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556

Matias Slavov

Essays Concerning Hume's Natural Philosophy

JYVÄSKYLÄN YLIOPISTO

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ABSTRACT

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The subject of this essay-based dissertation is Hume's natural philosophy. The dissertation consists of four separate essays and an introduction. These essays do not only treat Hume's views on the topic of natural philosophy, but his views are placed into a broader context of history of philosophy and science, physics in particular. The introductory section outlines the historical context, shows how the individual essays are connected, expounds what kind of research methodology has been used, and encapsulates the research contributions of the essays. The first essay treats Newton's experimentalist methodology in gravity research and its relation to Hume's causal philosophy. It is argued that Hume does not see the relation of cause and effect as being founded on *a priori* reasoning, similar to the way in which Newton criticized non-empirical hypotheses about the causal properties of gravity. Contrary to Hume's rules of causation, the universal law does not include a reference either to contiguity or succession, but Hume accepts it in interpreting the force and the law of gravity instrumentally. The second article considers Newtonian and non-Newtonian elements in Hume more broadly. He is sympathetic to many prominently Newtonian themes in natural philosophy, such as experimentalism, critique of hypotheses, inductive proof, and the critique of Leibnizian principles of sufficient reason and intelligibility. However, Hume is not a Newtonian philosopher in many respects: his conceptions regarding space and time, the vacuum, the specifics of causation, the status of mechanism, and the reality of forces differ markedly from Newton's related conceptions. The third article focuses on Hume's Fork and the proper epistemic status of propositions of mixed mathematics. It is shown that the epistemic status of propositions of mixed mathematics, such as those concerning laws of nature, is that of matters of fact. The reason for this is that the propositions of mixed mathematics are dependent on the Uniformity Principle. The fourth article analyzes Einstein's acknowledgement of Hume regarding special relativity. The views of the scientist and the philosopher are juxtaposed, and it is argued that there are two common points to be found in their writings, namely an empiricist theory of ideas and concepts and a relationist ontology regarding space and time.

Keywords: David Hume, history of philosophy and science, Isaac Newton, causation, experimentalism, laws of nature, Hume's Fork, space and time, Albert Einstein

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As a final remark, the (already published or forthcoming) essays of this dissertation may, and indeed do, contain some minor errors. Retrospectively, I acknowledge and take full responsibility for them. But let me also loosely paraphrase Hume: such philosophical errors are at most ridiculous but not dangerous.

Jyväskylä, July 1, 2016
Matias Slavov

FIGURE

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1 INTRODUCTION

The present work provides an account of David Hume's (1711–1776) natural philosophy in the history of philosophy and science. In the dissertation essays, the relevant factors of Hume's natural philosophy include the topics of causation, experimentalism, laws of nature, reality of forces, his "fork" and mathematics' relation to nature, and the ideas and concepts of space and time. These topics are treated notably in the context of history of physics. The timeline of the essays ranges from the late 17th century Newtonian dynamics to Einstein's special relativity of the early 20th century. The work is interdisciplinary in nature as it explores the interrelations of the history of philosophy and science.

At first sight, composing such a dissertation might appear rather unconventional. I can identify two reasons why this might be so. These reasons are both related to stereotypical, although not entirely false, assumptions of Hume's professional status and the aim of his philosophy.

First, in his own time, Hume was primarily known as a historian and essayist (Brown, Morris, 2014). As a humanist "man of letters," we might think that he lacked a proper mathematical competence to be deeply interested in physical science. Peter Jones (1984, p. 12), for example, argues that Hume lacked any general interest in science, and that his work is altogether free from the scientific conceptions of his day.[1] Second, Hume's skeptical remarks concerning induction and causation can be seen to make a constructive attitude toward empirical science a contradiction in terms. A good example of this can be found in Werner Heisenberg's (1958/2007, p. 58) popular account of the history of philosophy and physics. In his view, Hume developed empiricism "to an extreme skepticism." He boldly claims that Hume "denied induction and causation and thereby arrived at a conclusion which if taken seriously would destroy the basis of all empirical science."

The present work provides a different picture of Hume's place in the history of philosophy and science than the two above-mentioned examples. The worry of Hume's competence in issues related to mathematical physics is cer-

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[1] See James Noxon (1973, p. 112), and also James E. Force's (1987, p. 166–167) comments on Jones' (1984) work.

tainly justified. In all likelihood, he was not able to follow the cutting edge physical science of his day on a detailed level (see De Pierris, 2006, fn. 8, p. 320–321, and Schliesser, 2009, p. 170). However, this does not mean that Hume did not have anything interesting to say about the role of mathematics in science or human knowledge in general. Hume's Fork, his treatment of mixed mathematics and laws of nature, as well as the measurability and predictability of forces and powers indicate his interest in such issues. These views played an important role in the formation of the later philosophy of science, most notably in the formation of logical positivism.[2] Many of Hume's natural philosophical views, as I argue in the actual dissertation essays, were intrinsically related to the scientific conceptions of the early modern era. Furthermore, his philosophy also has a marked and constructive role in philosophy and science after his time. It is no accident that figures such as Charles Darwin and Albert Einstein acknowledged the significance of Hume's philosophy to their works.[3]

It is also true that in Hume's philosophy there is a fundamental "tension," as Peter Millican (2002, p. 108) notes, "between Hume the inductive sceptic, and Hume the apostle of empirical science."[4] But Hume's critical remarks concerning induction (or "transference from past to future," as he wrote himself (T 1.3.12.22; SBN 139)) and causation are not meant to "destroy the basis of all empirical science," as Heisenberg says. Rather, Hume's aim is to show that the information we have on the relation of causation is not founded on *a priori* reasoning or supposedly rational intuition, but on experience (T 1.3.1.1; SBN 69). Hume is thus targeting *a priori* speculative metaphysics and natural theology, or "school metaphysics" and "divinity," which do not "contain any experimental reasoning concerning matter of fact" (EHU 12.34; SBN 165). He does not deny the validity of propositions of inductive empirical science. In fact, the best causal inferences we can make amount to "proofs" in Hume's epistemic categorization of matters of fact. Provable causal relations are justified by relevant past uniform experience.[5] Factual knowledge can be highly probable, even provable, although neither demonstratively certain nor necessary. Hence in this dissertation, Hume's philosophy is interpreted as providing a constructive way of understanding empirical science.

This introductory section has seven main objectives. To expound them, I make use of the following distinction of subsections. Next, in subsection 1.1, I clarify the notion of "natural philosophy" in Hume, and explain the historical context of this concept. In 1.2, I show how the various themes in Hume's natural philosophy that are treated in the dissertation essays are connected. I also

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2 An excellent example of Hume's impact on logical positivism is A. J. Ayer's (1936/2001) *Language, Truth and Logic*. On Hume's role in the history of philosophy of science, see Alexander Rosenberg (1993).

3 For the influence of Hume on Darwin, see Robert J. Richards (2003, p. 95). The connection of Hume and Einstein is the topic of essay **IV** of this dissertation.

4 This tension is also analyzed in detail by Graciela De Pierris (2001).

5 However, justification of factual propositions requires assuming the Uniformity Principle on instinctive, habitual, and customary basis. The Principle itself cannot be justified, neither by demonstration nor by experience. See essay **III** of this dissertation.

argue that it is important to put Hume's arguments into a broader context of history of philosophy and science. In 1.3, I explain the methodology that has been used in the essays, and in 1.4 I articulate my interpretative angle on Hume. 1.5 outlines the essays and their historical backgrounds, and 1.6 sums up the research contributions. In the final subsection, 1.7, I point out some crucial problems that future scholarship on Hume and history of philosophy and science should take into account, as these problems have not been properly solved in the actual dissertation essays. I finish the introduction in 1.7.1 by putting forward a few ideas for the future study of Hume's natural philosophy.

1.1 The Concept of Natural Philosophy in Hume

In naming this dissertation, I wanted to stress Hume's own concept of "natural philosophy." I consider the umbrella term "natural philosophy" (or "philosophy of nature") to be a more accurate depiction than the contemporary notions of "epistemology" or "philosophy of science." I do not claim that the latter contemporary notions are illegitimate. Specific parts of this dissertation are also about epistemology and philosophy of science, as well as about ontology, metaphysics, philosophy of mathematics, and so on. However, there are important reasons to think that the historical term "natural philosophy," which Hume himself widely applies,[6] encapsulates the overall topic of the separate dissertation essays better than "epistemology" or "philosophy of science."

The problem with the label "epistemology," understood in the pre-Quinean sense, is that it presumes a distinction between a philosophical, often normative theory of knowledge and an empirical psychological investigation of the human mind. However, nowhere in Hume does this kind of distinction appear explicitly. He did not use the terms "epistemology" or "psychology" himself. The term "epistemology" was used for the first time by James E. Ferrier in 1854 (Woleński, 2004, p. 3). In the 18th century, what we now call psychology was placed under the label of "moral philosophy."[7] Thus one could say that, to use our contemporary constructs, Hume's philosophical project employs both psychology and epistemology. Hume's theories of perception, memory, imagination, and personal identity in the first book of the *Treatise* could very well be conceived as works of cognitive psychology. In turn, his distinction between "proofs" and "probabilities" in the tenth section of the first *Enquiry* utilizes normative epistemic standards, as Hume recommends that "a wise man" should proportion "his belief to the evidence." In this sense, Hume is not only interested in describing the way human cognition works but also in prescribing epistemic virtues which should be adopted by a reasonable cognizer.

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6 Nearly all of Hume's works mention "natural philosophy," as the name appears in the *Treatise* and its Abstract, in both of the *Enquiries*, in the *Essays*, and in the *History*. It does not appear in the *Dialogues*.

7 In addition to psychology, this "philosophy" can be seen to include, broadly speaking, the proto-forms of history, economics, and sociology.

The problem with the contemporary notion of "philosophy of science," when applied to Hume's natural philosophy and its context, is that by the very definition of the term, it presupposes a categorical distinction between "science" and "philosophy:" "philosophy of science" is philosophizing *about* science. Such categorical distinction cannot be accurately applied to the early modern intellectual world. This would give us a too narrow picture of what the 18th century natural philosophy was about. To explain this, it is useful to refer to Andrew Janiak's (2015, p. 18–19) study on the matter:

> Seventeenth-century philosophers who studied nature investigated such things as planetary motions, the nature of matter, causal relations, and the possibility of a vacuum, but they also discussed many aspects of human beings, including the human psyche or the soul, and also how nature reflects its divine creator.

We may consider, for example, Newton's (1687,1713,1726/1999) *Principia: Mathematical Principles of Natural Philosophy*, which arguably is the major natural philosophical work of the era. It includes aspects that in contemporary language we can understand to be physics, such as an axiomatic system based on mathematical definitions and propositions concerning laws of nature, collection of data, and the application of computational, observational, and experimental techniques. The mathematical-empirical inquiry of the work can be properly labeled as "science," to use our contemporary language. But some parts of the *Principia* can be understood as being closer to what we would call philosophy. Newton's dynamics leans heavily on a philosophical notion of causation, and his argument for absolute space and time, which is intended to give his laws of motion a robust realist status, is clearly a metaphysical-philosophical pursuit. The Introduction, the section of Rules for the Study of Natural Philosophy, and the General Scholium in the second edition of the work include methodological remarks and critical thinking about the foundational epistemological and ontological issues concerning experimentation, induction, explanation, the universality and the reliability of results, mechanism, and intelligibility. These aspects of the *Principia* could be labeled as "philosophy." As the paradigmatic work of natural philosophy does not contain any dichotomous distinction of science and philosophy (or theology, for that matter),[8] it should be concluded that in the early modern world there was no sharp dividing line between the two disciplines, as we might understand the difference today.[9]

Moreover, a terminological confusion may arise when applying the terms "science" and "philosophy" to the early modern works. "Science" (together

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8 As Katherine Brading (2015, p. 14) puts it, physics and philosophy had (and arguably still have) important "overlapping domains of investigation." For a thorough analysis of the status of science and philosophy in Newton, see Janiak (2015, chapter 2). Note that I do not claim that philosophy and science are the same thing. I allow that distinctions can be made between the two. What I object to is that there would a dichotomy, that is, an all-encompassing distinction between them.

9 It should be noted, however, that Newton's work was instrumental to transforming the old natural philosophy into the modern specialized scientific discipline of physics (see Cohen, Smith, 2002, p. 1–4, and Grant, 2007, p. 314–315).

with its Latin, French, and Italian cognates) in the 17th and 18th centuries was usually reserved for knowledge that was capable of demonstration, typically mathematics (Hatfield, 1996, p. 495).[10] In turn, the meaning of the word "philosophy" during that period is reminiscent of the meaning which we give to "science" today. Ephraim Chambers' (1728, p. 803) dictionary understands the word "philosophy" to mean what we at present could just simply call "science," namely the natural sciences (natural philosophy), for which physics is the paradigm,[11] and the human/social/economic/historical sciences (moral philosophy).

In Hume the distinction between what we at present call natural sciences and the human/social sciences is drawn in terms of "natural philosophy" and "the science of human nature," or "science of man." As the title of this dissertation suggests, the focus of my research is on the first term. However, inquiring into Hume's natural philosophy comes with the following caveat.

Hume himself is clear that what he is engaged in is science of man, not natural philosophy. Commenting on the Introduction (4–5; SBN xv) and the Abstract (3; SBN 646) to the *Treatise*, Miren Boehm (2013, p. 5) astutely remarks that to Hume natural philosophy is "in some measure dependent" on the science of human nature. This is "because to do science, scientists *must employ ideas and engage in reasoning*." Boehm identifies this with Hume's logic, that is, his explanation of "the principles and operations of our reasoning faculty, and the nature of our ideas." Hume's logic,[12] according to Boehm, adjudicates "on questions within natural philosophy."[13]

I am partly sympathetic to Boehm's interpretation. The problem is that it is rather one-sided. It would be a false dichotomy to claim that Hume's natural philosophy *either* ensues from his science of man, *or* that it has an entirely independent status. A particularly good example of the falsity of this dichotomy can be found in Hume's treatment of the ideas of space and time. It is true that his logic (that is, his cognitive psychology) confines the application of these ideas within natural philosophy. We do not have impression-based ideas of absolute space and time, since these abstract ideas would ultimately have to be caused by finite simple impressions. Hence Hume cannot subscribe to this crucial aspect of Newton's natural philosophy. However, it would be wrong to say that Hume's position on this issue is altogether free from the natural philosophy of

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10 In the Introduction to the *Treatise* (4; SBN xv), Hume speaks about the sciences of mathematics, natural philosophy, natural religion, logic, morals, criticism, and politics. However, his application of the term "science" becomes much more restricted in the first Book of the work, as it includes only the demonstrable knowledge of algebra and arithmetic, and even (for the most part) excludes geometry (T 1.3.1.5–6; SBN 71).

11 Chambers' (1728, p. 617) definition of natural philosophy explicitly recognizes physics as *the* natural philosophy: "Natural *Philosophy*, that Science which considers the Powers of *Nature*, the Properties of *Natural* Bodies, and their mutual Action on one another; otherwise call'd *Physics*."

12 The meaning of the word "logic" is rather confusing for contemporary readers, because in this context it is synonymous with "an empirical *science of cognition*" (Boehm 2013, p. 5).

13 Other scholarship which largely agrees with Boehm includes Schliesser (2009) and Hazony (2014).

his day. His understanding of space as extension, his critical stance on the vacuum, and his relationist ontology regarding space and time are very similar to René Descartes' and G.W.F. Leibniz's natural philosophical positions. In this sense, Hume can be reasonably interpreted as contributing to both science of man and natural philosophy, although he does not present himself as doing the latter.

Further, it is not clear whether the science of human nature really is epistemically privileged over natural philosophy in Hume. For one thing, Hume is clear that natural philosophy temporally precedes his moral philosophy: "the application of experimental philosophy to moral subjects should come after that to natural at the distance of above a whole century" (T Intro 7; SBN xvi). This indicates that Hume has had to learn from experimentalism in natural philosophy. Importantly, consider also the subtitle of the *Treatise*: "Being an Attempt to Introduce the Experimental Method of Reasoning into Moral Subjects." Here Hume speaks about an "attempt to introduce" the experimental method *from* philosophy of nature *to* moral philosophy. The title of the *Treatise* in its entirety does not assert any privilege to the science of human nature: it asserts that the experimental method of natural philosophy *should be taken* as the method for the science of human nature.[14] These passages, unlike those quoted by Boehm (T Intro 4–5; SBN xv, Abstract 3; SBN 646), do not indicate any hierarchy between natural and moral philosophies but a methodological continuum between the two.

I do not wish to claim that Hume is first and foremost a natural philosopher. To clarify this point, it is useful to compare Hume's views concerning natural philosophy to his metaphysical positions. Hume has traditionally, perhaps due to the influence of Kant and logical positivism, been received as a critic of metaphysics. This traditional reception is definitely partly true. Hume is critical of a considerable part of metaphysics, of "school metaphysics and divinity," as he says himself (EHU 12.34; SBN 165). For example, he rejects the following metaphysical enterprises: the Cartesian philosophy of mind based on the notion of substance in which perceptions inhere, and synchronic personal identity, as well as the Leibnizian principle of sufficient reason, and (perhaps anticipating, as Kant thought in the Introduction to his *Critique of Pure Reason*, B 19−20) the possibility of synthetic *a priori* knowledge. But as in the case of Hume's criticism and his support of parts of natural philosophy, it would be a false dichotomy to say that Hume is *either* a destructive critic of metaphysics *or* a full-blown metaphysician. Donald L. M. Baxter (2008, p. 6) shows that Hume supports several metaphysical doctrines. He thinks, among others, that "only particular things exist," "alteration is contrary to identity," "the conceivable is possible," and that "there is no middle way between existing and not existing." Some of Hume's philosophical positions pertain to metaphysics in the same

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14 Hume possibly even implements natural philosophy into parts of his science of human nature. In his cognitive psychology, he makes a reference to Newtonian attraction (see Schliesser, 2007). In his economics, the study of hydrostatic phenomena is in relation to his account of the flow and circulation of money (see Schabas, 2001, p. 412).

way as some of his positions pertain to natural philosophy. He is not primarily a metaphysician nor a natural philosopher, and he does in many cases criticize the latter disciplines. But an interesting part of his philosophical work engages with the two.

The natural philosophy present in Hume deserves to be seriously studied. Moreover, as I shall establish in this dissertation, his natural philosophy plays a partly constructive role in the subsequent development of science.

1.2 The Various Topics and their Historical Contexts

The central topics in the four dissertation essays are Hume's conception of causation, experimentalism, laws of nature, his position on the reality of forces, the distinction between mathematical and empirical propositions, mathematics' relation to nature, and the ideas and concepts of space and time.

All of the four dissertation essays are individual, original works intended to contribute to specific and well-defined research problems. Still the problems treated in these essays are by no means incongruous with respect to each other. To show this, consider the following pivotal part of Hume's natural philosophy, his conception of laws of nature. This conception hinges on many other important aspects of his philosophy.

Hume's conception of laws is related to his conception of causation, as laws of nature are matters of fact that are founded on the relation of causation. The knowledge we have on the relation of causation is acquired by experience, or, in Hume's language, also by experiments. Both of these conceptions, of laws of nature and of causation, are related to his understanding of the reality of forces. Hume's position on the ontology of forces cannot be understood without his empiricist idea theory, the Copy Principle. In turn, the Copy Principle is the foundation of his philosophy of space and time. Moreover, propositions concerning laws of nature can be expressed in mathematical terms, so to understand Hume's conception of laws, it is necessary to investigate into his conception of propositions. As Hume draws a sharp distinction between the propositions concerning relations of ideas and matters of fact with his "fork," how should we then understand the epistemic status of propositions of mixed mathematics, such as the propositions concerning the law of conservation of momentum, or the laws of Newtonian dynamics? As the propositions of pure mathematics are absolutely necessary, what about the propositions of applied mathematics? Do laws which can be expressed in mathematical terms instantiate necessity, or mere regularity? How does mathematics actually relate to nature? Is the book of nature written in the language of mathematics, or is mathematics just a useful tool for expressing the magnitudes of causes and effects in a precise and predictable manner? All of the above-mentioned questions are tightly connected in Hume's natural philosophy. Hence it is meaningful to compose a single dissertation which deals with such a variety of topics.

This dissertation is still not solely about Hume's natural philosophy. He did not work in an intellectual vacuum, so understanding his natural philosophy requires putting his arguments into a proper historical context. Many elements of Hume's natural philosophy, such as experimentalism, critique of hypotheses, inductive proof, and critique of Leibnizian principles of sufficient reason and intelligibility, are related to Newton's research methodology and to the results of his natural philosophy. Some other themes in Hume's philosophy of nature, including the association of space to extension, critical position concerning the vacuum, and the status of mechanism in causation are rather based on Cartesian natural philosophy. Hume's position on the ontology of forces closely resembles George Berkeley's views. Leibniz's distinction between "truths of reason" and "truths of fact" precedes Hume's Fork, and Leibniz's relationist ontology concerning space and time is very congenial to Hume's position. Hume's application of the term "mixed mathematics" has its history: The term was applied by other early moderns like Francis Bacon and Jean le Rond d'Alembert. In this generally Aristotelian tradition of thinking about mathematics, which strictly distinguishes between pure and applied mathematics, Hume's treatment of mixed mathematics leads to a salient problem about the epistemic status of mixed mathematics and to the question of how mathematics relates to nature.

It is also interesting to note that Hume's natural philosophy has a serious role to play in philosophy and science after his time. While working with his new theory of special relativity, Einstein was given assistance by Hume's empiricist epistemology of ideas and relationist ontology of space and time. This partly helped him to debunk the Newtonian absolute conception of time and space. This evinces that inquiring into post-Humean developments can also help us to contextualize Hume's views better and appreciate their significance.

1.3 Remarks on the Method

The main research method of this dissertation is comparative textual analysis. Essays **I**, **II**, and **IV** are comparative. This means that, although the main focus in these essays is Hume's concept of natural philosophy, his views are compared with other contributions to the history of philosophy and science. The significance of this comparison is to put Hume's natural philosophical views in their proper historical contexts. The textual sources used in the dissertation essays consist of original publications of historical authors, their private correspondence and unpublished manuscripts, as well as contemporary secondary sources.

Essays **I** and **II** focus on the following question: in what way is Newton's natural philosophy at the intellectual background of Hume's philosophy? The experimentalist methodology Newton assumed in the context of gravity research and his critique of hypothesis profoundly shaped early modern British philosophy, including Hume's work. A detailed analysis and interpretation of

Hume's Newtonianism is provided in both of these essays. Essay **IV** concentrates on the following question: what did Einstein find useful in his reading of Hume when formulating his theory of special relativity? I argue that Einstein made use of an empiricist theory of concepts which he learned from Hume (and Mach) in his argument for the relativity of simultaneity, as well as a relationist ontology concerning space and time when formulating his new theory. This critical reflection enabled Einstein to debunk the Newtonian assumption of time (and space) being absolute structures independent of any objects, observers or natural events of the universe. Essay **III** focuses directly on Hume's philosophy, specifically on his conception of mixed mathematics and its relation to his "fork." The historical background of mixed mathematics is also taken into account, and an interpretation of the epistemic status of propositions of mixed mathematics in Hume is provided.

It is important to clarify the notion of "historical context" in this study. When referring to the historical context of a philosophical or a scientific argument, I have in mind the textual environment, rather than the non-textual sociocultural environment. Tad M. Schmaltz (2013, p. 319–320) clarifies this distinction:

> History of philosophy, as a branch of philosophy, focuses primarily on the philosophical context of a particular text, as provided in other texts. In contrast, social history of science, as a branch of history, is concerned primarily with the non-textual environment of most interest to historians. Of course, this is to say neither that philosophical historians of philosophy are uninterested in the social context, nor that social historians of science are uninterested in the philosophical context. It is a matter rather of where the priorities lie: is the philosophical upshot of the text the main point, or is the concern rather with social connections and implications?

My priority in the dissertation is to analyze and interpret "the philosophical upshot of the text" and its context understood in the above-mentioned sense. The context of an argument, in this sense, refers to the surrounding philosophical and scientific works (see also Galison, 2008, p. 113).

I examine the history of philosophy and science from the viewpoint of argument analysis. I am interested in analyzing arguments, the basis of their justification, their background assumptions, and their consistency. I do not evaluate the truthfulness of the conclusions of the arguments that are scrutinized. My research objective is to provide original and consistent interpretations. Importantly, this dissertation is not about vindicating Hume's philosophy. It is a scholarly enterprise of history of philosophy and that of science. The main motivation of this work is to place Hume's arguments into a broader philosophical and scientific framework, and expound his views in a historically sensitive way.

A crucial methodological aspect of this dissertation is the interplay of the history of philosophy and the history of science. As has been established in the subsection 1.1, it is highly problematic to draw a dichotomous distinction between the two. Since the integration of the two disciplines is such an important starting point in my dissertation, I wish to explain in what way the two can be seen to be related to each other.

The historical apposition of philosophy and science can be understood by drawing on Thomas Kuhn's (1962/1996, p. 88) theory of the development of a science: scientists who introduce a new paradigm into a science work extensively in the old pre-paradigmatic science themselves. Introduction of new paradigms, as Kuhn puts it, are "both preceded and accompanied by fundamental philosophical analyses." Kuhn suggests that it is no accident that this happened both in the case of Newtonian physics and relativity (and in the case of quantum mechanics, too). The intellectual background of Newton's work was in the late medieval Aristotelian natural philosophy and then-contemporary Cartesian natural philosophy (Smith, 2008, section 1.2). In giving his arguments, Newton had to explain in detail his methodology and a whole number of philosophical presuppositions that were relevant in assessing the results of his natural philosophy. For example, the debate he engaged in with G. W. Leibniz was not about the details of astronomical data concerning the paths of planets, or even the mathematical model of the inverse-square law; rather, the debate focused on fundamental philosophical issues, such as the metaphysics of forces, causation, and the role of reason and intelligibility in acquisition of knowledge (see Janiak, 2015, p. 24–26). Likewise, when formulating his theory of special relativity, Einstein worked himself in the old pre-paradigmatic ether-based electrodynamics, which assumed that electric fields and space and time are absolute quantities (see Norton, 2014). The introduction of the new paradigm was preceded by extensive reading and discussion of philosophy, not only that of Hume's, but, among others, the philosophies of Ernst Mach, Henri Poincaré, Pierre Duhem, Immanuel Kant, and Richard Avenarius (Stachel, 2002, p. 125). Some of the pervasive assumptions of Newtonian dynamics and ether-based electrodynamics had to be re-evaluated. This required philosophical analysis of concepts, namely epistemic, semantic, and ontic analyses.

1.4 On the Interpretative Angle

The central interpretative quarrels in Hume scholarship that are relevant to this dissertation include two aspects of his philosophy: the Copy Principle, and his conception of causality.

With respect to the Copy Principle, we may distinguish between two interpretation traditions: the so-called old and new Hume interpretations. The old Hume line of interpretation (notably Millican, 2009, p. 647–648) maintains that our thoughts are exclusively confined within our ideas. Simple ideas are copied from their corresponding simple sensory impressions. Impressions are the source of the existence and of the meaning of our ideas. If a term is to be meaningful and non-fictitious, it must be that this term can be employed with an idea which has its origin in and is reducible to an impression. The new Hume interpretation does not accept the aforementioned. It denies that the Copy Principle is a principle of meaning. According to this position (notably Kail, 2007, chapter 2.2.2), it is not necessary to trace ideas back to their impressions in order to as-

certain that they are meaningful. We might be acquainted with some objects, although we are not able to reduce simple ideas to simple impressions.

Regarding causation, it is possible to separate three different interpretations: the traditional interpretation (or the old Hume interpretation),[15] projectivism, and skeptical realism (the new Hume interpretation). Helen Beebee (2006, p. 108) encapsulates the traditional interpretation by introducing a positive and a negative claim:

> The positive claim is that Hume holds that causation in the objects is a matter of temporal priority, contiguity and constant conjunction: our causal talk and thought cannot succeed in describing or referring to any more in the world than these features. The negative claim is that it is illegitimate or incoherent to apply the idea of necessary connection to external events.

The projectivist and the skeptical realist interpretations challenge this traditional interpretation. Projectivism denies the negative claim, while skeptical realism denies the positive.

Based on the dissertation essays, I defend the traditional, old Hume reading. It may be noted that it is unlikely that this interpretative dispute could be definitely solved. There is textual evidence for all of these readings, and it is unclear whether Hume even has a single theory of causation.

In my old Hume interpretation, the Copy Principle (T 1.1.1; SBN 1–2 and EHU 2; SBN 17–22) is taken very seriously: simple ideas are derived from and they can be reduced back to simple impressions.[16] Terms that cannot be annexed to impression-based ideas are "altogether insignificant" (T Abstract 7; SBN 649). Likewise, I interpret causation in Hume to be constant conjunction. It is neither mere projection nor necessary connection. The following line of reasoning in the *Treatise* (T 1.3.14.26-8; SBN 167–9) summarizes my reading of Hume's conception of causality. He starts first by distancing himself from mere projectionism. Then he goes on to deny the view of necessary connection among causally related objects:

> What! the efficacy of causes lie in the determination of the mind! As if causes did not operate entirely independent of the mind, and wou'd not continue their operation, even tho' there was no mind existent to contemplate them, or reason concerning them. Thought may well depend on causes for its operation, but not causes on thought. This is to reverse the order of nature, and make that secondary, which is really primary […] As to what may be said, that the operations of nature are independent of our thought and reasoning, I allow it […] But if we go any farther, and ascribe a power or necessary connexion to these objects; that is what we can never observe in them, but must draw the idea of it from what we feel internally contemplating them.

The way I understand Hume's conception of causality in the context of his natural philosophy is this: he thinks that causation is a matter of discovery of con-

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15 In Don Garrett's (2015b, p. 173) classification of the three interpretations, the traditional interpretation is called "reductionism."

16 Excluding the famous case of the missing shade of blue.

stant conjunctions in nature.[17] Especially in the first *Enquiry*, Hume provides a number of examples where he is explicit about discovery.[18] These examples include the discoveries of the law of conservation of momentum (EHU 4.13; SBN 31), of water causing drowning to non-aquatic beings, and flame causing heat (EHU 4.6; SBN 27), of two pieces of marbles being easily separated by later force, instead of exerting a force in a direct line (EHU 4.7; SBN 28), of gunpowder's explosiveness, and loadstone's attraction (EHU 4.7; SBN 28), of motions produced by colliding billiard balls (EHU 4.9; SBN 29), of objects falling to the ground by the force of gravity (EHU 4.9; SBN 29), and of crystal being a product of very high temperature, and ice of cold temperature (EHU 4.13; SBN 31–32).

But what is discovered in these cases is constant conjunction, not necessary connection. We surely do have an impression of necessary connection, but this is an internal impression of reflection in the mind. Don Garrett (2015a, p. 74) explains this in a way that is congenial to my reading:

> The impression of necessary connection cannot be the sensory perception of something external to the mind and located in the cause and effect; instead it must be something new that arises in the mind itself as the result of the repeated conjunction.

The source of the information we have of the relation of cause and effect is experience, which Hume understands as being observation and memory of constant conjunction among species of objects or events (T 1.3.6.2; SBN 87). The knowledge we have of objects or events is provided by perceptions according to the Copy Principle. Thus factual discourse in natural philosophy is limited to perceptions of objects or events and their constant conjunctions. "School metaphysics" and "divinity" fall outside the scope of perception and experience, so they may be committed to the flames, as they "contain nothing but sophistry and illusion" (EHU 12.34; SBN 165).

1.5 The Essays and their Backgrounds Outlined

The first two of the essays (**I** and **II**) explore the Newtonian background of some of the key elements in Hume's philosophy of nature. Newton's natural philosophy, both its methods and results, shaped early modern and enlightenment philosophies in many ways. To name some figures, John Locke, Émilie du Châtelet, Leibniz, Berkeley, Voltaire, Thomas Reid, and Immanuel Kant were all to some extent involved with the results and methods of Newton's philosophy of nature. Newton's input provoked criticism, support, and even propagandistic awe among his interlocutors and philosophers after him. Particularly

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17 Note that my interpretation concerns exclusively causation in nature, not mental causation. For example, association of ideas in the mind can cause human actions. In this case the causal relations between ideas of the mind are certainly not discoveries in nature.

18 The word "discovery" appears, in different contexts, 71 times in total in the first *Enquiry*.

momentous was his influence over the 18th century Britain. He was considered as a national hero even among people who were not well acquainted with his work in mathematics and natural philosophy (see Fara, 2002, chapter 3). Thus inquiring into the philosophical ramifications of Newton's natural philosophy can help us to understand some of Hume's natural philosophical positions better. However, some cautionary remarks have to be made in connecting the views of Newton and Hume, and in interpreting some of Hume's views as Newtonian.

Nowadays we can compare Newton and Hume in a way that was not possible in the early modern period. Hume did not have access to many of Newton's writings as we do today, since a significant number of them have been published for the first time in the 20th century.[19] Newton scholarship has increased rapidly in the past ten years, so we inevitably have some information of the aspects of Newton's work that Hume could not have known. There is no evidence that Hume read the *Principia* or the *Opticks*. There is evidence that Hume's education involved the study of Newton's work through secondary sources (Stewart, 2005, p. 21; Ducheyne, 2009, p. 78).

Studying Newton's natural philosophical work nevertheless enables us to make interesting interpretations of Hume's conception of natural philosophy. In this respect, especially important is Newton's experimentalist methodology in gravity research and his critique of hypotheses and intelligibility, on which the first dissertation essay (**I**) focuses. This does not imply that all of Hume's positions in natural philosophy are thoroughly Newtonian, as is pointed out in the second dissertation essay (**II**).

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My task in essay **I** is to investigate the similarities between Newton's experimentalism and critique of hypothesis in the context of gravity research, and Hume's conception of causality. I argue that in Hume *a priori* reasoning is not the foundation for identifying the relation of cause and effect. This crucial point is similar to the way Newton criticized non-empirical hypotheses for the causal properties of gravity. Although the support for experimentalism in Newton and Hume does not operate entirely analogously, they both contrast it with hypothesizing, and with the demand of reason and intelligibility. However, there are some caveats that have to be taken into account. Newton's law of universal gravitation is not entirely compatible with Hume's rules by which to judge causes and effects. This is because the law does not include a reference either to contiguity or to temporal priority. I argue that Hume nevertheless lends his support to the law by interpreting the force of gravity instrumentally, since the proposition concerning the law is still a statement of an exceptionless repetition.

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19 John Maynard Keynes purchased Newton's private writings from Cambridge auction in the 1930s. Newton's manuscript "De Gravitatione" was not published until 1960. This indicates that Hume did not have access to many of Newton's texts that Newton scholars today use in their research.

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In essay **II**, I take a more holistic view of Hume's Newtonianism. I coin two interpretation traditions of Hume's Newtonianism: the traditional and the critical interpretation traditions. According to the traditional line of interpretation, of which essay **I** is an example, Hume continued Newton's experimentalism and critique of hypothesis, and implemented Newtonian philosophy into his theories of causation and induction.[20] Against this traditional reading, a critical interpretation tradition has presented many dissident views. The main thesis of the critical reading is that Hume does not rely on Newtonian philosophy when formulating the foundations of his philosophical system. Rather, Hume's positions in natural philosophy are seen to follow from his science of man.

I argue that it is not fruitful to interpret Hume's Newtonianism via any single line of interpretation. Rather, essay **II** proposes that there are both Newtonian and non/anti-Newtonian elements in Hume. The traditional reading is right in emphasizing the constructive connection of Newton's natural philosophy to many of Hume's philosophical positions. Both are experimentalists that are critical concerning hypotheses. Newton's rule 4 for the study of natural philosophy grounds inductive and fallible proof of laws of nature. This is consistent with Hume's classification of Newtonian laws as proofs: In Hume proofs are matters of fact that are supported by past uniform experience but may be revised if future contrary experience so demands. Neither of the two accepts the Leibnizian principles of intelligibility or sufficient reason.

The critical interpretation is also correct on many details, since in many cases the background assumptions of Hume's philosophical system are contrary to Newton's work in natural philosophy. Newton frames his laws of motion by defining space and time in absolute terms, thus arguing for an unobservable theoretical structure to give his laws of motion a robust realist status. Conceiving space and time in this way is at odds with Hume's Copy Principle and his perceptual conception of space and time. Newton refers to space as an empty Boylean vacuum. Although Hume mentions Newtonian philosophy when discussing the existence of a vacuum, he is hesitant about forming a judgment about vacuum. Newton insists on the reality of forces as true causes of motion but Hume provides an instrumentalist interpretation of forces as calculating devices for making predictions. Hume argues that contiguity and temporal succession are rules by which to judge causes and effects. These arguments are in tension with Newton's second law of motion and the law of universal gravitation. Newton refers to God as the final remote cause for proximate causes, whereas Hume is agnostic with respect to final causes. The status of mechanism differs in the two, as Hume's rules of causation tacitly assume a mechanism, whereas Newton's dynamics is not purely mechanical.

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20 See Noxon's (1976, p. 106) comments on Capaldi (1975).

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In the third essay (**III**), I examine Hume's conception of mixed mathematics and its tension with his "fork" (HF). The notion of "mixed mathematics" can be traced back at least as far as Bacon's 1605 work *Of the Proficience and Advancement of Learning*. In this work Bacon presented his tree of knowledge, the model of the branches of human learning (Brown, 1991, p. 81).[21] The intellectual background of the early modern conceptions of mixed mathematics was in the Aristotelian tradition of thinking about the difference between pure and applied mathematics. Douglas M. Jesseph (1993, p. 13) depicts the Aristotelian thinking as follows:

> If the objects of mathematics are abstracted from the contents of the physical world, then we can take pure mathematics to be concerned with fully abstract objects and applied mathematics to treat partial abstractions which retain some of the sensible qualities of material objects.

The idea of mixed or applied mathematics is that it takes its principles from pure mathematics and then applies them to physical reality. As pure mathematics is understood to be absolutely certain,[22] consequently mathematical demonstrations about the natural world would also be absolutely certain. Such treatment of the application of mathematics was apparent already in the works of Euclid and Archimedes.[23] In Hume's time, d'Alembert shared the same kind of conception of mixed mathematics.

The proper epistemic status of propositions of mixed mathematics in Hume's philosophy is problematic. HF divides all propositions of knowledge into two: relations of ideas and matters of fact. These propositions concern different kinds of relations, as the former concerns the relation of intuition and the latter the relation of causation. Intuitive relations, given their relata, are necessary and certain, whereas causal relations are probable and fallible (T 1.3.1; SBN 69). Hence propositions of mixed mathematics seem to be both necessary/certain and probable/fallible. If this were so, HF must be false. What is more, the concept of mixed mathematics enables one to deduce a contingent conclusion from contingent premises with demonstrative certainty.

Essay **III** shows that Hume's conception of mixed mathematics is not an unsolvable mystery. I argue that propositions of mixed mathematics are matters of fact because they are dependent on the Uniformity Principle (UP). It is possible to deduce a contingent conclusion from contingent premises if UP is as-

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21 Sayaka Oki (2013, p. 83) shows that Bacon's view had predecessors, such as Adriaan van Roomen, Rudolf Snellius, and Petrus Ramus. van Roomen explicitly used the notion of "mathematica mixta" in his 1602 work *Universae mathesis idea*.

22 Hume certainly thinks that mathematics is absolutely certain in many cases. For clarification, see subsection 1.7 of this introductory section.

23 See the *Opticks* of Euclid (ca. 300 BC/1945), where Euclid applies only Euclidian geometry to demonstrate optical ratios, and Archimedes' (3rd century BC/1897) the law of the lever in his *On the Equilibrium of Weights*.

sumed but UP itself cannot be deduced. Thus factual propositions that can be formulated mathematically, such as in Hume's own example, the proposition concerning the law of conservation of momentum in EHU 4.13 (SBN 31), have the same certainty than other matters of fact propositions that instantiate exceptionless repetition. Hume labels these matters of fact as proofs. Proofs can be both quantitative and qualitative, but they share the same level of probabilistic certainty as they both are dependent on UP.

In conclusion of essay **III**, I claim that the only difference that quantitative proofs, such as propositions concerning laws of nature, have compared to qualitative proofs is that the former represent the epistemic virtues of precision, predictability, and usefulness. Rather than asserting that nature has a mathematical structure that we are able to intuitively grasp—that the "Book of nature is written in the language of mathematics," to paraphrase the implication of Galileo's famous slogan—Hume thinks that mathematics is just a useful tool for assisting experience in discovery and application of laws of nature.

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The fourth and final essay (**IV**) considers Einstein's acknowledgment of Hume regarding the special theory of relativity (STR). The essay centers on the following question: What did Einstein find helpful in Hume's philosophy when formulating his STR?[24] Einstein retrospectively acknowledged his debt to Hume many times. He did not, however, specify what it was in Hume's philosophy that he found useful to his physics.

Historically, there are many philosophical and physics-related grounds for Einstein's STR. Newton's laws of motion in the *Principia* presupposed absolute space and time,[25] which were criticized by Leibniz and Berkeley already in the early 18th century.[26] At the beginning of the 19th century, Thomas Young's diffraction experiments lended support to the wave theory of light, thus casting doubt to Newton's corpuscular conception (Tretkoff 2015).[27] In the 1860s, James Clerk Maxwell's equations implied that electromagnetic waves travel by the factor of $v_{em} = 1/\sqrt{\varepsilon_0 \mu_0}$, where v_{em} is the velocity of the waves, ε_0 is the vacuum permittivity, and μ_0 is the permeability constant. Friedrich Kohlrausch and Wilhelm Eduard Weber had measured the values for ε_0 and μ_0, so Maxwell (1861–1862/1965a, p. 499–500) was able to compute the velocity of these waves.

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24 Einstein read Hume in the "Olympia Academy" reading group with Conrad Habicht and Maurice Solovine in Bern. The group was formed in 1902 (Howard, 2005, p. 36).

25 See the Scholium to the Definitions of the first Book.

26 See Berkeley (1710/2009, sections 97–98, and 110–117), and Leibniz's (1717, § 4–6) third letter to Samuel Clarke. This type of criticism was also put forward by some of Einstein's contemporaries, such as Mach (1893/1919, p. 229) and Poincaré (1914/1919, p. 93–116).

27 It should be noted, however, that Newton also considered that light is periodic in nature. He pointed out that differences in vibrations result in different colors, and he compared this to "the manner that the Vibrations of the Air, according to their several bignesses, excite sensations to several Sounds" (Whittaker, 1952/2012, p. lxviii–lxix).

The result approximated the measurement of the speed of light in Hippolyte Fizeau's optical experiment, deviating by less than 1.5 per cent. Thus Maxwell deduced that light is an electromagnetic wave. Although he took some precautions with the ether hypothesis, he was inclined to think that light waves require an ethereal medium in which they travel, as he claimed that "we are obliged to admit that the undulations [of light] are those of an aethereal substance" (Maxwell, 1865/1965b, p. 528).[28] The famous Michelson–Morley experiment in 1887 gave disconfirming evidence for any absolute rest frame. But it did not revoke the ether hypothesis; Michelson's and Morley's (1887) original publication of the experiment was still named "On the Relative Motion of the Earth and the Luminiferous Ether."

In his original 1905 publication of STR, "On the Electrodynamics of Moving Bodies," Einstein applied his famous magnet and conductor thought experiment concerning Faraday's law of electromagnetic induction. By this theoretical argument, he showed that Maxwellian-Hertzian electrodynamics, if it presupposes the ether, is inconsistent. The ether hypothesis needed to be set aside. The principle of relativity should be extended to electrodynamics. The quantities of electric field, and those of space and time, were not to be treated as absolutes, but they were to be treated as subject to the Lorentz transformation equations. With this critical argument the two postulates of STR, the invariance principle and the light principle, were reconciled (see Norton, 2010).

Notwithstanding all of the various philosophical and physical influences on STR, Einstein claimed in his 1915 correspondence with Schlick that it was

> Mach, and, even more, Hume, whose Treatise of Human Nature I studied with passion and admiration shortly before discovering the [special] theory of relativity. Very possibly, I wouldn't have come to the solution without those philosophical studies. (Einstein, 1998, p. 220.)

Later, in a letter to Michelle Besso in 1948, he made a similar claim:

> How far (Mach's writings) influenced my own work is, to be honest, not clear to me. In so far as I can be aware, the immediate influence of D. Hume on me was great. I read him with Kondrad Habicht and Solovine in Bern (Speziali, 1972, p. 153).

In essay **IV**, I draw parallels between Hume's philosophy and Einstein's philosophical analysis related to his STR. I argue that there are two common points to be found in their writings, namely an empiricist theory of ideas and concepts, and a relationist ontology regarding space and time. The main thesis of the essay is that these two points are intertwined in Hume and Einstein: the empiricist theory entails that the notions of space and time are intrinsically related to observable physical objects; in turn, ideas and concepts of these objects can be justified and acquired by relevant sensuous impressions. However, I argue that there are also salient differences between the two. In Hume, the ideas of space

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[28] For a more comprehensive account on Maxwell's position on the ether hypothesis, see his "Ether"-entry in the *Encyclopædia Britannica* (1878).

and time are abstract ideas caused by discretely disposed finite points and moments but in Einstein they are physical quantities. What is more, Einstein's conventionalist theory of concepts instantiates a more mitigated form of empiricism than Hume's radically empiricist Copy Principle.

1.6 Research Contributions

The four dissertation essays make four main research contributions. These contributions can be encapsulated as follows:

(1) *An instrumentalist interpretation of the force of gravity and the law of universal gravitation in Hume* (essay **I**)

Essay **I** puts forward an instrumentalist interpretation of Hume on the force of gravity and the law of universal gravitation. While Newton espouses causal realism on gravity (see Janiak, 2007; Kochiras, 2011; Belkind, 2012; Ducheyne, 2012), Hume interprets this force instrumentally. This means that Hume understands the concept of the force of gravity to be a mathematical instrument which enables one to make predictions about the observable outcome of the motion of bodies. This reading contributes to the so-called New Hume, or skeptical realist, debate. I argue against the New Hume reading (i.e., Wright, 1983; Broughton, 1987; Strawson, 1989, 2000; and Kail, 2007, 2011).

According to my interpretation, however, Hume does not deny the existence of forces or powers. His position is rather non-realist: he neither accepts nor denies the existence of entities which go beyond observed constant conjunctions. Although an entity to which the law refers is imperceptible, Hume is able to accept the law of universal gravitation as a law of nature. This is because the law instantiates perfect uniformity, and thus satisfies Hume's rule 4 for causation in the Rules by which to judge of causes and effects in the first Book of the *Treatise*. Nonetheless, Hume cannot maintain that the law of universal gravitation is a complete causal law, since the law is not consistent with Hume's first two rules of causation. Thus Hume's position on the law of universal gravitation and the force of gravity is instrumentalist.

(2) *There are both Newtonian and non-Newtonian elements in Hume* (essay **II**)

For the past 40 years, two distinct lines of interpretation of Hume's Newtonianism have emerged: the traditional line of interpretation (which includes Capaldi, 1975; Force, 1987; Buckle, 2004, 2011; Millican, 2007; De Pierris, 2001, 2006, 2012; Slavov, 2013; Brown and Morris, 2012, 2014), and the critical line of interpretation (which includes Laudan, 1981; Jones, 1984; Schliesser, 2009; Hazony, 2009; Ducheyne, 2009; Barfoot, 2010; and Boehm, 2013). Essay **II** shows that we are not forced to choose just one of these lines of interpretations at the expense of the other. Hume's natural philosophy applies some Newtonian elements,

whereas some of his natural philosophical positions are corollaries of the principles of his science of human nature. Hence essay **II** provides a detailed analysis of both lines of interpretation and adds further arguments that contribute to the permanent debate on Hume's Newtonianism.

(3) *In Hume's account, the epistemic status of propositions of mixed mathematics is that of matters of fact* (essay **III**)

The tension between HF and propositions of mixed mathematics has been a neglected issue in Hume scholarship so far. Antony Flew (1961), Farhang Zabeeh (1973), Claudia Schmidt (2003), and Millican (2003) touch upon the problem briefly, and the only stand-alone article on the topic of Hume's applied mathematics is written by David Sherry (2009). However, Sherry's article does not solve the discrepancy between HF and mixed mathematics.

Essay **III** traces Hume's fork back to the *Treatise's* first Book (T 1.3.1 SBN 69–73), which is the foundation of Hume's theory of relations. This connection has not been investigated previously in Hume scholarship. It is, then, a contribution which illustrates the main difference between propositions concerning relations of ideas and matters of fact: these propositions concern different kinds of relations. Thus HF is a dichotomous distinction among propositions of knowledge. Propositions of mixed mathematics are matters of fact because they are dependent on UP: they presuppose that future is conformable to the past. This indicates that they are non-necessary, fallible, and *a posteriori* factual propositions, unlike the propositions of pure mathematics.

(4) *A novel interpretation of Einstein's acknowledgement of Hume regarding special relativity: empiricism and relationism are intertwined* (essay **IV**)

Although Mach's influence on Einstein's science has been carefully reviewed (i.e. Holton, 1968, 1992; Zahar, 1977; Feyerabend, 1980, 1984; Hentschel, 1985; Barbour, 2007; Wolters, 2012; Berman, 2012), Einstein's acknowledgement of Hume has been properly researched previously only by Stachel (2002) and Norton (2010). Stachel has argued that Hume's relationism on space and time was most congenial to Einstein. Norton has claimed that Einstein inherited an empiricist theory of concepts from Hume (and Mach), which he then realized in his argument for the relativity of simultaneity.

Essay **IV** argues that these two points, relationism about space and time and empiricism about ideas and concepts, are intertwined in Hume and Einstein. These two matters are not separate but tightly connected in the two. This crucial point has not been recognized before in the literature assessing the relation between Hume and Einstein. Relationism entails that there is no absolute structure of space and time, but that the notions of space and time refer to physical objects; in turn, the information we have of these objects is provided empirically. Inquiring into Hume's theory of perception thus increases our insight of the connection of Hume and Einstein. Essay **IV** is also helpful for understand-

ing the philosophical background assumptions related to the concepts of space and time in Einstein's STR.

1.7 Problems for Future Research

In the end of his *Opticks*, Newton (1704/2012, p. 516) submitted a list of unresolved natural philosophical problems that he thought required further research. Rather modestly he tells us that he wishes to "conclude with proposing only some queries, in order to a further search to be made by others." For my part, let me also conclude this introductory section by explicating some of the basic problems in Hume's philosophy that are relevant to this dissertation. The explication of these problems sheds new light on the basic interpretative difficulties of his views.

In the course of writing the essays, I have come across three remarkably hard-pressing problems that arise when reading Hume's philosophy in a critical way. These are (1) causal interpretation of laws of nature, (2) the relationship between HF and skepticism with regard to reason, and (3) the relationship of radical empiricism to a relationist ontology regarding space and time. The first problem concerns essay **I** (and in part essays **II** and **III**), the second problem concerns essay **III**, and the third problem concerns essay **IV**. I feel that I have not been able to solve these problems properly in the essays, and that these problems require further research to be done in the future.

(1) *Causation and the laws of nature*

Hume interprets laws of nature, such as the laws of Newtonian dynamics, and the law of conservation of momentum, in terms of causes and effects. Hume thinks that forces and momenta are causes, and that changes of motion are their effects. At the same time, Hume's conception of causality includes, among others, the following preconditions: 1) causes and effects are contiguous to each other, 2) causes temporally precede effects, and 3) causes and effects are distinctly separable (T 1.3.15.3–4; SBN 173, EHU 4.11; SBN 30).

The problem with the three preconditions is that the laws of dynamics and the law of conservation of momentum are not consistent with such preconditions. As the force of gravity is a long-range force, the first criterion is not satisfied.[29] Two objects exert a mutual force on each other, although there is nothing in between them. Second, the exercise of force is simultaneous with acceleration. There is no temporal succession in dynamical interactions, as the second precondition demands. Third, forces are not individual things or properties of bodies. Rather they "emerge" (it is not clear what would be the appropriate verb to be used, since the application of active words may be misleading here) from

[29] Hume famously drops the contiguity requirement in the first *Enquiry*. However, the first *Enquiry* still includes preconditions 2 and 3.

interactions of at least two bodies. For example, when I push the table in front of me with my hand, the table "pushes" (here the application of such verbs might lead to anthropomorphizing nature) my hand back with equal and opposite force. Is it possible to distinguish between cause and effect in this scenario? Is my pushing the cause, and the opposite force of the table on my hand the effect, or vice versa?[30]

The same problem can be observed when applying the notion of causation to the law of conservation of momentum, which Hume takes to be a discovered causal law (EHU 4.13; SBN 31). The law states that in an isolated system, the total linear momentum, the quantity of motion, of the system is a conserved quantity. When a cue ball is shot and hits the object ball in a game of pool, the total momentum is preserved in the impact. Can we differentiate cause and effect in this scenario? Hume seems to think that the quantity of motion of the cue ball is the cause, and the change of motion of the object ball is the effect. However, the resultant motion of the object ball does not suffice to show that it is the effect in the scenario; both of these objects may change their state of motion. In my view, it is perfectly uncontroversial to say that the quantity of motion is conserved in the impact of the balls, since this is what the proposition concerning the law actually states. But it is highly controversial to say that one of the objects is the cause for the other object's motion, as Hume assumes.

In essay **I**, I have tried to solve the tension that is apparent in Hume's conception of causality and the causal interpretation of forces. I provide an instrumentalist interpretation of Hume on the force of gravity. I claim that Hume does not hold the law of gravity to be a complete causal law, because the law does not include a reference either to contiguity or to temporal priority. Hume nevertheless gives his support to the law as he interprets the force of gravity instrumentally, as if it bore a causal relation to motion. I argue that despite the fact that the law does not ascribe either contiguity or temporal priority to the way gravity works, it is still an instance of an exceptionless repetition, and thus it satisfies Hume's rule 4 for causation, namely that "the same cause always produces the same effect" (T 1.3.15.6; SBN 173).

The problem with this line of reasoning which reduces causation into regularity, into a succession where "one thing is followed by another," is that it seems to be too weak of a criterion for causation. The night is also followed by a day, although the day does not cause the night in any way. Accordingly, the proposition "the night is followed by the day" is not a proposition concerning a law of nature, since it does not describe a physically necessary sequence (it would be physically possible to stop the rotation of the Earth).[31]

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30 Newton's third law is not meant to be a causal law, but rather a law of coexistence (see Tooley, 2004, p. 87–88). Still it is noteworthy to analyze it as it sheds light on the trouble of interpreting laws in causal terms.

31 The debate between the Humean and the Nonhumean views about laws is still certainly an open problem (see Schrenk's online edition). My point is that in this specific aspect Hume's position is particularly problematic, since it assumes that laws are merely accurate records of universal regularities.

Thus it might be that Hume, and many other early moderns such as Newton himself, are wrong in assuming that laws of nature are causal. Maybe laws should not be understood in terms of causes and effects at all? There is now a rich acausal tradition in the philosophy of physics that endorses this claim.[32] In his classical article "On the Notion of Cause," Bertrand Russell (1912−1913/1953, p. 395) argues, by using Newton's law of universal gravitation as an example, that "in the motions of mutually gravitating bodies, there is nothing that can be called a cause, and nothing that can be called an effect; there is merely a formula." Rather than interpreting the law in causal terms, Russell proposes that a physical system can be expressed in terms of differential equations, which render the configuration of particles theoretically calculable. "That is to say," he continues,

> the configuration at any instant is a function of that instant and the configurations at two given instants. This statement holds throughout physics, and not only in the special case of gravitation. But there is nothing that could be properly called "cause" and nothing that could be properly called "effect" in such a system.

As I have explained in the methodological subsection 1.3 of this introductory section, my objective in the dissertation essays is not to judge in what ways Hume's philosophical positions are true or false. However, even when reading Hume in a tolerant and approving way, there is a great tension between his understanding of laws of nature as being causal and his preconditions for causality.

If the causal interpretation of laws is nevertheless considered to be a desirable goal, it might be that the projectivist interpretation could surmount this conflict. According to Beebee's (2007, p. 225) projectivist interpretation,

> Hume holds that our causal thought and talk is an expression of our habits of inference. On observing *a*, we infer that *b* will follow, and we 'project' that inference onto the world.

To follow this line of interpretation, causation is not something discovered in nature. When we say that *a* causes *b*—for example, that the impact of the cue ball (*a*) causes the object ball to change its state of motion (*b*)[33]—we are merely projecting our habits of inference onto natural phenomena. Projectivism about causation stresses that we should focus on the aspects of the human mind, or human nature, which make us think and say that objects or events are causally related.

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32 The tradition which takes a critical position on causation concerning the laws of nature, before and after Russell, includes Berkeley (1721/1992), Reid (1788/2010), Auguste Comte (1840−1852/2012), Mach (1893/1919), Friedrich Waismann (2011), John D. Norton (2003), and James Ladyman, Don Ross, David Spurrett, and John Collier (2007).

33 It could be further objected that distinguishing between a cause and an effect in such scenario is somewhat arbitrary. It is not clear whether cause and effect stand for objects or events, and where exactly does the cause end and the effect begin.

Although this reading seems plausible for reconciling Hume's causal philosophy with causal interpretation of laws, there are still some caveats that would have to be taken into account. Especially in the first *Enquiry*, Hume seems to think that causal relations are discovered in nature by experience; they are not mere projections.[34]

This topic needs to be investigated more thoroughly in the future. Perhaps the notion of "discovery" should be made explicit? At this point, it is not clear how the tension between Hume's preconditions for causality and the way laws of nature supposedly instantiate causation could be reconciled.

(2) *Hume's Fork and his skepticism with regard to reason*

In many instances, Hume seems to think that true mathematical propositions and their constitutive intuitive relations are absolutely certain. In the first Book of the *Treatise* (1.3.1.5; SBN 71), he counts algebra and arithmetic as "the only sciences, in which we can carry on a chain of reasoning to any degree of intricacy, and yet preserve a perfect exactness and certainty." As "we are possest of a precise standard, by which we can judge of the equality and proportion of numbers," we determine their relations "without any possibility of error." In the *Treatise*, geometry is not "a perfect and infallible science." However, Hume later changed his mind. In the first *Enquiry* (4.1; SBN 25), he claims that "though there never were a circle or triangle in nature, the truths, demonstrated by Euclid, would for ever retain their certainty and evidence," thus ascribing impeccable certainty to geometry. Also in the second *Enquiry* (1.5; SBN 171), he asserts that "propositions in geometry may be proved."

Mathematical certainty is contrasted with empirical probability. The relations between quantities, numbers, and figures are intuitive, and thus capable of demonstration. Matters of fact are founded on the relation of causation (EHU 4.4; SBN 26), which is a probable relation (T 1.3.1; SBN 69). Mathematical propositions (in the *Enquiries*, at least) are subject to the principle of contradiction, whereas factual propositions are not. The negations of demonstrative propositions are utterly inconceivable but the negations of matters of fact are distinctly conceivable. Thus matters of fact "are evidently incapable of demonstration" (EHU 12.28; SBN 164). HF implies a categorical distinction of certainty: relations of ideas, which include mathematics, are certain, whereas matters of fact, which include causal propositions, are probable.

However, the distinction HF draws is in stark contrast to Hume's argument of skepticism with regard to reason in the first Book of the *Treatise* (1.4.1.2; SBN 180–181). The skeptical argument runs as follows:

> There is no Algebraist nor Mathematician so expert in his science, as to place entire confidence in any truth immediately upon his discovery of it, or regard it as any thing, but a mere probability. Every time he runs over his proofs, his confidence encreases; but still more by the approbation of his friends; and is rais'd to its utmost

[34] See the examples listed in subsection 1.4 of this introductory chapter.

> perfection by the universal assent and applauses of the learned world. Now 'tis evident, that this gradual encrease of assurance is nothing but the addition of new probabilities, and is deriv'd from the constant union of causes and effects, according to past experience and observation.

Here Hume seems to understand our knowledge about the truth of mathematical theorems to depend on two psychological and sociological factors: 1) the memory of the mathematician proving a theorem, and 2) the assent of the relevant mathematical community. This argument reduces mathematics to causal beliefs. To demonstrate a mathematical proposition, fallible cognitive and social abilities such as memory and collaboration between the members of the mathematical community are required.

To elucidate Hume's skeptical argument of math's certainty, I shall use a contemporary example. In recent years, mathematician Shinichi Mochizuki has claimed to have proven the notoriously difficult abc conjecture. The proof is approximately 500 pages long. Other mathematicians working on the same field have not yet been able to review the proof thoroughly (Aron, 2015). Is the abc conjecture true? Is it certain? Well, here Hume the skeptic would take psychological and sociological conditions, that is, causal factors into account when evaluating the certainty of the conjecture/theorem.

First, there is the psychological issue of memory. Mochizuki wrote a proof that is close to 500 pages long. Is it possible that in the process of proving the conjecture he may have forgotten some deductive steps? It seems that the *probability* of the conjecture being a theorem is dependent on how many times "he runs over his proofs," as Hume would say. Second, there is the sociological issue of collaboration between the members of the relevant mathematical community. Not many people can follow the arguments provided in this proof. Should we trust Mochizuki's own words? It seems that the *probability* of the conjecture being a theorem would increase had he more "approbation of his friends," as Hume would say. Thus a mathematical truth cannot be regarded "as any thing, but a mere *probability*" (T 1.4.1.2; SBN 180, my emphasis).

Hume's concern for humans making inexact judgments makes all knowledge reduce into probability. Be the rules of mathematics as infallible as they may, humans are nevertheless fallible beings, and may err in demonstration. The skeptical argument shows that the paradigmatic certainty of mathematics might not be as paradigmatic as Hume in many cases seems to think. Mathematics does not have the privileged status of certainty that is usually attributed to it, and which distinguishes it from empirical probability. Therefore, no definite line between indefeasible mathematical truths and probabilistic empirical facts can be drawn. If this is the corollary of Hume's skeptical argument with regard to reason, the consequences to HF are devastating: The epistemic categorization of HF, which divides propositions into certain and probable, cannot be right.

Kevin Meeker (2007, 2011) has thoroughly argued that Hume's skeptical argument with regard to reason weakens the distinction between relations of

ideas and matters of fact.[35] He (2011, p. 237) even goes so far as to claim that in Hume "there is no sharp dividing line between relations of ideas and matters of fact."

It seems to me that Meeker is right in claiming that the skeptical argument concerning reason *and* HF as a distinction between certain/probable relations cannot both be true at the same time. However, I think his argumentation does not succeed in showing that HF collapses altogether. Propositions concerning relations of ideas and matters of fact are still two distinct propositions: the former concerns relations between ideas, the latter the relation of causation. Meeker's conclusion about T 1.4.1 does not take into account the fact that, especially in the first *Enquiry*, HF is an important epistemological tool for Hume. As I have argued in essay **III**, he uses his fork effectively as an epistemic vehicle by repeatedly contrasting the *a priori* and the empirical (for example, in 4.6–7; SBN 27–8, 4.9–11; SBN 30, 4.13; SBN 31–2, 4.18; SBN 35, 12.29; SBN 164). The relation of intuition and that of causation are two distinct relations, so mathematical and factual propositions cannot be legitimately connected.[36] HF is still of the highest importance, as can be read in the famous conclusion of the first *Enquiry* (12.34; SBN 165), that is, in his mature epistemological work.

The specific tension between the skeptical argument in T 1.4.1 and the way Hume applies his fork in the first *Enquiry* thus requires further research to be done. In contemporary Hume scholarship, our understanding of the precise nature of the distinction between relations of ideas and matters of fact is insufficient. In addition to the certainty/probability distinction, there are other distinctions in HF that would benefit from more research, such as: the relations between necessity and contingency, *a priority* and *a posteriority*, and perhaps also analyticity and syntheticity.

(3) *Copy Principle, physical objects, and simultaneous events*

In essay **IV** of the dissertation, I claim that Hume's philosophy of space and time is a form of relationism. This position indicates that we do not have the ideas of absolute space and time but that these (abstract) ideas refer to physical objects. The central claim of essay **IV** is that Einstein, in a Humean way, sees empiricism and relationism as being intertwined: our ideas and concepts of space and time refer to physical objects; in turn, our knowledge concerning these objects is acquired empirically, namely by the senses of vision and touch.

The problem is that the meaning of "physical object" is highly problematic in Hume's philosophy. He does not apply the notion of "physical object" by himself (he does talk about "physical points," "physical causes," and "physical necessities" in the first Book of the *Treatise*). Hume speaks about bodies. But what is the ontological status of bodies in Hume? If we follow, as I have done in all of the essays, the old Humean interpretation of the Copy Principle rigorous-

35 Or, in the subsequent history of philosophy, the analytic/synthetic distinction.

36 Excluding the propositions of mixed mathematics, because they are matters fact that are dependent on UP.

ly, the following problem may arise: are bodies just bundles of perceptions in the mind? Yumiko Inukai (2011, p. 205) contends that this is the conclusion of Hume's radical empiricism. She clarifies her interpretation as follows:

> The external bodies that could be affirmed consistently in Hume's system are no different from perceptions. For Hume, strictly speaking, only perceptions exist, constituting both the internal and external worlds *for us*, and these worlds are known to us in our experience. I call this aspect of Hume's empiricism "*radical* empiricism." It is radical because Hume does not move from what is available in sensible perceptions to what bodies are in the extramental world in the way Locke sometimes does.

If this reading were correct, it would evidently pose a significant problem in connecting the ontologies of Hume and Einstein. The problem becomes most troublesome with respect to Einstein's argument for the relativity of simultaneity. In essay **IV** I have followed Norton's (2010) interpretation, according to which Einstein adopted an empiricist epistemology and semantics so that he could define simultaneity in a way that it could be tested empirically. But the argument for the relativity of simultaneity assumes, in addition to the criterion of empirical testability and the postulates of STR, also the following: There is a distinction between true events and our observations of, say, light flashes perceived by the observer. To make this assumption clear, and to show the tension it inflicts on Hume's philosophy, consider the following example (which is also imaged in Figure 1 below).

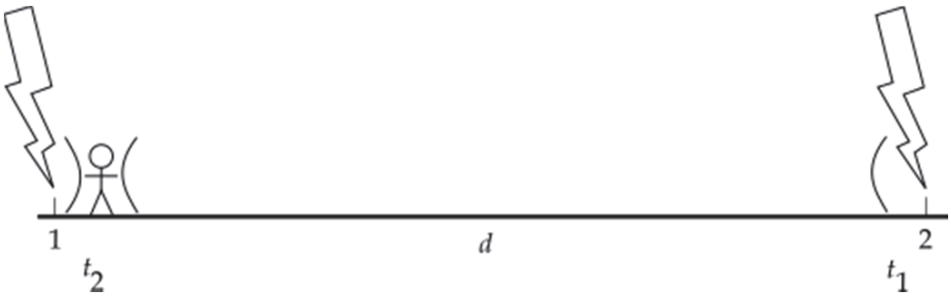

Figure 1 Time ordering of two non-causally related physical events in an inertial frame of reference.

An observer in an inertial frame of reference is located at point 1. The distance from point 1 to point 2 is d. Two lightnings strike at both points. The observer, at her point, sees the lightning strikes simultaneously. As the observer perceives the flashes to be simultaneous, does it mean that the two events, the lightning strikes at points 1 and 2, happened at the same time? No, because they really do not happen at the same time. The observer can infer that the lightning at point 2 happened first, as the light wave reaches her at the speed of c over a distance of d. As $t_2 > t_1$, the lightning strikes are not simultaneous. The observer has per-

ceived an event after it really happened. There is a difference between observation of and the happening of an event.

It is difficult to see how Hume's Copy Principle could explain this. To accept Einstein's argument, one must assume that there is a *real physical event* in a specific spatial location although *no one has yet perceived it*. The distinction between "what really happens" and "how we see things happening" fits poorly with Hume's radical empiricism. But this is exactly what Einstein's argument for the relativity of simultaneity maintains. It is requisite that, as Einstein (1936, p. 358) himself points out, we "differentiate between 'simultaneously seen' and 'simultaneously happening.'" One could say that the fundamental entity of STR is a real event, that is, some physical activity taking place at a certain spatial point at a certain time. It is *not* an immediate particular perception of an object.

On the other hand, there might be a way in which Hume's Copy Principle could be made consistent with Einstein's argument. One can infer the non-simultaneity of the lightning strikes because the strikes make successive, non-simultaneous auditory impressions.[37] Although the observer sees the lightning flashes simultaneously, she hears the strikes successively. Could this enable Hume to say that physical events are different from our perceptions, and that different visual and auditory perceptions have a common natural origin? There are some explicit passages in the *Treatise* which indicate that Hume thought that our perceptions are affected by physical causes. For example, in T 2.1.1.2 (SBN 275), Hume explicitly states that perceptions in the mind "depend upon natural and physical causes." If our visual and auditory perceptions have such natural causal origin, then Hume's position would readily be reconcilable with the argument for the relativity of simultaneity.

But Hume is very enigmatic on this issue. A strikingly skeptical argument appears in T 1.3.5.2 (SBN 84):

> As to those impressions, which arise from the senses, their ultimate cause is, in my opinion, perfectly inexplicable by human reason, and 'twill always be impossible to decide with certainty, whether they arise immediately from the object, or are produc'd by the creative power of the mind, or are deriv'd from the author of our being. Nor is such a question any way material to our present purpose. We may draw inferences from the coherence of our perceptions, whether they be true or false; whether they represent nature justly, or be mere illusions of the senses.

Here Hume says that our perceptions may be caused by mind-independent nature, by our minds themselves, or by God. This is a thoroughly skeptical remark: there is no intelligible way to differentiate between the three (or perhaps even more) options. Hume is no Lockean representational realist.

Although Hume's philosophy is of central importance for understanding the philosophical background assumptions of the concepts of space and time in STR, Einstein's argument for the relativity of simultaneity includes assumptions which are incompatible with the old Humean radical empiricist interpretation

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37 I thank Wayne Myrvold for pointing this out to me in the CLMPS congress at the University of Helsinki on August 7, 2015.

of the Copy Principle. To make the larger point, agreeing with STR (a theory which has been extremely well confirmed) requires a realist ontology of physical events. It is unclear whether the radically empiricist and skeptical aspects of Hume's philosophy could be made consistent with such realism. This critical remark could be developed further, but as this would be a topic for future research concerning the relationship of Hume and Einstein, I cannot defend this claim here.

1.7.1 Conclusive Remarks with Some Suggestions

I trust my dissertation establishes the following: Hume's natural philosophy has a notable role in the interrelated history of philosophy and science. It would be wrong to claim that his philosophical system was independent of the scientific conceptions of his day. Not only that, Hume's work has a partly constructive role in the formation of natural science after him. Nevertheless, there are difficult unresolved problems in this area of study that require further research to be done.

What would be the desirable future direction for the study of Hume's natural philosophy? I wish there were—in addition to the commonplace charitable readings of his texts—more critical studies of his work. Usually historians of philosophy aim at providing consistent and novel interpretations of the texts of authorial figures. The trouble is that sometimes the argumentation of these figures, including Hume's, involves inconsistencies. This indicates that it is not always the fault of the historian of philosophy if she fails to provide a consistent interpretation. I suggest that the way to remedy this defect is to allow interpreters to also raise critical issues when reading classical works. I think this trend is already apparent in the integrated studies of history and philosophy of science. In my opinion, the study of history of philosophy would also benefit if it allowed more critical commentaries of classical works.

YHTEENVETO (SUMMARY IN FINNISH)

Tämän artikkeliväitöskirjan pääaihe on David Humen (1711–1776) luonnonfilosofia. Väitöskirja koostuu neljästä erillisestä, toisiinsa temaattisesti liittyvästä artikkelista sekä johdannosta. Artikkelien keskeiset teemat ovat Humen käsitykset kausaliteetista, kokeellisuudesta, luonnonlaeista, hänen kantansa voimien olemassaolosta, matemaattisten ja empiiristen väitelauseiden erosta, matematiikan suhteesta luontoon sekä ajan ja avaruuden ideat ja käsitteet. En tutki ainoastaan Humen näkemyksiä näistä aiheista, vaan sijoitan ne osaksi laajempaa filosofian ja tieteen, erityisesti fysiikan, historian kontekstia. Johdantoluku osoittaa, kuinka yksittäiset artikkelit liittyvät toisiinsa. Se myös selventää väitöksen näkökulmaa sekä tutkimusmenetelmää. Lopuksi johdantoluvussa tunnistetaan toistaiseksi ratkaisemattomia ongelmia, joiden selvittäminen vaatii jatkotutkimusta.

Ensimmäinen artikkeli käsittelee Newtonin kokeellista menetelmää painovoimatutkimuksessa sekä sen suhdetta Humen kausaliteetin filosofiaan. Argumentoin, että Newtonin kokeellinen menetelmä on tärkeä tausta Humen kausaliteettikäsityksen ymmärtämiselle. Hume katsoo, ettei syyn ja seurauksen suhteen tunnistaminen perustu *a priori* -päättelyyn, samalla tavalla kuin Newton kritisoi ei-empiirisiä hypoteeseja painovoiman kausaalisista ominaisuuksista. Humen kausaliteettia koskevien päättelysääntöjen mukaan yleinen painovoimalaki ei kuitenkaan ole täydellinen kausaalilaki, sillä laki ei sisällä viittausta fyysiseen kosketukseen eikä ajalliseen peräkkäisyyteen. Argumentoin silti, että Newtonin teorian empiirisen menestyksen – painovoimalaki ilmentää poikkeuksetonta toistoa – takia Hume asettuu kannattamaan sitä tulkitessaan painovoiman instrumentalistisesti niin kuin voimalla olisi kausaalinen suhde liikkeeseen.

Toinen artikkeli tarkastelee Humen filosofian newtonilaisia ja ei-newtonilaisia tekijöitä. Perinteisen tulkinnan mukaan, josta oma edellinen artikkelini on esimerkki, Hume kannatti Newtonin painovoimatutkimuksen kokeellista menetelmää ja hypoteesien kritiikkiä, joita hän sitten sovelsi omiin kausaliteetti- ja induktioteorioihinsa. Kriittinen tulkinta kiistää tämän väittäessään, että Humen teoriat eivät pohjaa newtonilaiseen luonnonfilosofiaan vaan hänen ihmisluontoa koskevaan tieteeseensä. Tässä artikkelissa esitän, että Humen filosofiasta on löydettävissä sekä newtonilaisia että ei-newtonilaisia tekijöitä. Argumentoin, että Hume suhtautuu sympaattisesti moniin newtonilaisina pidettyihin teemoihin luonnonfilosofiassa, kuten kokeellisuuden vaatimukseen tiedonhankinnassa, hypoteesien kritiikkiin, induktiiviseen todistukseen sekä leibnizilaisten riittävän perusteen ja käsitettävyyden periaatteiden kritiikkeihin. Toisaalta Hume ei ole newtonilainen filosofi monessakaan muussa suhteessa: hänen käsityksensä ajasta ja avaruudesta, tyhjiöstä, kausaliteettia koskevista yksityiskohdista, mekanismin asemasta sekä voimien olemassaolosta eroaa merkittävästi Newtonin vastaavista käsityksistä.

Kolmas artikkeli keskittyy Humen haarukkaan sekä sovelletun matematiikan väitelauseiden tiedolliseen asemaan. Humen haarukka erottaa toisistaan

ideoiden relaatioita koskevat väitteet, kuten matematiikan totuudet, sekä tosiasiaväitteet, joihin lukeutuvat kaikki empiiris-kausaaliset väitteet. Edelliset ovat täysin varmoja sekä ilmentävät välttämättömyyttä, kun taas jälkimmäiset, ilmentäessään todennäköisyyttä, voivat tulevan tutkimuksen myötä osoittautua mahdollisesti virheellisiksi. Nämä kaksi väitetyyppiä perustuvat kahteen tarkasti erotettavaan relaatioon, intuitioon ja kausaatioon. Ongelmaksi muodostuvat tällöin sovelletun matematiikan väitteet. Ne ilmentävät sekä intuitiivista varmuutta että pelkkää todennäköisyyttä. Artikkeli osoittaa, että sovelletun matematiikan väitteet, kuten luonnonlakeja koskevat väitteet, ovat tosiseikkoja koskevia väitteitä. Perustelen tätä sillä, että sovelletun matematiikan väitteiden oikeutus on Humen filosofiassa riippuvaista yhdenmukaisuusperiaatteesta, toisin kuin puhtaan matematiikan totuuksien kohdalla.

Neljäs artikkeli analysoi Einsteinin Humelle antamaa tunnustusta suppean suhteellisuusteorian kehittämisen kontekstissa. Teoriansa kehittämisen jälkeen Einstein kertoo lukeneensa Humen filosofista pääteosta ”intohimoisesti ja ihaillen juuri ennen kuin löysin [suppean] suhteellisuusteorian. On hyvin mahdollista, etten olisi päätynyt ratkaisuun ilman kyseisiä filosofisia opintoja.” Vertaan fyysikon ja filosofin näkemyksiä, ja argumentoin, että heidän kirjoituksistaan on löydettävissä kaksi yhteistä tekijää: empiristinen teoria ideoista ja käsitteistä, sekä relationistinen käsitys ajan ja avaruuden olemassaolosta. Empiristinen teoria ideoista ja käsitteistä edellyttää, että ajan ja avaruuden ideat ja käsitteet viittaavat fysikaalisiin objekteihin. Vastaavasti tietomme fysikaalisista objekteista perustuu havaintoihin ja mittaustuloksiin. Tämä kriittinen pohdinta avitti Einsteinia luopumaan newtonilaisesta oletuksesta, jonka mukaan aika ja avaruus ovat havaitsijoista, kappaleista ja luonnontapahtumista riippumattomia absoluuttisia rakenteita. Argumentoin lisäksi, että Humen ja Einsteinin kannat eroavat siinä, että Einsteinin empirismi on tämän konventionalismista johtuen maltillisempaa kuin Humen. Heidän käsityksensä ajasta ja avaruudesta eivät myöskään ole yhteneviä seuraavassa merkityksessä: Humelle aika ja avaruus ovat ensi sijassa yksittäisistä aistivaikutelmista kopioituja abstrakteja ideoita; Einstein ymmärsi ajan ja avaruuden olevan fysikaalisia suureita, joita koskevat tapahtumat tulee ilmaista Lorentzin muunnosten avulla.

Väitöskirja haastaa kaksi perinteisesti Humen filosofiaan liitettyä näkemystä. Ensiksi, vaikka Hume on ensisijaisesti humanistinen filosofi, joka pyrkii luomaan ihmisluontoa koskevan tieteen perusteet, hänen filosofiansa kytkeytyy myös olennaisesti aikansa luonnontieteelliseen perinteeseen. Hänen luonnonfilosofiset näkemyksensä vaikuttivat myös osaltaan myöhemmän tieteenfilosofian ja tieteen kehitykseen. Toiseksi, Hume ei ole parantumaton skeptikko, joka kiistäisi kausaliteetin ja induktiivisen päättelyn. Hume kritisoi viimekätisiä metafyysisiä ja teologisia selityksiä, muttei empiirisen tieteen väitteitä.

Avainsanat: David Hume, tieteen ja filosofian historia, Isaac Newton, kausaliteetti, kokeellisuus, luonnonlait, Humen haarukka, aika ja avaruus, Albert Einstein

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ORIGINAL ESSAYS

I

NEWTON'S LAW OF UNIVERSAL GRAVITATION AND HUME'S CONCEPTION OF CAUSALITY

by

Matias Slavov, 2013

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II

NEWTONIAN AND NON-NEWTONIAN ELEMENTS IN HUME

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III

HUME'S FORK AND MIXED MATHEMATICS

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Matias Slavov

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IV

EMPIRICISM AND RELATIONISM INTERTWINED: HUME AND EINSTEIN'S SPECIAL THEORY OF RELATIVITY

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Empiricism and Relationism Intertwined: Hume and Einstein's Special Theory of Relativity*

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ABSTRACT: Einstein acknowledged that his reading of Hume influenced the development of his special theory of relativity. In this article, I juxtapose Hume's philosophy with Einstein's philosophical analysis related to his special relativity. I argue that there are two common points to be found in their writings, namely an empiricist theory of ideas and concepts, and a relationist ontology regarding space and time. The main thesis of this article is that these two points are intertwined in Hume and Einstein.

Keywords: Hume, Einstein, History of Special Relativity, Space and Time.

RESUMEN: Einstein reconoció que su lectura de Hume influyó en el desarrollo de su Teoría Especial de la Relatividad. En este artículo yuxtapongo la filosofía de Hume y el análisis filosófico de Einstein en relación a la relatividad especial. Argumento que hay dos puntos en común que pueden encontrarse en sus escritos, a saber: una teoría empirista de las ideas y conceptos y una ontología relacionista en lo que se refiere al espacio y al tiempo. La tesis principal del artículo es que estos dos puntos están en interconexión en Hume y en Einstein.

Palabras clave: Hume, Einstein, historia de la relatividad especial, espacio y tiempo.

1. Introduction

On the 14th of December 1915, Albert Einstein wrote a letter to Moritz Schlick. The main purpose of this short letter was to compliment Schlick about his paper on special and general relativity, which Einstein had read the previous day. Einstein (1998, 220) pointed out that it was "among the best yet of what's been written about relativity. Nothing nearly as clear has previously been written about its philosophical aspects." He acknowledged that Schlick had correctly recognized that his special theory of relativity (henceforth STR) was influenced by Ernst Mach's and David Hume's philosophies. Einstein wrote to Schlick, that it was

> Mach, and, even more, Hume, whose Treatise of Human Nature I studied with passion and admiration shortly before discovering the [special] theory of relativity. Very possibly, I wouldn't have come to the solution without those philosophical studies. (*Ibid.*)

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Although much ink has been spilled about Mach's influence on Einstein's science (e.g. Holton 1968, 1992; Zahar 1977; Feyerabend 1980, 1984; Hentschel 1985; Barbour 2007; Wolters 2012; Berman 2012), the relationship between Hume's philosophy and Einstein's philosophical analysis related to STR is far less well known. Still, in the quote above, Einstein insists that more than Mach, it was Hume who enabled him to put all the decisive pieces of the puzzle together. Later, in a letter to Michelle Besso in 1948, he makes a similar claim:

> How far (Mach's writings) influenced my own work is, to be honest, not clear to me. In so far as I can be aware, the immediate influence of D. Hume on me was great. I read him with Konrad Habicht and Solovine in Bern. (Speziali 1972, 153)

Einstein read the German translation of the *Treatise* in the early 1900's, and discussed it in the "Olympia Academy" reading group in which he participated in Bern (see Howard 2005, 36). Yet his acknowledgement does not specify what it was in Hume's philosophy that he found beneficial to the formulation of STR.

To answer this question, John Stachel (1989, 2002) and John D. Norton (2010) have both provided possible answers. Stachel emphasizes the similarities between Hume's and Einstein's views on space and time.[1] He asks, what Einstein could

> have gotten from Hume? I think it was a relational —as opposed to an absolute— concept of time and space. This is the view that time and space are not to be regarded as self-subsistent entities; rather one should speak of the temporal and spatial aspects of physical processes. (Stachel 2002, 166)

Norton provides another interpretation on the relationship between Hume's philosophy and Einstein's philosophical analysis related to STR. His main thesis is that (the young) Einstein was most influenced by the way Hume (and Mach) saw concepts to be grounded in sense impressions or sensations. The early Einstein implemented empiricism in his argument for the relativity of simultaneity. If the concept of simultaneity is grounded in sensible impressions, such as in visual sensations of immediate light flashes in two mirrors, it follows (given the two postulates of STR and conventional definitions and stipulations) that there is no absolute simultaneity. Different inertial reference frames can observe the timely order of two spatially distant events, the two light flashes, in different order. The revision of the concept of simultaneity defied the absolute Newtonian character of time. As Einstein recognized later in his 1949 autobiographical writing:

> The type of critical reasoning required for the discovery of this central point [the denial of absolute time, or simultaneity] was decisively furthered, in my case, especially by the reading of David Hume's and Ernst Mach's philosophical writings. (Einstein 1949a, 53)

In Norton's interpretation, this "critical reasoning" eventually helped Einstein to reconcile the two postulates of STR, namely the invariance of laws of nature and the constancy of speed of light in vacuum.

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[1] Lenzen (1949, 359) also comments on the similarities between Hume's and Einstein's conceptions of space and time, but he does not mention relationism.

In this article, I shall provide a detailed comparison of Hume's philosophy and Einstein's philosophical analysis related to STR. I argue, as has been suggested by Norton and Stachel, that both Hume and Einstein support an empiricist theory of ideas and concepts and a relationist ontology regarding space and time. However, these previous studies on the topic have regarded the two points as being separate. My interpretation shows that they are instead tightly connected. This new interpretation will provide a better understanding of the connection of Hume and Einstein. Moreover, it will help to clarify the philosophical background assumptions related to the concepts of space and time in Einstein's STR, for which Hume's philosophy is of central importance.

Although I find Hume's and Einstein's views to overlap about the two crucial points, empiricism about ideas and concepts and relationism about space and time, it has to be noted that Hume's and Einstein's conceptions of space and time have important differences. In Hume, they are abstractions from simple perceptions but in Einstein they are physical quantities. Further, Einstein's conventionalism about the origin of concepts instantiates a more mitigated form of empiricism than Hume's copy principle. Einstein frequently emphasizes that concepts are free creations of the human mind, and that they are not deducible from sensations. Hume's case is different, since according to his copy principle simple impressions cause simple ideas—there is a complete isomorphy between the two—and our will regarding this relation is not free.

The goal of my article is not to state that Hume anticipated STR. My purpose is to investigate in what way Hume's copy principle, which is the foundation of his theory of ideas and, hence, his theory of space and time, has similarities compared to the philosophical analysis related to Einstein's STR. I also do not wish to state that Einstein's views on space and time were solely intertwined with his philosophical theory of concepts. Doubtless, as his original 1905 special relativity article "On the Electrodynamics of Moving Bodies" (henceforth EMB) suggests, they were largely influenced by the 19th century electrodynamic physics; I will briefly take this into account. The scope of this article is limited to questions related to STR only. I do not analyze Einstein's views related to his general relativity, or his conception of the existence of atoms, as it would not be relevant to this article.

The rest of this article is structured into the three following sections. In section 2, I argue that although Einstein's special relativity[2] is a product of the 19th century electromagnetic physics, the processes that lead to its formulation do have important philosophical roots, too. As Einstein so overtly acknowledges his debt to Hume, this evinces that the comparison of the philosophical doctrines of Hume and Einstein deserves to be seriously studied. I lead off section 3 by arguing for the similarities (and for some dissimilarities) between Hume's philosophy and the philosophical analysis related to Einstein's STR. I begin my analysis with Hume's copy principle, which is the general epistemic and semantic principle of his philosophy. I claim that Hume's copy principle is similar compared to Einstein's empiricist theory of concepts. Both Hume and Einstein insist that ideas and concepts are justified by and made meaningful by impressions and sensations. However, I ac-

[2] To avoid confusion between the terms "special relativity" and "principle of relativity," I use the anachronistic term "special relativity" regarding Einstein's original publication of 1905, although Einstein did not use this expression (*die spezielle Relativitätstheorie*) until 1915 (Stachel 2002, 192).

knowledge that the level of their empiricism differs. In section 4, I argue that because of their empiricist theories of ideas and concepts, they hold physical objects to be central reference points for the notions of space and time. This leads to the main thesis of my article, which is the following. I argue that these two points, empiricism about ideas and concepts and relationism about space and time, are intertwined in Hume and Einstein: the empiricist theory of ideas and concepts entails that the notions of space and time are intrinsically related to physical objects; in turn, the conception of physical objects can be justified and made meaningful by relevant sensuous impressions, such as vision and touch.

To support my interpretation, I marshal the textual evidence from Einstein's original 1905 publication, his "Contributions to Science" in Carl Seelig's 1981 edition of *Ideas and Opinions*, and from his private writings and correspondence. Regarding Hume, the text that I analyze is mainly his *Treatise of Human Nature*, since this is the book that Einstein refers to in his quotation where he indicates his debt to Hume (see Norton 2010, 374). When needed, I analyze the "Abstract" of the *Treatise* and his later work *An Enquiry concerning Human Understanding*.[3]

2. *On the Relevance of Philosophy to STR*

In his "What is the Theory of Relativity" (1919/1981c, 225), Einstein asserted retrospectively that "the special theory of relativity [...] was simply a systematic development of the electrodynamics of Maxwell and Lorentz." This becomes immediately clear for the reader of Einstein's original publication of STR. In the first paragraph of the abstract of EMB, Einstein presents his famous magnet and conductor thought argument concerning Faraday's law of electromagnetic induction. This intricate argument and its important consequences to the formulation of STR have been carefully reviewed elsewhere (i.e. Earman 1989, 54, Cushing 1998, 229-230, Visser 2011, 11-15, and Norton 2010, 362-365, 2014, 83-85). To put it briefly and succinctly, the crux of the magnet and conductor argument is to argue for the principle of relativity, [4] and to argue against the ether hypothesis, or "the idea of absolute rest," as Einstein (1905/1923, 37) says. The implication of this argument is that electric fields, as well as the dimensions of space and time, are not absolute quantities (see Norton 2014, 85). Rather, these quantities depend on the inertial motions of observers moving with respect to each other, and are thus subject to Lorentz transformations.

Although the original publication of STR ensued from a critical reflection of the 19th century electromagnetic physics, the processes that lead to its formulation do have important philosophical roots, too. This can be explained by Thomas Kuhn's (1996, 88) theory of the development of a science: scientists who introduce a new paradigm into a science work extensively in the old pre-paradigmatic science themselves. Introduction of this new paradigm, as Kuhn puts it, is "both preceded and accompanied by fundamental philosophi-

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[3] References to Hume's *Treatise of Human Nature* and *An Enquiry Concerning Human Understanding* are in accordance with the Hume Society's exhortation. I employ the abbreviations T and EHU as well as the Selby-Bigge/Nidditch (SBN) numbering.

[4] Retrospectively, Einstein (2002, 20) went as far as to claim that "the phenomenon of magneto-electric induction compelled me to postulate the (special) principle of relativity." See also Einstein (1914/1981a, 218, 1940/1981h, 320-321).

cal analyses" (*Ibid*.).[5] This is no doubt the case with Einstein. He worked himself in the old pre-paradigm ether-modeled mechanics (Einstein did believe in the ether for quite a long period of time),[6] which saw electric fields and space and time as absolutes. The introduction of STR was preceded by extensive reading and discussion of philosophy, not only that of Hume's, but, among others, the philosophies of Mach, Mill, Poincaré, Spinoza, Kant, and Avenarius (see Stachel 2002, 125).

Einstein did use philosophical analysis to suit his physical ends. But just to say that he did use philosophical analysis is in itself quite vague. What kind of philosophy? To answer this question, I quote the first chapter of his philosophically oriented text *Physics and Reality* (1936/1981g, 283) at length. In it, Einstein clarifies his position about the need of a certain kind of philosophy to assist physics:

> It has often been said, and certainly not without justification, that the man of science is a poor philosopher. Why, then, should it not be the right thing for the physicist to let the philosopher do the philosophizing? Such might indeed be the right thing at a time when the physicist believes he has at his disposal a rigid system of fundamental concepts and fundamental laws which are so well established that waves of doubt cannot reach them; but, it cannot be right at a time when the very foundations of physics itself have become problematic as they are now. At a time like the present, when experience forces us to seek a newer and more solid foundation, the physicist cannot simply surrender to the philosopher the critical contemplation of the theoretical foundations; for, he himself knows best, and feels more surely where the shoe pinches. In looking for a new foundation, he must try to make clear in his own mind just how far the concepts which he uses are justified, and are necessities.

In the quote above, Einstein suggests that "when looking for a new foundation," the physicist needs to make clear "just how far the concepts which he uses are justified, and are necessities." This indicates that he is essentially interested in epistemological problems. He did value epistemological analysis in his physical research when he was forming a novel physical theory, such as STR (see also Einstein 1949b, 683-684). It should be noted that he did not regard himself as a "systematic epistemologist," but rather an "unscrupulous opportunist." Still his "occasional utterances of epistemological content" can be interpreted as having systematicity, as he himself also allows this in his summary to the volume of Library of Living Philosophers (*Ibid.*, 683).

Interestingly, Hume's *Treatise of Human Nature*, a work that Einstein reported to have studied "with passion and admiration shortly before discovering the [special] theory of relativity," begins with asking essentially the same kind of questions that Einstein dealt with in his more philosophically oriented texts: what are the origin, meaning, and justification of our ideas?[7]

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[5] The examples Kuhn (1996, 88) uses of the sciences preceded and accompanied by philosophical analyses include Newtonian physics, relativity and quantum mechanics.

[6] Einstein had been devising thought experiments about electrodynamic phenomena which include a reference to the ether as early as 1895. See Einstein (1987, 4-6), "On the investigation of the state of the ether in magnetic field."

[7] Einstein's term "concept" (*Begriff*) and Hume's term "idea" cannot be used interchangeably: "concept" is more definitional and conventional, whereas "idea" is given to the mind, and our will regarding it is not free. However, Einstein sometimes conflates the two terms. Although he usually speaks about

In the next section, I begin to draw parallels between Hume's and Einstein's philosophical writings. I shall argue that Hume and Einstein have different positions concerning the origin of concepts but similar views regarding their justification and meaning.

3. Hume's copy principle and Einstein's empiricist theory of concepts

In Hume's view, perception begins with impressions. According to the copy principle, all cognitive and meaningful ideas, except for some particular shades of a color (see T 1.1.1.10; SBN 5-6, EHU 2.8; SBN 20-21), are and have to be originally derived from resembling individual sensible impressions (T 1.1.4-1.1.5; SBN 1-10, EHU 2 and 3). David Landy (2012, 25-26), following Don Garrett's (1997, 41) seminal work, argues that if an idea is to be a copy of an impression, two requirements have to be satisfied. First, it must be that an idea is caused by an impression ("being caused" understood in the Humean sense of experiencing the constant conjunction between species of objects). Second, it must be that an idea exactly resembles the impression that caused it. Exact resemblance is limited to simple ideas and their impressions. The application of the copy principle requires that complex ideas can be separated into simple ideas (T 1.1.2; SBN 2; Landy 2012, 26). In turn, these differentiated ideas have their origin in simple impressions.

Einstein shares a theory about concepts which is analogous to Hume's copy principle. This fact is present in a variety of his texts, written between quite vast periods of time, from 1916 to 1949. In the quotes below, it can be seen that Einstein clearly maintains an empiricist theory about concepts (*Begriff*):[8]

> "The concept does not exist for the physicist until he has the possibility of discovering whether or not it is fulfilled in an actual case" (*Relativity. The Special and General Theory*, 1916/2001, 24).
>
> "... the physicist has to limit himself very severely: he must content himself with describing the most simple events which can be brought within the domain of our experience" ("Principles of Research," 1918/1981b, 221).
>
> "The fundamental principle here is that the justification for a physical concept lies exclusively in its clear and unambiguous relation to facts that can be experienced" ("On the Theory of Relativity," 1921/1981d, 241).
>
> "Concepts can only acquire content when they are connected, however indirectly, with sensible experience" ("The Problem of Space, Ether and the Field in Physics," 1934/1981f, 270).
>
> "... concept [...] owes its meaning and its justification exclusively to the totality of the sense impressions which we associate with it" (*Physics and Reality*, 1936/1981g, 284).

"concepts" (see Einstein 1918/1981b, 221, 1921/1981d, 241, 1934/1981f, 270, 1936/1981g, 284, 286, 1949a, 13, 1916/2001, 24), in his *Meaning of Relativity* he begins with "investigation of the origin of our *ideas* of space and time" (Einstein 1922/2003, 1, my emphasis). Further, Hume's term "impression" is more extensive than Einstein's "sensation": Hume's "impression" covers also feelings and emotions, not only "sensations," if by sensations is meant "comes from the senses."

8 Note that I am not saying that Einstein supports an empiricist theory regarding propositions, theories, or laws of nature. My claim is that Einstein is an empiricist regarding concepts. I do not wish to state that his overall epistemology or philosophy of science is empiricist.

> "Science uses the totality of the primary concepts, i.e., concepts directly connected with sense experiences" (*Ibid*., 286).
>
> "all thought acquires material content only through its relationship with that sensory material" ("Remarks on Bertrand Russell's Theory of Knowledge," 1944/1981j, 33).
>
> "Concepts [...] get "meaning," viz., "content," only through their connection with sense-experiences" ("Autobiographical Notes," 1949a, 13).

The excerpts above are by and large in line with Hume's copy principle. The difference between Hume's and Einstein's positions in this issue is rather a difference of degree, not kind. In Hume's theory, there is a complete isomorphy between a simple impression and a simple idea. The former causes the latter, and our will regarding this relation is not free. This is what the copy principle actually means, as Landy (2012, 30) clarifies it:

> Consider a standard office copier. What it produces are copies just in case these are caused by the original (they are not produced *ex nihilo*) and exactly resemble that original (they exactly replicate all the relevant intrinsic features of the original).

Einstein denies that concepts could be unequivocally derived from and reduced to sensations. As he and Leopold Infeld write in their *The Evolution of Physics* (1960, 31): "Physical concepts are free creations of the human mind." Concepts require conventional stipulations; they do not grow out to the mind automatically. According to Don Howard, Einstein doubted strongly that there would be "a clean, principled distinction between the empirical and the conventional" (Howard 1994, 48). Hume does allow conventionality in case of complex ideas: we can freely form the idea of a centaur or a golden mountain, since we have acquired the component simple ideas from simple impressions (EHU 2.5; SBN 19). But unlike Hume, Einstein does not think that impressions cause ideas. Hume and Einstein have a different understanding about the origin of ideas.

Einstein's critical remarks concerning metaphysical concepts seem to be more mitigated than Hume's. In the first *Enquiry* (2.9; SBN 21), Hume suggests that if the copy principle is used properly, it is possible to "banish all that jargon, which has so long taken possession of metaphysical reasonings, and drawn disgrace upon them." In Hume's theory, if a given philosophical term is to be meaningful, the term must be employed with an idea which can be reduced to an impression. If this condition is not satisfied, the philosophical term is "altogether insignificant" (T Abstract 7; SBN 649).

In his essay "Remarks on Bertrand Russell's Theory of Knowledge," Einstein discusses specifically Hume's critique of metaphysics:[9]

> As soon as one is at home in Hume's critique one is easily lead to believe that all those concepts and propositions which cannot be deduced from the sensory raw material are, on account of their "metaphysical" character, to be removed from thinking. (1944/1981j, 33)

[9] It must be noted that there is a dispute in Hume-scholarship concerning whether Hume is a metaphysician or not. Baxter (2008) argues that "Hume is a great metaphysician," but Morris (2009) claims that Hume is committed to a "resolutely anti-metaphysical stance." However, Einstein's quotation indicates that *he* took Hume to have been a critic of metaphysics.

Einstein is slightly more careful with his critique of metaphysics than Hume,[10] as he explains:

> In order that thinking might not degenerate into "metaphysics," or into empty talk, it is only necessary that enough propositions of the conceptual system be firmly connected with sensory experiences. (*Ibid*., 34)

He adds that

> by his clear critique Hume did not only advance philosophy in a decisive way but also—though through no fault of his—created a danger for philosophy in that, following his critique, a fateful "fear of metaphysics" arose which has come to be a malady of contemporary empiricist philosophizing (*Ibid*.).

Einstein distances himself from a bundle view of physical objects—"conceiving of the 'thing' as a 'bundle of qualities'"—and from the "fear of metaphysics [...] of contemporary empiricist philosophizing" (*Ibid*.). There is "no metaphysical danger in taking" a physical object to have an independent existence.[11]

According to Howard (1994, 48), Einstein came to realize that an austere empiricism (for example, of Hume or Einstein's positivist interlocutors) would "cripple theoretical physics." Einstein thought that freely creative theoretical thinking is possible, if the produced concepts and their constituent propositions are loosely and holistically consistent with sensible experience. Nevertheless, he does think that the justification for our concepts is in recurring complexes of sensations. In his *The Meaning of Relativity*, Einstein contends that "the only justification for our concepts and system of concepts is that they serve to represent the complex of our experiences; beyond this they have no legitimacy" (Einstein 1922/2003, 2). He adds that "I am convinced that the philosophers have had a harmful effect upon the progress of scientific thinking in removing certain fundamental concepts from the domain of empiricism" (*Ibid.*). When referring to "the philosophers [...] removing certain fundamental concepts from the domain of empiricism," he does not identify any philosopher by name. Since in this context he targets his critique at the *a priori* status of space and time, it is reasonable to assume that he is criticizing Kant's transcendental idealism about space and time. To give an example of the tension between Einstein's empiricist theory of concepts and Kant's transcendental theory, it is useful to shortly quote from the second section of the "Transcendental Aesthetic" of Kant's *Critique*, where Kant discusses the concept of time:

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[10] Einstein himself was not hostile to metaphysics. In the end of his text on Russell's theory of knowledge (1944/1981j, 35), he writes as having being "particularly pleased to note that [...] it finally turns out that one can, after all, not get along without "metaphysics.""

[11] In this sense, there is a difference between Hume and Einstein. For Hume's radical empiricism the question about mind-independent status of physical objects poses a significant metaphysical problem. Jani Hakkarainen (2012) has thoroughly argued that this is a problem about Hume's attitude to skepticism and his view on the relation between skepticism and naturalism (see also Inukai, 2011). Doubtless, this is a problem in Hume's philosophy, but since it does not belong to the main body of this article, I shall pass it without further ado.

> Time is not an empirical concept that is somehow drawn from an experience. For simultaneity or succession would not themselves come into perception if the representation of time did not ground them *a priori*. Only under its presupposition can one represent that several things exist at one and the same time (simultaneously) or in different time (successively) [...] Time is therefore given *a priori*.

Einstein is against Kant's above position. In Einstein's view, time *is* "an empirical concept." Simultaneity or succession *is not* "given *a priori*." [12] To Einstein, the concepts of simultaneity and succession are defined in such a way that they can be tested empirically, and justified with the aid of visual sensations. To put the concept of simultaneity into a more "malleable" form, Einstein went on to "purge" the *a priori* elements from concepts (see section 3.2 of Norton 2010). In his correspondence with Max Born in 1918, Einstein writes that he wishes to "water down the 'a priori' to 'conventional'" (Howard 1994, 52).

Einstein does not think that the source of concepts is impressions, as Hume would (Lenzen 1949, 360). Rather, their origins are in the free creations of the human mind. In this sense, Einstein can be seen to be closer to Kant than Hume. Kant's philosophy emphasizes the active and constructive aspects of perception, whereas Hume's understanding of perception is that it is passive; Hume thinks that senses are inlets through which ideas are conveyed (EHU 2.7; SBN 20, EHU 12.9; SBN 152). Nevertheless, Einstein's rhetoric in his correspondence with Born and Paul Ehrenfest indicates that he is more sympathetic to Humean empiricism than Kantian transcendentalism. He claims that "the details [of Kant's philosophy] do not fit,"[13] and that "it is not as good as his predecessor's Hume's work" (Howard 1994, 52). In 1916, he wrote to Ehrenfest that "Hume really made a powerful impact on me. Compared to him, Kant seems to me truly weak" (*Ibid*., 50). In Hume and Einstein space and time are empirical ideas and concepts. They are not *a priori* preconditions for all possible experience, as Kant thinks.

Mara Beller (2000) has questioned the relevance of Hume's philosophy to Einstein's empiricism. Beller refers to Einstein's article "Remarks on Bertrand Russell's Theory of Knowledge," which she takes to provide evidence against the empiricist reading. She writes the following:

> While Einstein's references to Hume's impact are often treated as a token of Einstein's empiricism, the discussion in this paper leads to a different appreciation of Hume's role in Einstein's critical thinking: "Man has an intense desire for assured knowledge. That is why Hume's clear message seemed crushing: the sensory raw material, the only source of our knowledge, through

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[12] Similarly, in his "The Problem of Space, Ether, and the Field in Physics," Einstein (1934/1981f, 271) argues that the concept of a body is not preceded by the notion of space: "Once the concept of the solid body is formed in connection with the experiences just mentioned [sight and touch]—which concept by no means presupposes that of space or spatial relation." He indicates that he has "never been able to understand the quest of the *a priori* in the Kantian sense" (*Ibid*.). Einstein differs from Kant in that he does not think that space (and time) are *a priori* forms of sensibilities which precede all possible experience, such as the experience of bodies. Rather, Einstein clearly contends that a material object precedes the concept of space (and time) (Einstein 1954/1981i, 355; see also Lenzen 1949, 367).

[13] See also Hentschel (1993, 619-621).

> habit may lead us to belief and expectation but not to the knowledge and still less to the understanding of lawful relations (Einstein 1944/1981j, 32)". Hume's impact on Einstein is then not necessarily an influence in the direction of empiricism, as usually assumed. (Beller 2000, fn. 5, 102-103)

I am partially sympathetic to Beller's reading. Einstein distances himself from the view that "the sensory raw material" would be "the only source of our knowledge." This is because according to his view concepts require conventions to be applicable. This is not the case with Hume. However, the passage quoted by Beller does not prove that "Hume's impact on Einstein is then not necessarily an influence in the direction of empiricism," nor does it even prove the weaker claim that there are no similarities between Hume's and Einstein's empiricisms. In the same text, "Remarks on Bertrand Russell's Theory of Knowledge," Einstein (1944/1981j, 33) supports an empiricist theory of concepts, as he writes that "all thought acquires material content only through its relationship with that sensory material." The quotation that Beller has selected concerns Einstein's conception of the knowledge and of the understanding of lawful relations. She is correct that Einstein did not support a Humean understanding of our belief and expectation of lawful relations as being founded on custom and habit. Yet this does not provide evidence that Einstein did not subscribe to an empiricist understanding of *concepts*.

As I have shown in this section, both Hume and Einstein maintain an empiricist theory of ideas and concepts. While Hume espouses radical empiricism, Einstein holds a nuanced view of this philosophical creed, mitigated by his conventionalist theory of concepts. In the next section, I shall argue that because of their empiricisms, they take physical objects to be central reference points for the notions of space and time. This is an important reason why Hume and Einstein take a relationist, and not an absolutist view: we do not have the ideas about space and time themselves, independent of perceptions and relational features of physical objects.

4. The intertwinement: empiricism about ideas and concepts, relationism about space and time

Hume's copy principle applies to objects which are at minimum the scale of what we can perceive by our senses. The mind has a threshold in forming adequate ideas. If ideas represent objects—if they are "applicable to the objects" (T 1.2.2.1; SBN 29)—adequate ideas require objects which are sensible. Because we cannot, by definition, perceive infinitesimally small objects, adequate ideas can represent only finite, perceptibly separable, particular objects (T 1.2.2; SBN 29-33). Since this is the general theory that Hume holds about representational ideas, it must be that ideas of space and time refer to finite, perceptibly separable and particular objects, too.

In Hume, ideas of space and time are abstract ideas. All abstract ideas are particulars, but they may be annexed to general terms which represent a variety of objects (T 1.2.3.5; SBN 34). The ideas of space and time represent individual things, namely discretely disposed points and moments (Falkenstein 2013, 111). Particular points and moments are not identical compared to each other but they resemble each other. Abstract ideas are to be understood in light of mutual resemblance of particulars (Baxter 2008, 18-19).

Hume claims that it is "from the disposition of visible and tangible objects we receive the idea of space" (T 1.2.3.7; SBN 35). He assimilates space to extension. The idea of extension is brought to the mind by two senses: sight and touch. Following his copy principle, Hume insists that "we have therefore no idea of space or extension, but when we regard it as an object either of our sight or feeling," and that "*the idea of space or extension is nothing but the idea of visible or tangible points distributed in a certain order*" (T 1.2.4.16; SBN 37, T 1.2.5.1; SBN 53).

Although Hume thinks that space is fundamentally perceivable extension, it is also a relational term to him. Perceivable objects are configured in a certain way; they can be distant from, contiguous with, above and below each other (T 1.1.5.5; SBN 14). We acquire the idea of space by considering the distance between perceivable bodies: "Upon opening my eyes, and turning them to the surrounding objects, I perceive many visible bodies; and upon shutting them again, and considering the distance betwixt these bodies, I acquire the idea of extension" (T 1.2.3.2; SBN 33). Distance is an instance of extension; it is known via extended bodies. Space in this sense is "known only by the manner, in which distant objects affect the senses" (T 1.2.5.17; SBN 59).[14]

In Hume's theory of time, it is requisite that there appears a change in objects. This change can be experienced either by succession in objects, or change in their state of motion. Conceiving time would not be possible without any "succession or change in any real existence" (T 1.2.4.2; SBN 40, see also Bardon 2007, 58).

Hume's account of genesis of time, or duration, is that we conceive it as "a succession of changeable objects" (T 1.2.3.11; SBN 37). For instance, hearing five successive flute chords and abstracting the order of their succession generates the idea of time to the mind (a single ongoing chord would not be sufficient). Time consists of indivisible and finite moments which are parts of succession. An abstraction of the succession of these moments is the time we experience (Baxter 2008, 17, 22-23). Moreover, Hume contends that time, or duration, can be abstracted from motions of objects. Hume does not accept that a steady, unchangeable object, if it is not a member of succession, could convey the idea of time (T 1.2.3.11; SBN 37). Rather, as the most important factor that needs to be satisfied in order for us to experience time in Hume's theory is change, motion of bodies provides change of place. In this sense, relative motion of bodies, along with succession of objects, such as auditory impressions, is a source for the idea of time.

Hume's conception of time indicates clearly that he is a relationist. "Time is," as he puts it, "nothing but the manner, in which some real objects exist" (T 1.2.5.28; SBN 64). Perception of time is relative to succession and/or motions of objects. Unchangeable objects, such as an ongoing chord or a pair of two motionless bodies could not convey an idea of time to the mind. Perceiving time depends on observer's relation to reference-objects; there is no absolute time independent of this relation. Thus there is no one universal time but many times depending on observer's relations to reference-objects. Hume asserts that we do not have an idea of time itself, independent of successive simple perceptions and relative motion:

> Wherever we have no successive perceptions, we have no notion of time, even tho' there be a real succession in the objects. From these phaenomena, as well as from many others, we may conclude, that time cannot make its appearance to the mind, either alone, or attended with a steady

[14] See Boehm's (2012) article on the notion of distance and its relation to extension in Hume.

> unchangeable object, but is always discover'd by some *perceivable* succession of changeable objects (T 1.2.3.7; SBN 35).

We can form adequate ideas about particular objects, their dispositions, intervals, successions, and motions. We cannot form an adequate idea of space and time in themselves; we do not have the ideas of an empty space or changeless time. Hume encapsulates his argument: "The ideas of space and time are therefore no separate or distinct ideas, but merely those of the manner or order, in which objects exist" (T 1.2.4; SBN 39-40, see also Wright 1983, 102).

Einstein's ontology of space and time, just like Hume's, is in connection with his empiricism. In his text "The Problem of Space, Ether, and the Field in Physics," he claims that "in any ontological question, our concern can only be to seek out those characteristics in the complex of sense experiences to which the concepts refer" (1934/1981f, 271). In his 1924 transcript, he makes a specific claim that our concepts "of space and time can only claim validity in so far as they stand in a clear relation to experiences" (Norton 2010, 369). In his *Physics and Reality*, he points out in a critical tone that the absolutist notions of space and time in "classical mechanics" are thought to be "independent of the empirical basis to which they owe their existence" (1936/1981g, 292, see also 1933/1981e 266-267).[15] If one wishes to find a concept that does have experiential, that is, observable and measurable consequences to the notions of space and time, the concept of a body can be regarded as one fruitful option. Einstein, in a Humean way, sees empiricism and relationism to be intertwined.

In his "Relativity and the Problem of Space," Einstein argues that concepts of space and time require a reference-body: "It appears to me, therefore, that the formation of the concept of the material object must precede our concepts of space and time" (Einstein 1954/1981i, 355; see also Lenzen 1949, 367). In a Humean way, he contends that the concept of a body, which is requisite for making judgments about spatial relations, requires tactile and visual impressions. Thus he writes:

> Now as regards the concepts of space: this seems to presuppose the concept of the solid body. The nature of the complexes and sense-impressions which are probably responsible for that concept has often been described. The correspondence between certain visual and tactile impressions [...] are some of those characteristics (Einstein 1934/1981f, 271).

Einstein defines space in terms of a body. A reference-body is requisite to justify the notion of space by an actual measurement: "it is necessary to have a body of reference for the measurement of a distance" (Einstein 1916/2001, 30). He argues that "certain visual and tactile impressions [...] are probably responsible for" the concept of a body, and that "the concept of the bodily object [...] is directly connected with complexes of sense experiences" (Einstein 1954/1981i, 354, see also *Ibid*., 355, 357). The content of this concept is justified by sense-perceptions: "The conception of physical bodies, in particular of rigid bodies, is a relatively constant complex of such sense perceptions" (Einstein 1922/2003, 2).

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[15] Einstein nonetheless recognizes that Newton's concept of acceleration required the reality of space and time, and emphasizes the meaning of these terms in Newton's system (Einstein 1954/1981i, 350). He is also very clear that he did not topple Newton (Einstein 1919/1981c, 227).

Einstein is clear that objects are not in space, but their extension is what enables us to make judgments about space: "Physical objects are not *in space*, but these objects are *spatially extended*. In this way the concept of 'empty space' loses its meaning" (Einstein 1916/2001, x). Edward Slowik (2005) has argued that Einstein's relationism about space is by and large analogous with René Descartes' denial of empty space, or vacuum. Einstein (1916/2001, 140, 157) writes that

> Descartes argues somewhat on these lines: space is identical with extension, but extension is connected with bodies; thus there is no space without bodies and hence no empty space.
>
> Descartes was not so far from the truth when he believed he must exclude the existence of an empty space.

Interestingly, Hume does also make a similar point in the first Book to the *Treatise*: "'tis impossible to conceive either a vacuum and extension without matter" (T 1.2.4.2; SBN 40, see also T 1.2.5.27; SBN 64). We cannot form an "idea of a vacuum, or space, where there is nothing visible or tangible" (1.2.5.1; SBN 53), that is, where there are no points. Hume does not believe that there is "a vacuum" in sense of a "pure extension" (1.2.5.10; SBN 57).

Similarly, a body of reference is needed in order to give a meaning to the concept of time. Importantly, motion is the measurable and observable attribute of a body that is requisite for this concept (Einstein 1905/1923, 39). Einstein's specific definition of time is based on judgments about simultaneous events. As he puts it in EMB:

> a mathematical description of this kind [of time] has no physical meaning unless we are quite clear as to what we understand by "time." We have to take into account that all our judgments in which time plays a part are always judgments of *simultaneous events*. (*Ibid*.)

In his own example, the meaning of a statement "train arrives at the station at seven o'clock" is this: "The pointing of the small hand of my watch to 7 and the arrival of the train are simultaneous events" (*Ibid*.) As simultaneity is relative to the state of motion of the observer, it follows that "every reference-body [...] has its own particular time; unless we are told the reference-body to which the statement of time refers, there is no meaning in a statement of the time of an event" (Einstein 1916/2001, 28-29).

In his *Physics and Reality*, Einstein claims that we do not have the concept of time without "connecting the temporal sequence of experiences with the readings of a "clock," i.e., of a periodically recurring closed system." His position is that a comparison between a sequence of experiences and a closed periodical system is enough for the concept of a time. It is not necessary to have the notion of time in itself, as he argues:

> ... as I see it, it does not mean a *petitio principii* if one puts the concept of periodical recurrence ahead of the concept of time, while one is concerned with the clarification of the origin and of the empirical content of the concept of time (Einstein 1936/1981g, 291).

He does allow that this definition contains arbitrariness, as he puts it in the *Meaning of Relativity*:

> I can, indeed, associate numbers with the events, in such a way that a greater number is associated with the later event than with an earlier one; but the nature of this association may be quite

> arbitrary. This association I can define by means of a clock by comparing the order of events furnished by the clock with the order of the given series of events. (Einstein 1922/2003, 1-2)

The concept of time can be conceived by inventing a series of integer numbers, and by associating these numbers to sensory experiences. To associate smaller numbers with "earlier" and larger numbers with "later" requires invention and an auxiliary convention. The concept of time does not automatically grow out of the givens of sensations (Einstein 1944/1981j, 33).

Both Hume and Einstein regard bodies to be intrinsic reference points for the notions of space and time. The concepts of space and time are in relation to the observable, relational, and measurable attributes of physical objects.[16] Hence the notions of absolute space and time are not justifiable, nor required. As Einstein summarizes his relationist view in the fifteenth edition to his popular book *Relativity. The Special and General Theory*: "I wished to show that space-time is not necessarily something to which one can ascribe a separate existence, independently of the actual objects of physical reality" (Einstein 1916/2001, x).

5. *Conclusion*

The main thesis of this article is that empiricist theories of ideas and concepts are intertwined with relationist and not with absolutist notions of space and time in Hume and Einstein. This crucial point has been neglected by the previous scholarship done on the topic, so the article contributes to our understanding of the relationship of Hume and Einstein. Inquiring into Hume's theory of perception also clarifies some of the philosophical background assumptions related to the concepts of space and time in Einstein's STR. It is nevertheless important to stress that Hume's and Einstein's views on these issues have important differences—notably, Einstein's theory of concepts emphasizes conventionality, which differs markedly from Hume's radically empiricist copy principle—but they do share a common understanding about the meaning and justification of ideas and concepts. It should be concluded that these empiricist aspects of their epistemologies are intrinsic to their conceptions of space and time.

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[16] Regarding time, it may be added that Hume does not universally think that acquiring its idea requires a physical reference object. Hume asserts a maxim according to which "*an object may exist, and yet be no where*" (T 1.4.5.10; SBN 235). The abstract idea of time can be caused by impressions which are not themselves physical objects. However, Hume's position is not very consistent, as he also claims that impressions "depend upon natural and physical causes" (T 2.1.1.2; SBN 275).

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