Toni,

[157]The neo-Kantian origin of logical empiricism and many of their most important advocates including Schlick, Reichenbach and Carnap has been emphasised repeatedly. See e.g. (Coffa, 1991) and (Ryckman, 2005).

[158](Ryckman, 2005, 50)

lived in England and Sweden before finally settling in the USA in 1941. Although Cassirer's interest in philosophy of science definitely did not vanish there, *Determinismus und Indeterminismus in der modernen Physik* was written in Göteborg, his focus spread to a wider scope which not only included scientific knowledge, but also religious, ethical and mythical knowledge. The foundations of his philosophy of science would remain those outlined in 1910.

3.4 Einstein

3.4.1 'Philosopher-Scientist'

In 1949 Paul Arthur Schilpp, editor of the series "Library of Living Philosophers" published two volumes in this series. The first was dedicated to Cassirer, who by that time, despite of what the title of the series suggests, was no longer a living philosopher due to heart failure in 1945. The second that year, and seventh in the series was devoted to Einstein. Carrying the subtitle "Philosopher-Scientist", this book aptly captures the fact that Einstein was more than just a capable physicist. As both the developer of the relativity theories and a contributor to the philosophical debate that surrounded these theories, Einstein took an interesting position in the discussion on Cassirer's interpretation on the relativity theories.

Einstein's interest in philosophy developed long before his fame as a scientist. In 1902 Einstein and his friends Maurice Solovine and Conrad Habricht formed the "Olympia Academy". Together they read a number of philosophical texts by Mach, Hume, Spinoza, Poincaré and Mill among others.[159] Einstein's interest in philosophy did not fade when he grew older and despite his scientific career always reached further than philosophy of science. In 1920, the same year Cassirer first approached him, Einstein wrote a poem to express his love for Spinoza[160] and allegedly the portrait of Schopenhauer that hung in between those of Maxwell and Faraday in his study around that time.[161]

At issue here however, are merely Einstein's philosophical views related to the theories of relativity and science in general. From the early 1920's onwards, Einstein expressed these views not only in his correspondences with a variety of philosophers,[162] but also in lectures and published articles. Many of these do not lack clear language on the views Einstein had on others who interpreted his theories. They therefore are valuable in the examination of the philosophical position Einstein took and how this compared to that of Cassirer.

Einstein's philosophical remarks must not be seen as those of a scientist who merely enjoyed the wandering of his thoughts in his spare time, but as those of a man who proved to be able both to develop some of the most revolutionary

[159] (Einstein, 1989, XXIV-XXV)
[160] *Zur Spinozas Ethik* in Einstein Archive, reel 33-264.
[161] (Howard, 1997, 87)
[162] Besides Cassirer, these included Mach, Schlick, Reichenbach, Carnap, Vaihinger, Petzold, and others. For a complete list of Einstein's correspondentsin the late 1910's and early 1920's see (Einstein, 2009).

scientific theories and to mingle in serious philosophical discussions. Schilpp's book on Einstein is one of the sixteen that he edited, with other volumes devoted to the likes of Moore, Russell, Jaspers, Carnap and Popper, who all were seen as leading contemporary philosophers. The authors of the articles found in the book, Reichenbach and Schneider among them, expressed their high regard of Einstein's philosophical thoughts. Although Cassirer did not contribute to the book, he too valued Einstein for more than just his scientific talents. Indeed, in response to Einstein's commentary on the manuscript for *Zur Einsteinschen Relativitätstheorie*, Cassirer wrote that the comments on the epistemological conclusions had been 'extremely beneficial' to him and that they lead him to revising his text on many points.[163]

3.4.2 Einstein and Cassirer

It is difficult to determine when Cassirer and Einstein first heard of each other, but Natorp might be the common acquaintance introducing both men to each other. The last pages of his *Die logische Grundslagen der exakten Wissenschaften*, footnote(Natorp, 1910) published in 1910, concerned the results of the special theory of relativity and its consequences for the Kantian notion of space. Most probably, Cassirer, who studied under Natorp in Marburg until 1902, remained in contact with him ever since and moreover had shown an interest in modern physics, read this book and hence got acquainted with Einstein's theories. Cassirer first contacted Einstein in may 1920 with the request of commenting on an early version of *Zur Einsteinschen Relativitätstheorie*. One may wonder if Einstein would have paid much attention to the text if he had not already heard of Cassirer.[164] One reason to believe that the name of Cassirer was not new to Einstein's ears, is again based on Natorp. Einstein had briefly corresponded with Natorp and met up with him twice in 1919.[165] Although the subject of their contact was political rather than philosophical, it is unlikely that, if Einstein had not already heard of Cassirer before, Natorp did not indirectly introduce Einstein to one of his most notable students, who by then had become one of Germany's leading philosophers himself.[166]

The first direct contact between Einstein and Cassirer appears to have been the latter's request to review a manuscript of the text that would later be published as *Zur Einsteinschen Relativitätstheorie*.[167] Cassirer sent this letter on May 10 1920, Einstein obliged and responded the next month. The previous

[163] "Was Ihre Kritik an einzelnen erkenntnistheoretischen Folgerungen, die ich aus ihr gezogen, betrifft, so brauche ich nicht zu sagen, daß sie mir gleichfalls ausserordentlich förderlich gewesen ist und mich veranlasst hat, das Ganze meiner darstellung nochmals eingehend durchzusehen und in vielen Punkte zu revidieren." (Cassirer, 2009, 47)

[164] Indeed, Einstein believed that too many philosophers contacted him during this period. (Hentschel, 1990, 552)

[165] Both the correspondence and their meeting concerned Natorp's request to sign the "Appeal of the German intellect for socialism". (Einstein, 2004, 59-60)

[166] See (Krois, 1987) and Chapter 2 for more information on Cassirer's status as a philosopher in the 1910's.

[167] In a letter to Schlick sent on 19 April 1920, Einstein noted that Cassirer too praised Schlick's book, but misspelled his name as 'Kassierer'.

year Einstein had complained to Schlick about the neo-Kantian attempts to reconcile Kant with relativity[168] and it appears that initially he considered Cassirer's manuscript as nothing more than another one of these attempts. A week after receiving the manuscript, he wrote his wife that he did not enjoy reading it.[169] His opinion must have changed whilst reading the book. Two weeks later, in his response to Cassirer, he wrote that he admired the text and had read it with great interest.[170] That these were not just soothing words,[171] is shown by his response to Vaihinger's request to publish an article by Einstein. Since he did not have time to write an article himself, he hinted at the possibility to contact Cassirer, who had written a 'very interesting essay on the theory of relativity.'[172]

Einstein had commented on the manuscript and besides praising it had criticised the neo-Kantian approach.

> I can understand your idealistic way of thinking about space and time, and I even believe that one can thus achieve a consistent point of view.[...] I acknowledge that one must approach the experiences with some sort of conceptual functions, in order for science to be possible; but I do not believe that we are placed under any constraint in the choice of these functions by virtue of the nature of our intellect.[173]

Einstein agreed that 'some sort of conceptual functions' are necessary in doing science. He rejected however, without claiming that Cassirer's position was untenable', the neo-Kantian idea that human reason supplied the distinction between which of these functions are applicable to nature and which are not. In the following pages we will see that, in reviewing other neo-Kantian texts, Einstein repeated this argument. On 16 June 1920 Cassirer wrote Einstein again, thanking him for his response and noting that his remarks had been useful. The revisions he made after receiving Einstein's response included a stronger emphasis on the empirical origins of the relativity theories, but he had not changed the character of their non-empirical origins, disputed by Einstein.

Einstein's claim that the principles of physics were 'not under any constraint', was not countered explicitly by Cassirer in a response. Nevertheless, Cassirer's defence was available in *Substanzbegriff und Funktionsbegriff* already. For Cassirer, even the relative a priori principles, whose particular contents were not considered to be necessary for experience in general, were guided by the regulative and absolute principles. As shown in chapter 1, Cassirer believed

[168] Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)

[169] "Ich habe mich sehr it den Kindern Ehrenfest angefreundet und spiele viel mit ihnen. Auch muss ich Cassirers Manuskript studieren, das weniger interessant ist." A. Einstein to E. Einstein, 19 May 1920, (Einstein, 2006, 264-265)

[170] "Ich habe Ihre Abhandlung mit sehr viel Interesse gründlich studiert und vor allem bewundert mit welche Sicherheit Sie die Relativitäts-Theorie dem Geiste nach beherrschen." Einstein to Cassirer, 5 June 1920, (Einstein, 2006, 293)

[171] Ryckman seems to suggest this was the case. (Ryckman, 2005, 47)

[172] "Für die Abfassung eines besonderen Aufsatzes fehlt es mir völlig an Zeit. Ich möchte Ihnen aber mitteilen, dass Herr Prof. Cassirer in Hamburg einen sehr interessanten Aufsatz über die Relativitäts-Theorie vom philosophischen Standpunkt geschrieben hat, der noch unveröffentlichtt ist." Einstein to Vaihinger, 3 June 1920, (Einstein, 2006, 289)

[173] Einstein to Cassirer, 5 June 1920. Quoted from(Howard, 1994, 54-55)

that these principles were required to guarantee the objectivity of science. The entirely unrestrained principles which Einstein advocated, thus would by Cassirer be understood as a potential danger for the unity of science, the idea that physicists today and those a century ago are essentially trying to understand the same world.

After this conversation, Cassirer and Einstein exchanged at least another ten letters.[174] In the previous chapter two of these have been mentioned. In July 1920 Cassirer invited Einstein to his home when he heard that the latter was going to come to Hamburg to lecture on his theories.[175] It is unprobable that Einstein made use of the offer to stay at Cassirer's house. From the memories of Toni Cassirer, Ernst's wife,[176] we learn that the house was used in 1921 as the agreed upon location to ask Einstein question that remained after a lecture on his theories which he had given earlier that day, but no mention of Einstein staying over is given.[177] The two met up in person again several times, also when both had emigrated from Germany and lived in England and the United States.[178] Cassirerhad always been full of admiration for Einstein, considering him to be a 'genius of the order of Newton, perhaps even greater'.[179]

Cassirer's sympathy for Einstein after the rally in Berlin's Philharmonic Hall in August 1920 has been the topic of a letter that has been mentioned in the previous chapter. The letter reveals a kinship between Einstein and Cassirer that went further than the devotion to relativity theory of one of the latter's books. Both Einstein and Cassirer were Jewish intellectuals who directly felt the influence of rising anti-Semitism in Germany. It is not unlikely that by reading the article on the rally against the relativity theory in the *Berliner Tageblatt*, Cassirer was reminded of an event that occurred four years earlier.[180] Indeed, the anti-Semitism, on which many of the arguments heard during the rally were based, and the distinction between *Deutsche Physik* and *Jüdische Physik* which would later be made by Philip Lenard,[181] showed great correspondence to Bruno Bauch's criticism of Cohen. In 1916 Bauch, a neo-Kantian professor in Jena and editor of *Kant-Studien* directly opposed Cohen's philosophy on the grounds

[174] A total of ten letters between Cassirer and Einstein are found in (Cassirer, 2009). The original letters are kept at the Hebrew University of Jerusalem and Yale University. In all likelihood the actual number of exchanged letters is higher than ten. No response, for instance, is known to the letter written by Einstein to Cassirer on 6 March 1926, in which he requested Cassirer for his help with Professor Koige who is looking for a job at a university. Einstein explicitly asked Cassirer to return the attached reference list, and it is unlikely that Cassirer never responded. Both Cassirer and Einstein escaped Germany in 1933 and it is possible that letters were left behind or even destroyed.

[175] (Cassirer, 2009, 48)

[176] To all the similarities to be drawn between Cassirer and Einstein we may add the peculiar fact that both men married their cousins.

[177] (Cassirer, 2003, 135)

[178] Toni Cassirer recalled seeing Einstein in London in 1933 and noted that Ernst Cassirer visited him in Princeton in 1945. (Cassirer, 2003, 136, 238)

[179] (Cassirer, 2003, 136)

[180] "Ich erfahre soeben erst, aus Ihrem Aufsatz im "Berliner Tageblatt", die Angriffe, denen Sie und Ihre Theorie in letzter Zeit ausgesetzt gewesen sind." Cassirer to Einstein, 28 August 1920, (Cassirer, 2009, 49)

[181] (Lenard, 1936)

that as a Jew, Cohen was essentially unable to give a correct representation of Kant's philosophy.[182] Born in a Jewish family himself and being a former student of Cohen, Cassirer sent a response, rejecting Bauch's argument, to *Kant-Studien*.[183] Bauch resigned as an editor of the journal, but Cassirer's letter was not published.[184] In a letter to Natorp, Cassirer expressed his hope that the political tendency then prevalent would not spread to philosophy and science.[185] The only correspondence revealing Einstein's and Cassirer's common Jewish heritage is a brief exchange in which they discussed an administrative issue at the University of Jerusalem in 1934.[186]

As with an early version of his treatise on relativity theory, Cassirer sent Einstein a version of *Determinismus und Indeterminismus in der modernen Physik*, his work on quantum mechanical problems for philosophy, in 1937. Most of the remaining letters not discussed here, concerned the recommendation of students who desire a place at the universities where Einstein and Cassirer were working. Philosophical discussion is hard to be found in most of these letters. An exception is Einstein's response to Cassirer's request to write a recommendation for Edgar Wind. Einstein obliged, and continued to comment on a lecture given by Cassirer. He remarked that he was highly impressed by the lecture and that it reminded him of a childhood joke. Nevertheless, he ends with a critical note on the Kantian notion of the a priori.[187] There are no existing documents in which Cassirer directly responded to any of Einstein's critical notes. What has remained are expressions of admiration of Cassirer for Einstein and a remarkable combination of Einstein's appraisal of Cassirer's qualities as a philosopher one the one hand and the disagreement with some of his fundamental philosophical ideas one the other.

3.4.3 Einstein Against Neo-Kantianism

Einstein's remarks on Cassirer's use of the Kantian a priori were not exceptional. Although, allegedly Kant was Einstein's favourite philosopher during his teenage years,[188] this appreciation started to fade in the 1910's. A decade later Einstein had become a fierce critic of the synthetic a priori. One of the first clues that reveal his opposition to Kant is a letter to his colleague Paul Ehrenfest in which he wrote. "Hume really made a powerful impact on me. Compared to him, Kant seems to me truly weak."[189]

Although this might be Einstein's first critical note on Kant, it certainly

[182] (Bauch, 1916)
[183] (Cassirer, 2008)
[184] (Cassirer, 2009, XXVI)
[185] Cassirer to Natorp on 26 November 1916. (Cassirer, 2009, 28)
[186] (Cassirer, 2009, 135-136)
[187] "Ihr fein geschliffener Vortrag hat mir grossen Eindruck gemacht." [...] "Sind denn die Begriffe Kuh und Esel nicht auch a priori? Man sieht doch nicht einen Esel sondern hat nur gewisse Gesichtswahrnehmungen, die man in eine Eselisidee a priori einordnet ..... sollte der Kantianer sagen." Einstein to Cassirer, undated, (Cassirer, 2009, 63)
[188] (Talmey, 1932, 164)
[189] Einstein to Ehrenfest, 24 October 1916. Quoted from (Howard, 1994, 50)

was not his last. The frequency of similar reflections began to intensify when neo-Kantian interpretations on the general theory of relativity began to appear. In his correspondences as well as in published articles, criticism of Kant, as well as of his contemporary advocates, was not uncommon. It must be noted that Einstein never declared the neo-Kantian position entirely impossible. Instead, he merely called it 'unnatural' and rejected it on the basis of his philosophical instinct. Nevertheless, he repeatedly argued that the incompatibility of his own physical theories and Kant's synthetic a priori was a sign that the latter had to be rejected. Not only in his response to Cassirer's interpretation of relativity but also in his reviews of Elsbach's and Winternitz's works, he was generally positive but each time made two critical remarks. The first point was that he agreed with the neo-Kantians that constitutive principles are required for the possibility of science. The second was his strong disagreement with the neo-Kantian claim that the contents of these principles are given by human reason. From the conclusion of the review of Winternitz's book it moreover becomes clear that Einstein believed that the constitutive principles had to be understood as conventions.

> Winternitz behauptet also mit Kant, daß Wissenschaft sei eine gedankliche Konstruktion auf Grund von Prinzipien a priori. Daß das Gebäude unserer Wissenschaft auf Prinzipien ruht und ruhen muß, die nicht selbst aus der Erfahrung stammen, das wird wohl ohne Zweifel anerkannt werden. Bei mir fängt der Zweifel erst an, wenn nach der Dignität jener Prinzipien gefragt wird, bezw. nach ihrer Unersetzlichkeit. *Sind jene Prinzipien wenigstens zum Teilso beschaffen, daß Wissenschaft mit ihrer Äbanderung unverträglich ist, oder sind sie insgesamt bloße Konventionen wie das Ordnungsprinzip der Wörter in einem Lexikon? W. neigt zu der ersteren Auffassung, ich zu der letzteren.*[190]

It is clear that Einstein's judgements were unequivocal; the Kantian a priori was irreconcilable with the relativity theories and the debate on the interpretations of these theories had been influenced by Kant only in a negative way.[191] Moreover, a great similarity btween Einstein's arguments and those of Schlick and Reichenbach is easily recognised. The previous section has shown that they made three important points that overlap with the above arguments by Einstein. They too maintained that the neo-Kantians were correct in claiming that there must be constitutive elements in knowledge, but wrong in asserting that these need to be synthetic a priori principles. Instead, it was suggested, they must be understood as conventions.[192]

Considering the above, it is hardly surprising that Einstein wholeheartedly welcomed the books and articles published by Schlick and Reichenbach in the early 1920's. Schlick had been the first to question the early neo-Kantian interpretations of the special theory of relativity of Natorp and Hönigswald. Already then, Einstein had appeared glad to read the criticism.

---

[190] (Einstein, 1924b, 21-22), my emphasis.

[191] "Nach meiner Ansicht hat Kant die Entwickelung ungünstig beeinflußt." (Einstein, 1924a, 1691)

[192] Einstein already used the term 'convention' in a letter to Max Born in 1918. Note that Schlick had not yet spoken of conventions then. (Howard, 1994, 50)

> It is among the best that have so far been written about relativity. From the philosophical side, nothing at all appears to have been written on the subject that is nearly so clear.[193]

When Schlick continued his opposition to similar, neo-Kantian interpretations of the general theory of relativity which appeared in large numbers around 1920, Einstein was equally enthusiastic. In 1919, Einstein turned to Schlick to both complain about the neo-Kantian attempts to 'cram the general theory of relativity in the Kantian system'[194] and to show his admiration of Schlick's alternative philosophy.

> Tomorrow I travel to Holland for two weeks and am taking along your *Erkenntnistheorie* as my only reading. This as proof of how gladly I read around in it.[195]

We have seen in the previous section that in 1921, when Schlick published his critical review of Cassirer's *Zur Einsteinschen Relativitätstheorie*, attacking its neo-Kantian argument, Einstein, again, had read it with great delight and called it 'clever and true'.[196] In the late 1910's and early 1920's, Einstein and Schlick developed a colloquial relation in which the exchange of philosophical ideas stood central.

That, despite his own viewpoints, Kantianism was so deeply grounded in philosophical thought and that the standpoint of the revisionist neo-Kantians was not so easily refuted, bothered Einstein. Cassirer in particular, whose theories Einstein considered a prime example of a tenable though 'unnatural' Kantianism,[197] was a hindrance in the battle against what he believed to be mistaken philosophical consequences of his theories. Einstein's opinion on Cassirer was twofold. He respected him for his great understanding of the theories and his eloquent writing, but meanwhile objected to his Kantian thought which only gained strength by these qualities. Schlick's memories in a letter to Reichenbach clearly illustrate this ambivalent attitude as well as the congeniality of the relation between Cassirer, Einstein, Schlick and Reichenbach.

> Gestern war ich eine Stunde mit Cassirer zusammen [...] Mann kann sich gut mit ihm vertsändigen. Einstein [...] nannte ihn (Cassirer) freilich ein "Volksverführer", weil er durch seinen guten Stil die Leute zum Kantianismus überrede.[198]

3.4.4 Einstein's Later Views

Although Einstein thus initially had joined Schlick's resistance against neo-Kantianism, during the 1930's he strongly disassociated himself from the empirical circles that formed around Schlick and Reichenbach. In the previous

[193] Einstein to Schlick, 14 December 1915. Quoted from (Howard, 1994, 51)
[194] Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)
[195] Einstein to Schlick, 17 October 1919, (Einstein, 2004, 204)
[196] Einstein to Schlick, 10 August 1920. Quoted from (Coffa, 1991, 189).
[197] In (Einstein, 1924a, 1688) Einstein refers exclusively to Cassirer as a viable interpretation of Kant in the light of relativity theory.
[198] Schlick to Reichenbach, June 1924. Quoted from (Hentschel, 1990, 519)

section the change that these philosophers made in order to successfully cope with neo-Kantian arguments, was described. Einstein did not follow blindly and in great contrast to his responses to Schlick's earlier texts, he spoke out against the newer empirical publications. Along with the similarity of their views, the friendly contact disappeared and in the years leading up to Schlick's assassination in 1936, Einstein had criticised his new works and hardly communicated with the philosopher he had held so close a decade and a half earlier.

In 1921, in one of his first epistemological treatises, Einstein had written about 'purely axiomatic geometry' and 'practical geometry'. The former was understood as merely a structurally coherent geometrical system, whereas the latter was such a system that moreover had been coordinated to the empirical world by the use of physical laws.[199] The difference between these two systems, as Einstein explicitly mentioned, boiled down to the exact same distinction Schlick had made between definitions and empirical judgements. However, whereas Schlick subsequently had come to believe a stronger emphasis on this distinction was necessary in order to refute neo-Kantianism, Einstein moved in the opposite direction and emphasised the relativity of this distinction. The strongest of Einstein's statements on the issue is found in a passage taken from *Physik und Realität*, which appeared in 1936.

> Which of the statements are to be regarded as definitions and which as laws of nature depends largely upon the chosen representation; in general it is only necessary to carry through such a distinction when one wants to investigate to what extent the whole conceptual system under consideration really possesses content from a physical standpoint.[200]

The idea expressed here by Einstein is the same as that which Schlick had maintained in the first edition of his *Allgemeine Erkenntnislehre* He argued that only entire theories have empirical content, when any one of its claims are taken in isolation, it loses its reference to experience. Considered individually, no judgement can therefore be said to be purely empirical and consequently the distinction is an artificial one which is relative and dependent on 'the chosen representation'. Ironically, this text appeared in the year that Schlick died, but were he still alive he would have strongly disagreed. He had abandoned this relativity more than a decade earlier.

Schlick had derived from a strict distinction the possibility to verify empirical claims in isolation. By claiming that only complete theories refer to experience, Einstein had refuted this possibility at the outset.[201] The developed empiricism which Schlcik had defended in the late 1920's thus was one that Einstein no longer supported. In 1931, when he had read an early version of Schlick's treatise on quantum mechanics, he did not receive it with the same enthusiasm he had welcomed Schlick's writings a decade earlier. He expressed his discontent with clear dismissive language that reminds one of his rejections of neo-Kantianism in the early 1920's.

[199] (Einstein, 1921)
[200] (Einstein, 1936)
[201] Howard argues that, by making this argument, Einstein relied on lessons he had drawn from Duhem. (**?**)

> From a general point of view, your presentation does not correspond to my way of viewing things, inasmuch as I find your whole conception, so to speak, too positivistic.[202]

After Schlick's unexpected death, Reichenbach continued to represent the logical empiricist view on modern physics and became the subject of Einstein's criticism. When Reichenbach contributed to Schilpp's volume on Einstein's philosophy, Einstein's response was nothing less than critical. Again, he rejected the positivist claim that isolated propositions can have empirical meaning and be verified by experience individually. In his response, published in the same book, Einstein cited a fictitious dialogue between Reichenbach and a non-positivist (most probably representing Einstein himself). The conclusion of this conversation was that the former's adherence to the claim of individual verifiability was not only untenable but that moreover such a positivist view revealed an undue disdain of Kant's philosophy.

> Do you not have to admit that, in your sense of the word, no "meaning" can be attributed to the individual concepts and assertions of a physical theory at all, and to the entire system only insofar as it makes what is given in experience "intelligible?" [...] It seems to me, moreover, that you have not at all done justice to the really significant philosophical achievement of Kant. From Hume Kant had learned that there are concepts (as, for example, that of causal connection), which play a dominating role in our thinking, and which, nevertheless, can not be deduced by means of a logical process from the empirically given.[203]

Recalling Einstein's fierce language about Kant when the philosophical debate on relativity was most intense, his later statements appear remarkable. To which extent Einstein changed his mind on epistemological issues is up for debate, but it is a fact that the appraisal of Kant in 1936 stood in stark contrast with the claim that the Prussian philosopher only influenced the debate negatively, made twelve years earlier. The next subsection discusses the possibility of Cassirer's influence on Einstein during these twelve years. First however, it must be noticed that Einstein never became a fully committed Kantian. Indeed, the proclaimed relativity of the distinction between definitions and laws of nature was one not only used against Schlick, but with equal force against neo-Kantians.[204] The neo-Kantian adherence to synthetic a priori principles, as apodictically valid principles, equally made use of the assumption that there are judgements which intrinsically differ from others. Although Schlick had deemed it necessary to emphasise the difference between the empirical and the a priori to counter neo-Kantianism, Einstein used their relativity to reject both the empiricist claim that there are purely empirical judgements, and the neo-Kantian claim that there are purely a priori judgements.

[202] Einstein to Schlick, 28 November 1931
[203] (Einstein, 1957, 678)
[204] See for instance (Einstein, 1924a, 1689)

3.4.5 Einstein's Appraisal of Kant

Einstein's neo-Kantianism

Despite the above claim, Mara Beller has argued that in all phases of Einstein's life, and in the later years in particular, there were strong neo-Kantian elements in his thought.[205] As Beller has correctly shown, the greatest similarities between Einstein and Kant are based on Einstein's belief that the formation of physical theory was guided by a need for 'simplicity' and 'unity of nature'. Einstein, in particular in the years that followed after the development of general relativity, had shown a firm belief that simplicity was of indispensable value when judging a physical theory. The perseverance in attempting to develop a unified field theory, the striving to unite the gravitational and the electromagnetic field in a single description, was often defended by the emphasis of the simplicity which such a theory would possess. When David Bohm expressed his worries that the development of such a theory was feasible due to the large difference in scale between the gravitational and the electromagnetic force, Einstein responded by remarking that the position of a single field would be a simpler representation of nature than the assumption of two distinctive fields:

> I believe that these [structure] laws are *logically simple* and that faith in this logical simplicity is our best guide, in the sense that it suffices to start from relatively little empirical knowledge. If nature is not arranged in a way corresponding to this belief, then there is no hope at all to arrive at a deeper understanding.[206]

It is the second sentence of this citation in particular, that reveals that Einstein considered simplicity to be a methodological demand, much more than a subjective preference. Without the presupposition of simplicity, he deemed understanding hopeless. Einstein's arguments for the evaluation of physical theories on the basis of 'unity of nature' often run along similar lines. Beller concludes that "the unity of the theoretical domain served in Einstein's case as an explicit criterion of truth of scientific theory, quite along Kantian lines."[207]

Indeed, as a non-empirical, non-analytic, demand that moreover seemed to be guided by reason, it displayed great correspondence with the Kantian a priori. More particularly we may recognize similarities between Einstein's demand of simplicity and Cassirer's absolute a priori. Not only do they share a purely regulative character, Cassirer too had proposed both simplicity as well as unity of nature as absolute a priori demands.[208] In his correspondence with Schlick he had even proposed the unity of nature as the sole true a priori principle.[209] Despite any of these similarities, Einstein's philosophical views, even in the later periods, in which his Kantianism is claimed to be the strongest, Cassirer's and Einstein's views did not fully overlap.

There was a second difference between Cassirer and Einstein however. As will be shown below, Einstein did not follow the transcendental method.

[205] (Beller, 2000)
[206] Einstein to Bohm, 24 November 1954. Quoted from (van Dongen, 2010, 182)
[207] (Beller, 2000, 92)
[208] (Cassirer, 1923, 260)
[209] Cassirer to Schlick, 23 October 1920, (Cassirer, 2009, 50-51)

No transcendental method

Recent study has made clear that Einstein's claim that his profession as a physicist made him, an epistemological opportunist[210] was no exaggeration and that there was a mutual dependence between his philosophy and the physical theories he was working on.[211] Einstein's repeated emphasis on the simplicity in physical theories not only served as a guide to the axioms of unified field theory, but also served as a justification for his efforts.

Indeed, these efforts were criticised from within the scientific community, often by those who did not see the virtues of it and argued that efforts in quantum physics proved to be more fertile. Lacking support from a large part of his colleagues as well as theoretical success, philosophical argumentation became an important element in Einstein's defence of his attempts to bring together the gravitational and electromagnetic fields. Ryckman has argued that this form of psychological rationalisation fed Einstein's increasing appraisal of Kant.[212]

Kantian theory indeed could supply the philosophical arguments to defend the task of the unification of two fields that, according to all other theories, were essentially distinctive. The efforts to develop such a unification would clearly not be in vain if they were guided by a principle that was fundamental to the notion of science. The idea of the unity of nature further buttressed this argument. With unity and simplicity as the methodological demands, the aim of a unified field theory followed directly for Einstein.[213] Moreover, the structure of Einstein's scientific method, based on the Kantian thought that the real is '*aufgegeben*', could be used against to argue against the usefulness of his colleagues who themselves were developing quantum physical theories. Their approach, with a stronger foundation in experiments, suggested that it was possible to develop theories without the position of 'freely' developed principles. The quantum physicists, in his view, were pretending that theory was deducible from experience, that they were *gegeben*, rather than *aufgegeben*. Einstein's appraisal for Kant's theory hence not only served as a guiding principle, but was also opportunistically chosen in order to justify his own physical efforts.[214]

The transcendental method dictates that science must be observed and its transcendental principles deduced. The problem for Einstein was to objectively observe science. Based (on a selective memory of)[215] the successful methods applied in the development of general relativity, Einstein had concluded that simplicity and unity were methods of successful science. Since he considered his own relativity theory a prime example of successful science, and dismissed quantum physical theories from the outset, his view on the notion of successful science was evidently restricted. Einstein, by looking for a justification of his

[210] (Einstein, 1957, 684)
[211] (van Dongen, 2010)
[212] (Ryckman, 2014a)
[213] Note that this consequence is not a necessary one. Simplicity is a concept that can be interpreted in different ways and indeed some quantum physicists rejected the idea that quantum mechanics did not rely on a method of simplicity. (van Dongen, 2010, 183)
[214] (Ryckman, 2014a, 385)
[215] (van Dongen, 2010, 32-35)

own theories, rather than analysing the entirety of modern science in search of the underlying principles, did not apply the transcendental method as it was practised and valued by Cassirer

3.4.6 Conjectures on Cassirer's Influence

If Einstein used philosophical arguments largely to justify his own practices, we may still wonder if he found a helping hand in Cassirer's arguments. Indeed, it has been suggested that the change in Einstein's philosophical remarks from the 1910's until the 1930's was influenced or partly caused by his contact with Cassirer.[216] Throughout this period Einstein came to criticise positivism and accentuate the value of Kant whose philosophy also was the cornerstone of many of Cassirer's works including his treatise on the relativity theories. Whether or not there was a relation between this change and Einstein's contact with Cassirer is a question that is not simple to answer. Although there are a number of indications that support this thesis, there also are arguments that make it very doubtful. Some arguments that either support or dispute the thesis, mainly based on the observations made in the above sections, will be discussed here.

It has been shown that throughout the 1920's and 1930's Einstein and Cassirer remained in contact. The published collections of their correspondences contain letters from June 1920 until March 1937.[217] It is very plausible that these collections are incomplete and that more letters have been exchanged of which the contents are unknown. Thus when Einstein's views started to diverge from those of Schlick, Cassirer, who himself had stood opposite Schlick in the relativity debate, may have functioned as a recipient who happily stimulated Einstein's arguments. Second, Einstein never claimed that Cassirer's views were untenable. Even in the early 1920's when it was sometimes hard to distinguish Einstein's opinions from those of Schlick, he considered Cassirer's neo-Kantianism 'unnatural', but explicitly recognised its tenability.[218] Thus, in opposition to his opinion of Sellien, for instance, Einstein never held Cassirer for a 'foolish' neo-Kantian and Cassirer's neo-Kantian arguments were not straightforwardly rejected by Einstein. Indeed, Einstein considered Cassirer to be one of the most competent defenders of the neo-Kantian position who also had proved his capability of understanding contemporary physical theories well. He had recognised Cassirer's eloquent way of speaking and hence there is a high probability that if we may speak of the influence of any neo-Kantian on the development of Einstein's thought, it is of that by Cassirer.

Despite these two arguments that hint at a possible influence of Cassirer on Einstein's thought, one must be careful not to draw conclusions too quickly. First of all Einstein never reached full agreement with Cassirer on the character of non-empirical concepts. He never accepted the a priori principles as unalterably 'conditioned by the nature of the understanding', an idea which Cassirer

[216] The possibility is mentioned by (Ferrari, 2003, 135) and (Katsumori, 1992, 583)
[217] All known written exchanges between Cassirer and Einstein are found in (Cassirer, 2009). The original letters are kept at the Hebrew University of Jerusalem and Yale University.
[218] See for instance (Einstein, 1924a, 1688) and (Cassirer, 2009, 46)

still maintained in 1936 when interpreting quantum mechanics.[219] If Cassirer thus influenced Einstein's philosophy, it did not completely convince him. Second, Einstein never referred to Cassirer as a source for his philosophical thought. Since he explicitly mentioned Hume, Mach and Schlick as inspirations in earlier articles, there is reason to believe Einstein would have mentioned Cassirer as such in his later articles if he felt he owed him any credits. In his rebuttal of Reichenbach's philosophy in 1949, where he blamed him for a lack of recognition of Kant, Einstein does not once mention Cassirer's name, nor, for that matter, that of any other neo-Kantians. Third, there is no evidence that the correspondence between Einstein and Cassirer lead to any change in the former's philosophical views. Although it is true that their was contact between them in the 1920's as well as in the 1930's, the number of letters, does not seem to have been very high. Moreover, the topics of their letters often did not include any exchange of well-structured thoughts on Kant or neo-Kantianism. If Cassirer influenced Einstein's thought, the influence thus must have come primarily from the reading and re-reading of Cassirer's books, an assumption that seems unlikely.

[219] (Cassirer, 1966)

Conclusion

On the basis of three chapters, Cassirer's philosophical ideas on Einstein's theories of relativity has been evaluated. An insight in Cassirer's philosophy and the arguments on which it was based has been developed. In chapter 1, the Marburg School doctrines of the transcendental method and the rejection of intuition were shown to have functioned as the foundation of his criticism of the substance-concept. The reconsideration of the notion of the a priori as having both a relative and constitutive element, as well as an absolute and regulative part. These pre-relativistic re-assessments of the concept and the a priori proved fertile in the defence of critical philosophy in the light of the theories of relativity. The proclaimed development of the concept meant that an understanding of space as a non-substantive concept was not in conflict with the relativity of space. Even more so the development from classical physics, first to the special theory of relativity and subsequently to the general theory, could be understood as a confirmation of the idea that scientists are led by the idea that their concepts should be functionalised. The distinction between the relative and the absolute a priori moreover meant that the application of a non-Euclidean geometry by Einstein did not conflict with critical philosophy. Two of the alleged problems were therefore solved by epistemological ideas developed in *Substanzbegriff and Funktionsbegriff* whose origin can be traced back to the Marburgian doctrines of the transcendental method and the rejection of intuition. Cassirer's interpretation of the theories of relativity, was therefore fundamentally based in deeply rooted in the revisionist version of Kantian philosophy as advocated by the Marburg School.

Cassirer's revisionist neo-Kantianism and his Marburg School background in their turn serve as a solid basis to explain his position as one of the participants in the philosophical debate on the theories of relativity. Due to his willingness to revise particular theses of the original Kantian doctrine, most importantly the ideas on intuition and the a priori, Cassirer revealed a closer kinship with the early logical positivists than with many other neo-Kantian contemporaries. Although Schlick was the strongest philosophical voice to disapprove of Cassirer, his fundamental outlooks on philosophy and science proved to be much closer to those of Cassirer than those of conservative neo-Kantians such as Schneider and Sellien. Both Schlick and Cassirer, and Reichenbach shared this opinion too, considered philosophy and science not to be unrelated practices. For Cassirer it was the transcendental method that led him to consider philosophy a form

of science analysis rather than science criticism. Schlick and Reichenbach did not believe it was possible to derive from such analysis any synthetic a priori principles, but nevertheless agreed with the fundamental idea that philosophers should not doubt, let alone criticise, the methods of the scientist. On a personal level too, Cassirer showed more affinity with Reichenbach, even when the latter would entirely repudiate his earlier held Kantian beliefs.

Due to these similarities as well as the strong deviations one may question the extent to which Cassirer's views may be considered neo-Kantian at all. A well-written article has evaluated this question already and places the answer in the thesis that 'methodologically speaking, Cassirer always remained a neo-Kantian'[220] Indeed, as we have seen above, the Kantian transcendental method stood at the heart of his evaluation of the theories of relativity too. Many other neo-Kantians saw the value of Kant in other parts of the original doctrine. From later reflections on these ideas Cassirer revealed that he believed them to be further away from his own than the of Schlick.

> [M]any of the theories ascribed to neo-Kantianism in the contemporary philosophical literature are not only foreign, but diametrically opposed to my own views.[221]

Such quotes make it even more remarkable, and more painful, that Schlick's criticism did not take into account Cassirer's revisions of the traditional doctrine. Schlick had claimed to have refuted Cassirer's arguments but explicitly had relied on an understanding of neo-Kantianism that could not include Cassirer's theories. Discussion of Schlick's article has made even clearer that Schlick had not understood Cassirer's notion of the absolute a priori as a regulative ideal in this correct sense. That Cassirer never fully responded to the article is remarkable. Nevertheless, it may be placed in the larger picture of Cassirer's character as a modest and conflict-avoiding person. Recently, Edward Skidelsky has, albeit without any argumentation, argued that "[I]t was not in Cassirer's nature to emphasize disagreement." [222] Indeed, the evaluation of Cassirer's position in the relativity debate confirms this image by a number of examples.

Cassirer's arguments reveal little criticism of other philosophers. Cassirer explicitly presented his work on the theory of relativity as a possible interpretation of relativity.[223] Cassirer either wished to stimulate the discussion in which a large variety of opinions were to be voiced, but more likely he did not believe the differences to be of much value.

Time and again, when others developed a view that they believed conflicted with Cassirer's views, Cassirer would correct them and express the opinion that

[220](Ferrari, 2009, 307)
[221](Cassirer, 1993, 200-201); Quoted from (Ferrari, 2009, 307)
[222](Skidelsky, 2009, 48)
[223](Cassirer, 1923, 349) Rather than clarifying differences of opinion with others, he believed it was necessary to have an open discussion in which each was treated with respect. This implied not only that he rejected the criticism of Einstein's physics at the rally in Berlin's philharmonic hall because it was based on non-scientific arguments, he even supported the publication of philosophical articles that were far from in agreement with his own ideas.[224], and Schlick (Cassirer to Witkop, 16,17 December 1920, documents 300 and 301 on the DVD accompanying (Cassirer, 2009))

there hardly existed any difference. In chapter 3 we have seen that Cassirer argued that his views hardly differed from the early comments on relativity by Reichenbach. More remarkable however, is that he explicitly mentioned the similarity between his own views and those of Schlick in the late 1920's, as well as claiming that the disagreements with Petzold were reducible to terminological issues. [225]

Other observations that fit this image are the lack of Cassirer's interference of the debate in which neo-Kantians accused each other of having used non-Kantain arguments. Whereas both Schneider and Reichenbach were using this argument to personally attack each other's theories,[226] one of the strongest opinions of Cassirer on the issue is the one found above. An expression that does not infer any qualitative judgements on any theory, let alone focus itself on any of his colleagues in particular. Finally, Cassirer's desire to unite philosophers and physicists in the debate on relativity, and the corresponding reformulation of the Natorpian argument about the distinction between ideal and empirical notions of space and time,[227] appears, in the light of the above, another attempt to avoid disagreement.

Cassirer's reluctance of posing disagreement where there need not to be any, may well have meant an undervaluation of his philosophy. As mentioned above, Cassirer never systematically refuted Schlick's argumentation as found in *Kritizistische oder empiristiche Deutung der neuen Physik?*. Instead he later argued that the greatest relation between his views and those of Schlick were their agreements, not their differences.[228] Not only was this opinion published in 1927, when, as Coffa has argued, the debate between Schlick and the neo-Kantians had been decided in favour of the former, it also failed to point out that Schlick's refutation of his philosophy was based on a crucial misinterpretation.

It is only in modern literature that Cassirer's philosophy has received the appreciation it deserves.[229] The appraisal Cassirer initially received for having well represented the theory of relativity and it physical aspects[230], soon disappeared behind the shadow of Schlick's criticism. Nevertheless, with the above description of Cassirer's character in mind, we may reassess his revisionist neo-Kantianism. Where other neo-Kantians publicly refuted the theory of relativity for its failure to correspond to Kantian theory or argued that philosophers and scientists had no common ground to have discussions on, Cassirer's initial response was that their was no reason to believe that there were fundamental disagreements between Kant's and Einstein's theories. Rather, he believed that, when properly considered, the two were two sides of the same coin. It is this idea, as much as the philosophical underpinning by the transcendental

[225] "Was die Differenz mit Petzold betrifft, so bin ich ganz Ihrer Ansicht und glaube auch, dass die Enistein'sche Bemerkung wesentlich darauf beruht, dass er nicht sachlich, sondern terminologisch von mir abweicht." Cassirer to Reichenbach, 27 April 1922, document 330 on the DVD accommpanying (Cassirer, 2009)

[226] See 65

[227] See section 2.3

[228] (Krois, 1987, 117)

[229] Notable examples are (Ryckman, 2005), (Friedman, 2000) and (Howard, 1994)

[230] See section 3.2.3

method and the rejection of intuitions that made it possible for Cassirer to write a text that is now considered to be 'the best of the neo-Kantian reactions to relativity'.[231]

[231] (Howard, 1994, 53)

Bibliography

Ariew, R. (1984). The Duhem thesis. *The British Journal for the Philosophy of Science*, *35*(4), 313–325.

Bauch, B. (1911). *Studien zur Philosophie der exakten Wissenschaften*. Heidelberg: C. Winter.

Bauch, B. (1916). Leserbrief. *Der Panther*, *4*(6), 742–746.

Beller, M. (2000). Kant's impact on einstein's thought. In D. R. Howard, & J. J. Stachel (Eds.) *Einstein - The fomative years 1879 - 1909*. Boston: Birkhäuser.

Bollert, K. (1923). Die Apriorität von Raum und Zeit in der Relativitätstheorie. *Zeitschrift für Physik*, *15*(1), 126–152.

Born, M. (1922). *Die Relativitaätstheorie Einsteins und ihre physikalischen Grundlagen*. No. 3 in Naturwissenschaftliche Monographien und Lehrbücher. Berlin: Verlag von Julius Springer.

Carnap, R. (1922). *Der Raum. Ein Beitrag zur Wissenschaftslehre*. Berlin: Reuther & Richard.

Cassirer, E. (1902). *Leibniz' System in seinen wissenschaftlichen Grundlagen*. Marburg: Elwert.

Cassirer, E. (1906). *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit. Erster Band*. Berlin: Bruno Cassirer.

Cassirer, E. (1910). *Substanzbegriff und Funktionsbegriff: Untersuchungen über die Grundfragen der Erkenntniskritik*. Berlin: Bruno Cassirer.

Cassirer, E. (1913). Erkenntnistheorie nebst den Grenzfragen der Logik. *Jahrbüchcher der Philosophie*, *1*, 1–59.

Cassirer, E. (1914). Die Grundprobleme der Kantischen Methodik und ihr Verhältnis zur nachkantischen Spekulation. *Die Geisteswissenschaften*, *1*(29), 784–787.

Cassirer, E. (1918). *Kants Leben und Lehre*. Berlin: Bruno Cassirer.

Cassirer, E. (1920a). *Das Erkenntnisproblem in der Philosophie und Wissenschaft der neueren Zeit*. Berlin: Bruno Cassirer.

Cassirer, E. (1920b). Hermann Cohen. *Korrespondenzblatt des Vereins zur Gründung und Erhaltung einer Akademie des Judentums*, *1*, 1–10.

Cassirer, E. (1920c). Philosophische Probleme der Relativitätstheorie. *Die Neue Rundschau*, *21*, 1337–1357.

Cassirer, E. (1921). *Zur Einsteinschen Relativitätstheorie*. Berlin: Bruno Cassirer.

Cassirer, E. (1923). *Substance and Function and Einstein's Theory of Relativity*. Chicago: Open Court Publishing.

Cassirer, E. (1924). Substance and function and einstein's theory of relativity (book review). *The monist : an international quarterly journal of general philosophical inquiry*, (p. 478).

Cassirer, E. (1927). Erkenntnistheorie nebst den Grenzfragen der Logik und Denkpsychologie. *Jahrbüchcher der Philosophie*, *3*, 31–92.

Cassirer, E. (1939). Was ist "Subjektivismus"? *Theoria*, *5*(2), 111–140.

Cassirer, E. (1966). *Determinism and indeterminism in modern physics: historical and systematic studies of the problem of causality*. Yale University Press.

Cassirer, E. (1993). *Erkenntnis, Begriff, Kultur*. Hamburg: Meiner Verlag.

Cassirer, E. (2008). Zum Begriff der Nation. Eine Erwidderung auf den Aufsatz von Bruno Bauch. In J. M. Krois, & C. Möckel (Eds.) *Zu Philosophie und Politik*, no. 9 in Nachgelassene Manuskripte und Texte, (pp. 29–60). Hamburg: Meiner.

Cassirer, E. (2009). *Ausgewählter wissenschaftlicher Briefwechsel*. No. 18 in Nachgelassene Manuskripte und Texte. Hamburg: Meiner.

Cassirer, E. (2010). *Vorlesungen und Vorträge zu philosophischen Problemen der Wissenschaft 1907-1945*. No. 8 in Nachgelassene Manuskripte und Texte. Hamburg: Meiner.

Cassirer, T. (2003). *Mein Leben mit Ernst Cassirer*. Hamburg: Meiner Verlag.

Coffa, J. A. (1991). *The semantic tradition from Kant to Carnap: to the Vienna station*. Cambridge: Cambridge University Press.

Cohen, H. (1871). *Kants Theorie der Erfahrung*. Dümmler.

Cohen, H. (1910). *Kants Begründung der Ethik: nebst ihren Anwendungen auf Recht, Religion und Geschichte*. Berlin: B. Cassirer.

Cohen, H. (1914). *Logik der reinen Erkenntnis*. Berlin: B. Cassirer.

Dingler, H. (1919). *Die Grundlagen der Physik. Synthetische Prinzipien der mathematischen Naturphilosophie*. Berlin: de Gruyter.

Drill, R. (1919). Ordnung und Chaos. Ein Beitrag zum Gesetz der Erhaltung der Kraft. *Frankfurter Zeitung und Handelsblatt*, (p. 64).

Earman, J., & Norton, J. (1987). What price spacetime substantivalism? The hole story. *British Journal for the Philosophy of Science*, (p. 515–525).

Edgar, S. (2008). Paul Natorp and the emergence of anti-psychologism in the nineteenth century. *Studies in History and Philosophy of Science Part A*, *39*(1), 54–65.

Einstein, A. (1905). Zur Elektrodynamik bewegter Körper. *Annalen der Physik*, *322*(10), 891–921.

Einstein, A. (1916). Ernst Mach. *Physikalische Zeitschrift*, *17*, 101–104.

Einstein, A. (1921). *Geometrie und Erfahrung*. Berlin: Springer.

Einstein, A. (1923). The foundation of the general theory of relativity. In H. A. Lorentz, H. Minkowski, & A. J. W. Sommerfeld (Eds.) *The principle of relativity: a collection of original memoirs on the special and general theory of relativity*, (pp. 111–164). New York: Methuen.

Einstein, A. (1924a). Review of Elsbach (1924). *Deutsche Literaturzeitung*, *45*, 1688–1689.

Einstein, A. (1924b). Review of Winternitz (1923). *Deutsche Literaturzeitung*, *45*(1), 20–22.

Einstein, A. (1936). Physik und Realität. *Journal of the Franklin Institute*, *221*, 313–347.

Einstein, A. (1952). The foundation of the general theory of relativity. In *The Principle of Relativity.*, vol. 1, (p. 109–164). New York: Dover publication.

Einstein, A. (1957). Reply to criticisms. In P. A. Schilpp (Ed.) *Albert Einstein: Philosopher-Scientist*, (pp. 663–688). New York: Tudor Publishing Company.

Einstein, A. (1989). *The Swiss Years: Writings, 1900- 1909*, vol. 2 of *The collected papers of Albert Einstein*. Princeton, N.J.: Princeton University Press.

Einstein, A. (1998). *The Berlin Years: Correspondence, 1914 - 1918*. No. 8 in The collected papers of Albert Einstein. Princeton, NJ: Princeton University Press.

Einstein, A. (2004). *The Berlin Years: Correspondence, January 1919 - April 1920*. No. 9 in The collected papers of Albert Einstein. Princeton, NJ: Princeton University Press.

Einstein, A. (2006). *The Berlin Years: Correspondence, May-December 1920, and Supplementary Correspondence 1909-1920*. No. 10 in The collected papers of Albert Einstein. Princeton, NJ: Princeton University Press.

Einstein, A. (2009). *Cumulative Index, Bibliography, List of Correspondence, Chronology, and Errata to Volumes 1-10*. No. 11 in The collected papers of Albert Einstein. Princeton, NJ: Princeton University Press.

Elsbach, A. C. (1924). *Kant und Einstein: Untersuchungen über das Verhältnis der modernen Erkenntnistheorie zur Relativitätstheorie*. Berlin: de Gruyter.

Euclid (1956). *The Thirteen Books of the Elements*, vol. 1. New York: Dover publications.

Ferrari, M. (2003). *Ernst Cassirer: Stationen einer philosophischen Biographie*. No. 11 in Cassirer-Forschungen. Hamburg: Meiner Verlag.

Ferrari, M. (2009). Is Cassirer a neo-Kantian methodologically speaking? In *Neo-Kantianism in Contemporary Philosophy*. Indiana University Press.

Freudenthal, G. (1996). Pluralism or relativism? *Science in Context*, *9*(2), 151–162.

Friedman, M. (1990). Kant on concepts and intuitions in the mathematical sciences. *Synthese*, *84*(2), 213–257.

Friedman, M. (2000). *A parting of ways: Carnap, Cassirer, and Heidegger*. Chicago: Open Court Publishing.

Friedman, M. (2001). *Dynamics of reason*. CSLI Publications Stanford.

Gardner, S. (1999). *Routledge philosophy guidebook to Kant and the critique of pure reason*. Routledge philosophy guidebooks. London: Routledge.

Gawronsky, D. (1949). Ernst cassirer: His life and his work. In P. A. Schilpp (Ed.) *The philosophy of Ernst Cassirer*, no. 6 in The library of living philosophers, (pp. 1–37). New York: Tudor.

Hartmann, E. (1924). Relativitätsliteratur der Jahre 1921–1923. *Philosophisches Jahrbuch*, *37*, 273–282, 368–379.

Heis, J. (2007). *The Fact of Modern Mathematics: Geometry, Logic, And Concept Formation In Kant And Cassirer*. Doctoral dissertation, University of Pittsburgh.

Heis, J. (2013). Ernst Cassirer, Kurt Lewin, and Hans Reichenbach. In N. Milkov, & V. Peckhaus (Eds.) *The Berlin Group and the Philosophy of Logical Empiricism*, no. 273 in Boston Studies in the Philosophy and History of Science, (p. 67–94). Dordrecht: Springer.

Heis, J. (forthcoming.a). Ernst Cassirer's Substanzbegriff und Funktionsbegriff. *History of Philosophy of Science*.

Heis, J. (forthcoming.b). Realism, functions, and the a priori: Ernst Cassirer's philosophy of science.

Hentschel, K. (1990). *Interpretationen und Fehlinterpretationen der speziellen und der allgemeinen Relativitätstheorie durch Zeitgenossen Albert Einsteins*. No. 6 in Science networks. Historical studies. Basel: Birkhäuser.

Hönigswald, R. (1912). *Zum Streit über die Grundlagen der Mathematik*. Heidelberg: Winter.

Howard, D. (1994). Einstein, Kant, and the origins of logical empiricism. In W. C. Salmon, & G. Wolters (Eds.) *Logic, Language, and the Structure of Scientific Theories: Proceedings of the Carnap-Reichenbach Centennial, University of Konstanz, 21-24 May 1991*, (pp. 45–105). Pittsburgh: University of Pittsburgh Press.

Howard, D. (1997). A peek behind the veil of Maya. *The Cosmos of Science: Essays of Exploration*.

Itzkoff, S. W. (1971). *Ernst Cassirer: scientific knowledge and the concept of man*. Notre Dame, Indiana: University of Notre Dame Press.

Kant, I. (1900). *Metaphysische Anfangsgründe der Naturwissenschaft*, vol. 1. Leipzig: Pfeffer.

Kant, I. (1911). Von dem ersten Grunde des Unterschiedes der Gegenden im Raume. In G. Reimer (Ed.) *Gesammelte Schriften*, vol. 2, (pp. 375–383). Berlin: Akademie Ausgabe.

Kant, I. (1977). *Prolegomena to any future metaphysics*. No. 27 in Library of liberal arts. Indianapolis: Bobbs-Merrill.

Kant, I. (1998). *Critique of pure reason*. Cambridge University Press.

Katsumori, M. (1992). The theories of relativity and Einstein's philosophical turn. *Studies in History and Philosophy of Science Part A*, *23*(4), 557–592.

Kaufmann, F. (1949). Cassirer's theory of scientifc knowledge. In P. A. Schilpp (Ed.) *The philosophy of Ernst Cassirer*, no. 6 in The library of living philosophers, (pp. 143–213). New York: Tudor.

Kranichfeld, H. (1922). Das Verhältnis der Relativitätstheorie Einsteins zur Kantschen Erkenntnistheorie. *Naturwissenschaftliche Wochenschrift*, *37*, 593–603.

Kraus, O. (1919). Über die Deutung der Relativitätstheorie Einsteins. *Lotos*, *67*, 146 – 152.

Kraus, O. (1920). Fiktion und Hypothese in der Einsteinschen Relativitätstheorie. *Annalen der Philosophie und philosophischen Kritik*, *2*(1), 335–396.

Krois, J. M. (1987). *Cassirer: symbolic forms and history*. New Haven: Yale University Press.

Lecat, M., & Lecat-Pierlot, M. (1924). *Bibliographie de la relativité: suivie d'un appendice sur les déterminants à plus de deux dimensions, le calcul des variations, les séries trigonométriques et l'azéotropisme*. Brussells: Lamertin.

Leibniz, G. W., Clarke, S., & Newton, I. (1956). *The Leibniz-Clarke correspondence: together with extracts from Newton's "Principia" and "Opticks"*. Philosophical classics. Manchester: Manchester University Press.

Lenard, P. (1936). *Deutsche Physik*, vol. 1. Munich: Lehmann.

Mach, E. (1953). *The principles of physical optics: an historical and philosophical treatment*. Dover.

Marck, S. (1949). Am Ausgang des jüngeren Neu-Kantianismus. Ein Gedenkblatt fuür Richard Hönigsrvald und Jonas Cohn. *Archiv für Philosophie: Organ der Internationale Gesellschaft für Philosophie und Sozialwissenschaft*, (3), 144–164.

Marcus, E. (1925). Kant und Einstein. *Frankfurter Zeitung und Handelsblatt*, (p. 1).

Natorp, P. (1887). Über objektive und subjektive Begründung der Erkenntnis. *Philosophische Monatshefte*, *23*, 257–286.

Natorp, P. (1910). *Die logischen Grundlagen der exakten Wissenschaften*. Leipzig Berlin, B. G. Teubner.

Natorp, P. (1912). Kant und die Marburger Schule. *Kant-Studien*, *17*(1-3), 193–221.

Natorp, P. (1981). On the objective and subjective grounding of knowledge. *Journal of the British Society for Phenomenology*, *12*(3), 245–266.

Ollig, H.-L. (1979). *Der Neukantianismus*. Sammlung Metzler. Stuttgart: Metzler.

Palmquist, S. R. (1990). Kant on Euclid: geometry in perspective. *Philosophia Mathematica*, *2*(1/2), 88–113.

Patton, L. (2005). The critical philosophy renewed. *Angelaki*, *10*(1), 109–118.

Petzold, J. (1921). *Das Weltproblem*, vol. XIV of *Wissenschaft und Hypothese*. Leipzig: Teubner, 3 ed.

Pyenson, L. (1987). Relativity in germany. In T. F. Glick (Ed.) *The comparative reception of relativity*, no. 103 in Boston studies in the philosophy of science, (pp. 63–111). Dordrecht: Reidel.

Reichenbach, H. (1920). *Relativitätstheorie und Erkenntnis apriori*. Berlin: Springer.

Reichenbach, H. (1922). Der gegenwärtige Stand der Relativitätsdiskussion. *Logos*, *10*, 316–378.

Reichenbach, H. (1924). *Axiomatik der relativistischen: Raum-Zeit-Lehre*, vol. 72. F. Vieweg & Sohn Akt.-Ges.

Reichenbach, H. (1958). *The philosophy of space & time*. No. 443 in Dover books on science. New York: Dover.

Reichenbach, H. (1965). *The theory of relativity and a priori knowledge*. Berkely: University of California Press.

Reichenbach, H. (1978). The present state of the discussion on relativity. In M. Reichenbach, & R. S. Cohen (Eds.) *Hans Reichenbach: Selected Writings 1909 - 1953*, vol. 2, (pp. 3–47). Dordrecht: Reidel.

Reichenbach, H. (2008). *The concept of probability in the mathematical representation of reality*, vol. 3. Open Court Publishing Company.

Ripke-Kühn, L. (1920). *Kant contra Einstein*. Erfurt: Keyserschen Buchhandlung.

Russell, B. (1926). Philosophical consequences of relativity. *Encyclopaedia Britannica*, (pp. 331–332).

Ryckman, T. (2005). *The reign of relativity: philosophy in physics 1915-1925*. New York: Oxford University Press.

Ryckman, T. (2014a). "a believing rationalist": Einstein and "the truly valuable" in kant. In M. Janssen, & C. Lehner (Eds.) *The Cambridge Companion to Einstein*, vol. 1. Cambridge: University Press.

Ryckman, T. A. (2014b). Early philosophical interpretations of general relativity. In E. Zalta (Ed.) *Stanford Encyclopedia of Philosophy*, (Spring 2014 Edition).
URL `http://stanford.library.usyd.edu.au/entries/genrel-early/`

Schlick, M. (1915). Die philosophische Bedeutung des Relativitätsprinzips. *Zeitschrift für Philosophie und philosophische Kritik*, *159*(2), 129–175.

Schlick, M. (1917). Raum und Zeit in der gegenwärtigen Physik. *Naturwissenschaften*, *5*(12), 177–186.

Schlick, M. (1918). *Allgemeine Erkenntnislehre*. No. 1 in Naturwissenschaftliche Monographien und Lehrbücher. Berlin: Julius Springer.

Schlick, M. (1921). Kritizistische oder empiristiche Deutung der neuen Physik? *Kant-Studien*, *26*(1-2), 96–111.

Schlick, M. (1925). *Allgemeine Erkenntnislehre*. No. 1 in Naturwissenschaftliche Monographien und Lehrbücher. Berlin: Julius Springer.

Schlick, M. (1979). Critical or empiricist interpretation of modern physics? *Philosophical Papers*, *1*, 322–334.

Schlick, M. (1985). *General Theory of Knowledge*. Open Court.

Schneider, I. (1921a). *Das Raum-Zeit-Problem bei Kant und Einstein*. Berlin: J. Springer.

Schneider, I. (1921b). Philosophisches über Einsteins Theorie. *Deutsche Allgemeine Zeitung*.

Scholz, H. (1924). Das Vermächtnis der Kantischen Lehre vom Raum und von der Zeit. *Kant-Studien*, *29*, 21–69.

Schultz, J. A. H. (1935). *Das Ich und die Physik*. Leipzig: Meiner.

Sellien, E. (1919). *Die erkenntnistheoretische Bedeutung der Relativitätstheorie*. No. 48 in Kantstudien. Ergänzungshefte. Berlin: Reuther & Richard.

Skidelsky, E. (2009). *Ernst Cassirer: The Last Philosopher of Culture*. Princeton, N.J.: Princeton University Press.

Sklar, L. (1977). *Space, time, and spacetime*. Berkeley: University of California Press.

Talmey, M. (1932). *The relativity theory simplified and the formative period of its inventor*. New York: Falcon Press.

van Dongen, J. (2007). Reactionaries and Einstein's Fame:"German scientists for the preservation of pure science," relativity, and the Bad Nauheim meeting. *Physics in Perspective*, *9*(2), 212–230.

van Dongen, J. (2010). *Einstein's unification*. Cambridge: Cambridge University Press.

von Laue, M. (1920). Gutachten über die Dissertation von Ilse Schneider, 9 July 1920, in archive HUB. Phil. Fak. Nr. 598 (12.10.1920), Bl.121R.

Wenzl, A. (1924). *Das Verhältnis der Einsteinschen Relativitätslehre zur Philosophie der Gegenwart mit besonderer Rücksicht auf die Philosophie des Als-Ob*. No. 9 in Bausteine zu einer Philosophie des "Als-Ob". München: Rösl.

Winternitz, J. (1923). *Relativitätstheorie und Erkenntnislehre*. Leipzig: Teubner.

Wolters, G. (1987). *Mach I, Mach II, Einstein und die Relativitaätstheorie: eine Fälschung und ihre Folgen*. Berlin: De Gruyter.