NEWTONIAN AND NON-NEWTONIAN ELEMENTS IN HUME

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ABSTRACT

For the last 40 years, Hume's Newtonianism has been a debated topic in Hume scholarship. The crux of the matter can be formulated by the following question: Is Hume a Newtonian philosopher? Answering to this permanent issue has produced two lines of interpretation. I shall call them "traditional" and "critical" interpretations. The traditional interpretation asserts that there are many Newtonian elements in Hume, whereas the critical interpretation seriously questions this.

In this article, I consider the main points made by both lines of interpretations, and offer further arguments that contribute to this debate. I shall first argue, in favor of the traditional interpretation, that Hume is sympathetic to many prominently Newtonian themes in natural philosophy, such as experimentalism, critique of hypotheses, inductive proof, and critique of Leibnizian principles of sufficient reason and intelligibility. Second, I shall argue, in accordance with the critical interpretation, that in many cases Hume is not a Newtonian philosopher: his conceptions regarding space and time, vacuum, reality of forces, specifics about causation, and the status of mechanism differ markedly from Newton's related conceptions. The outcome of the article is that there are both Newtonian and non/anti-Newtonian elements in Hume.

Key Terms: David Hume, Isaac Newton, Newtonianism

I INTRODUCTION

Stereotypically, Hume is considered to be a Newtonian philosopher. He did generally portray Newton in a very favorable way. For example, in his *History of England*, Hume's rhetoric concerning Newton's achievements reaches the limits of nationalist propaganda, as he writes that "in Newton this island may boast of having produced the greatest and rarest genius that ever arose for the ornament and instruction of the species" (*History*, VI, 542, see also RP 20; Mil 121–122). Thus it is hardly surprising that Hume is frequently called the "Newton of the moral sciences" (McIntyre 1994, see also Olson 1993, 98, and Porter 2003, 12). As Newton was so highly esteemed in Britain at the 18th century (see Fara 2002), Hume would have benefited from the Newtonian label in formulating the foundations of his science of human nature.

However, the precise nature of Hume's Newtonianism is a matter of great controversy. In what sense can it be said that Hume is a Newtonian philosopher? In the secondary literature, we find two distinctly recognizable lines of interpretation that address this issue: the "traditional," and the "critical" interpretations.[1] The first argues that there are many inherently Newtonian elements in Hume. This vantage point sees Newton's experimentalist methodology and critique of hypotheses in gravity research to have made a deep impact on Hume. In turn, the critical interpretation tradition seriously questions that there are Newtonian elements in Hume. It points out that Hume does not really rely on Newtonian philosophy in formulating the foundations of his philosophical system, his science of man.

In this article, I shall consider the main points made by both interpretations, and offer further arguments that contribute to this debate. In the next section, I shall argue that Hume is sympathetic to many prominently Newtonian themes in natural philosophy, such as experimentalism, critique of hypotheses, inductive proof, and critique of Leibnizian principles of sufficient reason and intelligibility. In the subsequent section, I shall argue that in many cases, Hume is not a Newtonian philosopher: Hume's and Newton's conceptions regarding space and time, vacuum, reality of forces, specifics about causation, and the status of mechanism differ markedly. In the conclusive section, I recapitulate the traditional and critical interpretations, and conclude that there are Newtonian and non/anti-Newtonian elements in Hume.

II THE TRADITIONAL OUTLOOK: HUME AS AN EXPERIMENTALIST NEWTONIAN PHILOSOPHER

Experimentalism, Intelligibility, and Critique of Hypothesis

Newton, by his own account, is an experimental philosopher. He distances himself from Descartes and Leibniz, who he takes to be the archetypes of hypothetical and speculative philosophers.[2] In his letter to Roger Cotes in 1713, Newton writes:

> Experimental philosophy reduces phenomena to general rules and looks upon the rules to be general when they hold generally in phenomena. It is not enough to object that a contrary phenomenon may happen but to make a legitimate objection, a contrary phenomenon must actually be produced. Hypothetical philosophy consists in imaginary explications of things and imaginary arguments for or against such explications, or against the arguments of experimental philosophers founded upon induction. The first sort of philosophy is followed by me, the latter too much by Descartes, Leibniz, and some others (Newton, Janiak, 2004, 120–121).

In the General Scholium to the *Principia*, Newton defends his work as experimentalist philosophy against the critique of his Cartesian and Leibnizian interlocutors. Newton's theory of gravity does not produce any contact mechanism or fluid in which gravity would physically act. He postulated an invisible force of gravity that acts between centers of masses of bodies, not between the common boundaries of the contiguous parts of them (*Principia*, Definition 8, and Newton, Janiak, 2004, 22). One can imagine that this force would somehow have to penetrate into hard, supposedly impenetrable bodies. This postulate deviated radically from the mechanical philosophies of Galileo, Descartes, Boyle, and Huygens. Leibniz was particularly dissatisfied with this kind of postulate. He could not find an intelligible mechanical explanation for such a force. He did not accept the fact that a body could be moved naturally if there was no other body that would touch and push it. In his correspondence with Samuel Clarke in 1717, he was highly critical of Newton for introducing "a strange imagination to make all matter gravitate […] towards all other matter." Leibniz added that gravitational attraction is "a chimerical thing, a scholastick occult quality" (Leibniz 1717, §35, §122).

In his correspondence with Richard Bentley in 1693, Newton is clearly puzzled by the fact that gravity acts through empty space without any contact mechanism (see Newton, Janiak, 2004, 102–103). He agrees that gravity entails unintelligible properties: action at a distance without a medium "is," he writes, "to me so great an absurdity, that I believe no man who has in philosophical matters a competent faculty of thinking can ever fall into it."

Newton famously answers to this difficult problem in the General Scholium by contending that he does not feign hypothesis. According to Newton, in natural philosophy, one does not have to provide a principle which meets the standards of mechanical intelligibility. Although Cartesian mechanical natural philosophy (as well as the late medieval Aristotelian natural philosophy) formed an important intellectual background for Newton's work (Smith 2008, section 1.2, and Janiak 2013a, section 4.2), he went on to radically change the standards of the mechanical philosophy. As Peter Dear (2006, 34) explains, Newton "took the intelligibility of Cartesian-style mechanical explanation as the starting point in his search for a better kind of natural philosophy," but he then "identified precisely where that kind of intelligibility *failed* to yield a satisfactory natural philosophy." In Newton's account, the core problem with the "Cartesian-style" mechanical natural philosophy is the framing of hypotheses that are not amenable to empirical investigation (Kochiras 2011, 173–174). A good example of this is Descartes' "hypothesis of vortices," which by means of *a priori* speculation intends to give an intelligible basis for the motions of astronomical objects (see also Anstey 2005, 234–235).

Newton's position is that natural philosophical principles have to be deduced from phenomena by the method of demonstrative induction.[3] Even though these principles, judged from the viewpoint of the traditional mechanical philosophy, reflect some unintelligible features, they cannot be revoked by any contrary hypothesis, only because their lack of such intelligibility. Thus Newton writes:

> For whatever is not deduced from the phenomena must be called a hypothesis; and hypotheses, whether metaphysical or physical, or based on occult qualities, or mechanical, have no place in experimental philosophy. In this experimental philosophy, propositions are deduced from the phenomena and are made general by induction.

Newton does not elude hypotheses altogether. By "hypothesis" he means "only such a proposition as is not a phenomenon nor deduced from any phenomena but assumed or supposed without any experimental proof" (Newton, Janiak, 2004, 118). Hypotheses can be used to the extent that they have testable implications, "in so far as they may furnish experiments," but they must not be used "in determining […] the properties of things" (Newton, 1974b, 5–6). Provisional physical hypotheses are constitutive of doing natural philosophy (as is indicated by his ether hypothesis in the *Opticks*, Query 21, and by his "Corporeity of Light" theory, see De Pierris 2006, 284–285), but its "main business" is still "to argue from phenomena without feigning hypotheses" (*Opticks*, Query 28). To Newton (1974b, 6), contemplating hypotheses is an example of "improper argumentation."

Hume is sympathetic to Newtonian experimentalism. In the Introduction to the *Treatise*, Hume emphasizes the importance of experimentation, observation, and experience, and eschews hypotheses (especially in T Intro 8–10; SBN xvii–xviii).[4] He does this roughly in the same manner that Newton did in arguing for his methodology in gravity research.

Hume thinks that philosophical reasoning is to stay within the bounds of experience, that is, within the results of "careful and exact experiments, and the observation of those particular effects" (T Intro 8; SBN xvii). For Hume, "the utmost extent" of human reason is when we acknowledge "our ignorance, and perceive that we can give no reason for our most general and most refined principles, beside our experience of their reality" (T Intro 9; SBN xviii). Like Newton, Hume also wants to be careful "in avoiding that error, into which so many have fallen, of imposing their conjectures and hypotheses on the world for the most certain principles" (T Intro 9; SBN xix). As Newton thinks that hypotheses, in his language, propositions not deduced from the phenomena, "have no place in experimentalist philosophy," so Hume also asserts that "any hypothesis, that pretends to discover the ultimate original qualities of human nature, ought at first to be rejected as presumptuous and chimerical" (T Intro 8; SBN xvii). Neither natural nor human sciences can "go beyond experience, or establish any principles which are not founded on that authority" (T Intro 10; SBN xviii).

Reading the Introduction of the *Treatise* as a manifestation of Newtonian philosophy has been challenged by Steffen Ducheyne (2009) and Eric Schliesser (2009). They point out that the label "experimental" was common in many textbooks of natural philosophy at Hume's time. The entry of "Experimental" in Chamber's (1728, 368) dictionary mentions, among Newton, also Francis Bacon, Accademia del Cimento, the Royal Society, the Royal Academy of Paris, and Richard Boyle. Schliesser (2009, 173) makes the specific point that Hume's endorsement of experimentalism is closer to Boyle's scientific methodology than Newton's.

I am partially sympathetic to these claims. Hume does not explicitly mention Newton by name in the Introduction to the *Treatise*. As his education in natural philosophy included the study of Hooke and Boyle (Rosenberg 1993, 65), it is not reasonable to assume that the Introduction to the *Treatise* is *exclusively* Newtonian in spirit. But there are two salient reasons to think that it is particularly (not exclusively) Newtonian.

First, Hume is especially critical about hypotheses (specifically in T Intro 9; SBN xix, see also Buckle 2011, 27). In his other writings (EHU 7.25; SBN 73, fn. 16, *History*, VI, 542),[5] Hume clearly recognizes that it was *Newton* who criticized hypotheses on the basis of his experimentalist methodology. Critique of hypotheses in the context of experimentalist methodology is a particularly Newtonian thought, as Newton's anti-hypothetical rhetoric became to be the most famous objection to the speculative philosophy among the early modern British natural philosophers (Anstey, Vanzo, 2012, 518).

Second, although Hume reveres Boyle's experimental work, for example, his experimentation with the air pump, he does not accept Boyle's mechanistic speculation about the hidden microstructure and configuration of bodies, his corpuscularianism. Hume considers this to be imaginary (*History*, VI, 542). Hume's experimentalism is thus closer to Newton[6]: In rule 3 of the *Principia* (795–96), Newton argues that the qualities of bodies, like their extension and impenetrability, can be known only by experimentation and inductive inference, not by *a priori* assumptions of primary qualities of matter. Newton's contentions, such as "the qualities of bodies can be known only through experiments," and "idle fancies ought not to be fabricated recklessly against the evidence of experiments," are very congenial to Hume's experimentalism (De Pierris 2006, 282–283).

Although Newton and Hume do not usually apply the term "experimental" in the same way,[7] in Rule 3 to the *Principia* Newton's use of the word "experimental" is similar to Hume's application of the term, which emphasizes regular experience, and extrapolation from the observed to the unobserved. In this generally Galilean tradition of experimentation, experiential conviction of a natural philosophical principle is based on the memory of the past instances that have been (collectively) experienced to be regular. For example, it can be witnessed that bodies fall at the same rate every time the experimental procedure is executed (Dear 1995, 125).

As Tamás Demeter (2012, 583) suggests, it is the "experimental method of reasoning" that is relevant for Hume, with a special emphasis on "*reasoning*" and not only "experimental method." Hume's experimentalism is thus intimately related to his conception of causality, because experimentation provides a way to identify causality. Matias Slavov (2013) argues that investigating into Newton's methodology in gravity research increases our understanding of Hume's conception of causality, since Newtonian experimentalism is clearly at its intellectual background. Hume is explicit that the source of causal relations is experience: "'tis evident *cause* and *effect* are relations, of which we receive information from experience" (T 1.3.1.1; SBN 69, see also EHU 4.4; SBN 26, EHU 4.6; SBN 27, EHU 4.14; SBN 32). Hume understands experience as observed constant conjunction between species of objects (T 1.3.6.2; SBN 87). The relation between causes and effects is not known *a priori*: there is nothing in reason, in the faculty of the human understanding itself that would inform us about any putative causal relations. Hence causation does not reflect intelligibility (see Millican 2007, xxx). Hume writes the following:

> If we reason *à priori*, any thing may appear able to produce any thing. The falling of a pebble may, for ought we know, extinguish the sun; or the wish of a man controul the planets in their orbits (EHU 12.29; SBN 164).

In Hume's account, as Alexander Rosenberg (1993, 73) argues,

> the whole notion that causation rests on or reflects the intelligibility or rationality of sequences among events is a mistake. Accordingly, for Hume, the aim of science cannot be to reveal the intelligible character of the universe, but simply to catalogue the regularities that causal sequences reflect.

As causation does not, nor does it have to, reflect intelligibility, Hume is able to accept the law of universal gravitation as a law of nature.

Inductive Proofs

Newtonian inductivism is apparent in Hume's positive account of causation. He thinks that uniform causal relations, such as the propositions concerning Newtonian laws, can be inductively proved (although the justification for these principles remains fallible). Graciela De Pierris (2001, 2012) shows that there are clear analogies between Newton's rule 4 for the study of natural philosophy, which concerns inductive generalizations, and Hume's attitude toward provable propositions which have "hitherto admitted of no exception" (EHU 6.4; SBN 57). Newton's original formulation of the rule is this:

> In experimental philosophy, propositions gathered from phenomena by induction should be considered either exactly or very nearly true notwithstanding any contrary hypotheses, until yet other phenomena make such propositions either more exact or liable to exceptions.

Hume thinks, in a Newtonian way, that as propositions concerning laws of nature are inductive generalizations, these propositions may be revised only if further empirical evidence forces us to revise them. In this sense, propositions expressing laws of nature are inductively proven.

Reading Hume as accepting the method of inductive proving in natural philosophy has been challenged by Eric Schliesser (2009, 168). In his view,

> for Hume the human sciences can attain the high epistemic status of 'proof', while much of the physical sciences must do with lower forms of 'probability' […] Hume's fundamental epistemic categories privilege common life and moral philosophy over parts of natural philosophy.

Schliesser's argument runs as follows. Proofs of common life are supported by collective uniform experience of humankind going back to prehistory. However, Newtonian laws of nature, such as the inverse-square law, "are known to and accepted by only a very narrow part of the collective experience of mankind" (Schliesser 2009, 184). Proofs of common life are thus categorically privileged over parts of natural philosophy. "In principle," Schliesser (2009, 185) explains, "the 'science of man' can be the subject of more reliable knowledge than important parts of natural philosophy."

I disagree with Schliesser's above reading for two reasons. First, Hume sees a continuum between every day reasoning and scientific research. In the first *Enquiry*, and in the *Dialogues* with the voice of Philo, Hume claims that

> Those who have a propensity to philosophy [scientific research], will still continue their researches; because they reflect, that […] philosophical decisions are nothing but the reflections of common life, methodized and corrected (EHU 12.25; SBN 162).

> … what we call *philosophy* is nothing but a more regular and methodical operation of the same kind [of common life]. To philosophise on such subjects is nothing essentially different from reasoning on common life; and we may only expect greater stability, if not greater truth, from our philosophy, on account of its exacter and more scrupulous method of proceeding (DNR 1.9; KS 134).

In the quotes above, Hume does not draw any sharp dividing line between every day reasoning and scientific research. Rather he understands scientific research to be a methodized and corrected form of every day reasoning. It is also more stable, exact, and scrupulous than reasoning in common life.

Second, Schliesser's reading of Hume's categorization of proofs and probabilities is fallacious. It is not true that physical sciences have a lesser degree of probability than facts concerning human nature, as he (2009, section 'Proofs of common life') indicates. Rather than being two different epistemic categories, they are members of the same epistemic category. In the sixth section to the first *Enquiry*, Hume categorizes the propositions of mixed mathematics (Newton's second law of motion, and the law of universal gravitation) in the same way as propositions of common life (fire burns and water causes drowning to non-aquatic beings). Facts, concerning the nature and the human nature, are labeled as proofs. The logic of induction and degree of certainty is the same in both kinds of facts because both are dependent on the uniformity principle.[8] Thus Hume concludes his argument: "All our reasonings concerning fact are of the same nature" (EHU 4.4; SBN 26).

Critique of Leibniz's Principle of Intelligibility

Both Newton's and Hume's positions are critical of Leibniz's principles of sufficient reason and intelligibility. In the *Monadology* (§32), and in his second letter to Clarke in their correspondence, Leibniz writes that

> of *sufficient reason*, in virtue of which we hold that no fact could ever be true or existent , no statement correct, unless there were a sufficient reason why it was thus and not otherwise.
>
> … in order to proceed from *Mathematicks* to *Natural Philosophy*, another Principle is requisite […] I mean, *the Principle of a sufficient Reason*, viz. that nothing happens without a *Reason* why it should be so, rather than *otherwise*.

In Donald Rutherford's (1992, 36) interpretation, Leibniz's principle of sufficient reason is founded on to his principle of intelligibility. The latter principle contains the former. The principle of intelligibility, in the broadest sense of the term, means that for any fact, truth, principle, or event, there is a reason why the fact or event is like it is, not otherwise.[9] Regarding universal gravity, this would mean that there is a mechanical reason for why the long-range action of gravitation is predicable of the force of gravity. In Leibniz's view, the law of gravity has to meet the standards of mechanical intelligibility if it is to be an acceptable principle in natural philosophy.[10]

In the General Scholium to the *Principia*, Newton is not willing to swallow the Leibnizian bait. Newton allows that he cannot tell "what the reason for" the unintelligible properties of gravity are. He nevertheless defends his theory on empirical grounds: the law of universal gravitation can be deduced (provided with a number of structural assumptions and background assumptions, see Belkind 2012) from the data gathered from pendulum experiments and astronomical observations. This empirical method provides "the highest evidence that a proposition can have in this philosophy" (Newton 1974a, 6). The fact that natural philosophical propositions entail properties that are not intelligible according to the standards of the mechanical philosophy confers no legitimacy to their rejection.

Hume is sympathetic to Newtonian experimentalism and reluctant concerning Leibnizian demand for reason and intelligibility. In his *History*, Hume comments on Newton's experimentalism and his critique of hypothesis by describing him as "cautious in admitting no principles but such as were founded on experiment; but resolute to adopt every such principle, however new or unusual" (*History*, VI, 542, see also De Pierris 2006, 304–305). Importantly, Hume does not think that natural philosophical principles require intelligibility; they can be accepted on experimental grounds, "however new or unusual" they are. In a Newtonian and anti-Leibnizian fashion, Hume claims that "we can give *no reason* for our most general and most refined principles, beside our experience of their reality" (T Intro 9; SBN xviii, my emphasis). Propositions concerning laws of nature are principles supported by uniform experience of causal relations. According to Hume's account, these causal relations do not have any sufficient reason for their operations: there is no "*satisfactory reason*, *why* we believe, after a thousand experiments, that a stone will fall" (EHU 12.25; SBN 162, my emphasis). Instead of reason or intelligibility, Hume emphasizes that "all the laws of nature, and all the operations of bodies without exception, are known only by experience" (EHU 4.9; SBN 29).

This section has shown that Hume is a Newtonian philosopher in many respects. He is sympathetic to a variety of prominently Newtonian themes of natural philosophy, such as experimentalism and critique of hypothesis, and the method of how propositions concerning laws of nature can be justified by fallible inductive prooving. Like Newton, Hume does not accept Leibnizian principles of sufficient reason or intelligibility.

In the next section, I proceed to analyze in what way Hume and Newton differ. I begin the section by articulating differences between their views on space and time, since these are themes in which Hume's and Newton's views clearly differ.

III DISSIMILARITIES BETWEEN NEWTON AND HUME

Space and Time

In the first book to the *Principia*, Newton (1999, 408) defines space and time in absolute terms. His aim is to show that his laws of motion are objective descriptions of the material world (see DiSalle 2004). The first and the second law of motion require a distinction between true and relative motions (see Newton 1999, 412). If an object is impressed by a force, the object moves, independent of its inertial motion, "along the straight line in which that force is impressed" with a definite quantity of motion (Newton 1999, 416). Definition of a "straight line" is provided by absolute three dimensional Euclidian space (Earman 1989, 9, Maudlin 2012, 5). As object moves a definite, objective distance relative to absolute space, it does it in a definite, objective, and absolute time. Thus Newton's "conceptions of space and time," as Robert DiSalle (2004, 34) puts it, "are assumptions implicit in laws of physics."

Hume's argumentation concerning space and time is based on to his copy principle. This principle implies that the mind cannot conceive infinitesimals (T1, Parts 1–2). Hume's approach is not, in its foundations, related to physics (see Falkenstein 2013). However, both Newton and Hume make epistemic and ontological commitments concerning space and time. In this respect, their views can be compared in a meaningful way, and it is possible to articulate a clear difference between the two.

Newton (1999, 408) begins his argumentation concerning space and time by eliminating "certain preconceptions." He contends that it is erroneous to think that space and time are "conceived solely with reference to the objects of sense perception." Newton posits that "abstraction from the senses is required" (Newton 1999, 411). Although Hume also holds space and time to be abstract (ideas), he takes a different approach in his philosophy of space and time. In the context where he is discussing space and time, Hume claims that

> *As* long as we confine our speculations to *the appearances* of objects to our senses, without entering into disquisitions concerning their real nature and operations, we are safe from all difficulties, and can never be embarrass'd by any question […] If we carry our enquiry beyond the appearances of objects to the senses, I am afraid, that most of our conclusions will be full of scepticism and uncertainty (T 1.2.5.26; SBN 64, fn. 12).

According to Newton, space is empty; it exists independent of objects (Newton, Janiak, 2004, 13). This is contrary to Hume's understanding which assimilates space to perceivable extension. Without "*visible or tangible points distributed in a certain order*" we would not have any idea of space (T 1.2.5.1; SBN 53, see also T 1.2.3.5; SBN 34). Consequently Hume thinks that we do not have any idea of empty space, or vacuum (T 1.2.4.2; SBN 40). There are important similarities between Hume's conception of space as extension and Descartes' related understanding in his *Principles of Philosophy*. Newton, in his tract "Descartes, Space, and Body" (2013, section 7), criticizes Descartes directly on assuming "that there is no difference between body and extension," as in Descartes extension is an attribute of the substance of body. Thus Hume can be seen rather a Cartesian than a Newtonian regarding space.[11] Furthermore, Hume shares Descartes' understanding of the inconceivability of a vacuum.[12]

Hume's doubt of vacuum also brings out an issue in his understanding of Newtonian laws of nature. Hume endorses Newtonian laws in the sixth section to the first *Enquiry*, and in footnote 16 to EHU 7.25 (SBN 73). But it is difficult to see how he could fully subscribe to Galilean-Newtonian laws without embracing the idea of a vacuum. For example, consider the following observation that Newton (1999, 939) makes in the General Scholium:

> The only resistance which projectiles encounter in our air is from the air. With the air removed, as it is in Boyle's vacuum, resistance ceases, since a tenuous feather and solid gold fall with equal velocity in such vacuum.

If Hume does not, like Newton, readily accept the existence of a vacuum, how could he then sustain that the acceleration of falling objects is independent of their mass? Accepting Galileo's law of falling bodies (which is a special case of Newton's law of universal gravitation) requires understanding that scientific principles are idealizations and abstractions. This understanding is not apparent in Hume's account of natural philosophy, which emphasizes repeated experience and direct perception.

In Newton the flow of time is absolute as it occurs "in and of itself and of its own nature, without reference to anything external" (Newton 1999, 408). The structure of time is entirely independent of any observers, objects, or events. The rate of flow of time does not depend on any change of objects, like succession or change in their motion.

Newton's philosophy of time is contrary to Hume's philosophy of time. Hume thinks that only succession and motions of objects cause the idea of duration of an object (T 1.2.3.11; SBN 37, T 1.2.3.7; SBN 35, T 1.2.3.7; SBN 35). Co-existent objects may have different durations depending on observers' relation to particular objects (see Baxter 2008, 37). Steady, unchangeable objects do not instantiate duration (T 1.2.3.7; SBN 35). The (abstract) idea of time cannot be correctly applied to them. Thus there is no absolute flow of time independent of objects and observers' relations to them. In Hume, duration is in relation to objects and perceptions, whereas; in Newton, duration is not related to objects in any way but it is an absolute and self-sustaining structure.

Reality of Forces

Regarding the reality of the force of gravity, Newton (1999, 943) claims in the General Scholium that “gravity really exists and acts according to the laws that” he has set down in the *Principia*. Newton makes this claim although the force of gravity is not a manifest phenomenon directly accessible to our senses. We do not observe this force but we are able to infer that it is a cause to observable phenomena. Steffen Ducheyne (2012, Chapter 1) shows that Newton takes causes to be ontologically primary to effects (although causes remain epistemologically secondary). Ori Belkind (2012, 143) expounds Newton’s inference of reality of gravity as follows:

> From the observed motions of the planets, for example, Newton derived the existence of a gravitational force. This force goes “beyond” or “behind” phenomena, and can be taken as the cause that generates the phenomena.

Although some introductory expositions to the history of science (e.g. Pine 1989, DeWitt 2004, and Millican 2007) portray Newton as an instrumentalist concerning the force of gravity, recent scholarship on Newton (Janiak 2007, Kochiras 2011, Belkind 2012, Ducheyne 2012) emphasizes Newton’s insistence on reality of forces as true causes of motion. It is true that Newton is dissatisfied with action at a distance without a contact mechanism, and that he does provisionally refer to forces and centers of masses only in mathematical and not in physical terms (*Principia*, First Book, Definition 8, see also Westfall 1993, 188). I. Bernard Cohen clarifies this issue as follows. In his research on the relation of centripetal forces to Kepler’s area law, Newton *begins* his research by inquiring into mathematical, rather than physical, proportions of forces. *After* that he concludes that “a mathematically descriptive law of motion” is ”equivalent to a set of causal conditions of forces and motions,” as Cohen (1980, 28) puts it.

It is unequivocally clear that Newton takes forces to be the true causes of changes of motion. In the *Principia*, Newton presents the following counterfactual argument. Without the centripetal force of gravity, there would be no planetary orbits or projectiles but objects would “go off in straight lines with uniform motion” (Newton 1999, 405). Newton also thinks this force exists as it is a measurable quantity (unlike ether) (Ducheyne 2012, 30). Determining this quantity requires completely uncontroversial quantities of mass and distance

(Janiak 2007, 81). Furthermore, if Newton were an instrumentalist about forces, i.e., if he would have understood them only in mathematical but not in physical terms, why would he have referred to absolute space and time to make a distinction between true and relative motions in the Scholium to the Definitions of the first book to the *Principia*? It should be concluded that Newton is a realist about forces causing accelerations.

Because of his copy principle, Hume does not allow making inferences from phenomena manifest to our senses to their putative unobservable causes. According to Hume, knowledge of causation (which is the founding relation in matters of fact) is founded on experience, that is, on observed constant conjunction between species of objects. Hume's rules for causal inference do not license a Newtonian derivation from "beyond" or "behind" phenomena to phenomena. Thus he sketches the goal of his philosophical project: "I content myself with knowing perfectly the manner in which objects affect my senses, and their connections with each other, as far as experience informs me of them" (T 1.2.5.26; SBN 64). Hume cannot take unobservable causes to his ontology. Ideas are caused by impressions. We do not have ideas about unobservable causes.

Regarding Newton's first and second laws, the law of conservation of momentum, and the law of universal gravitation, Hume emphasizes that they are found or discovered "by experience" (EHU 4.13; SBN 31, 7.25; SBN 73, fn. 16). When addressing the principles of inertia and gravity, Hume argues that "we only mark these facts, without pretending to have any idea of the inert power; in the same manner as, when we talk of gravity, we mean certain effects, without comprehending that active power" (EHU 7.25; SBN 73, fn. 16). The knowledge we have about laws of nature comes from our senses and observations of constant conjunctions. What we perceive is motion, not forces or powers:

> Sight or feeling conveys an idea of the actual motion of bodies; but as to that wonderful force or power, which would carry on a moving body for ever in a continued change of place, and which bodies never lose but by communicating it to others; of this we cannot form the most distant conception (EHU 4.16; SBN 33).

Although we do use words such as force and power, "that is no proof, that we are acquainted, in any instance, with the connecting principle between cause and effect, or can account ultimately for the production of one thing by another" (EHU 7.29; SBN 77, fn. 17).

“Frequent Conjunction of objects” is available to us by experience, but we are never “able to comprehend any thing like Connection between them” (EHU 7.21; SBN 70, see also Garrett 2015, 38).

In my interpretation, Hume, unlike Newton, understands the concept of force instrumentally.[13] Rather than asserting the reality of forces, Hume argues that the term force is a mathematical instrument, a calculating device which *relates* cause to its effect, to its change in state of motion: “the idea of power is *relative* as much as that of cause; and both have a reference to an effect” (EHU 7.29; SBN 77, fn. 17, my emphasis). Forces and powers are relative to causes, and these causes refer to observable effects. “The degree and quantity” of an effect “is fixed and determined” by a force or power. The effect can be predicted by measuring the cause: “the effect is the measure of power.” Forces are measurable quantities despite the fact that we do not have any corresponding impression-based ideas of them. What is known about forces is what the mathematical proportions of laws of nature say about them. Beside the mathematics of force laws and phenomenal constant conjunctions of objects we do not comprehend what forces are. To Newton the measurability of force is evidence of its existence, whereas; to Hume this measurability means that the magnitudes of causes and effects[14] can be expressed in precise mathematical terms. By his instrumentalism, Hume remains agnostic on whether there are mind-independent powers or forces that necessitate and ground laws of nature.[15]

Reading Hume as an instrumentalist regarding forces would certainly be challenged by the New Hume skeptical realist reading. The crux of the skeptical realist reading is this: observable regularity is not all there is to causation; there are secret powers and forces that underlie and necessitate these regularities, although the nature of these powers and forces is epistemically inaccessible to us (Kail 2011, 448). Despite the fact that the nature of these mind-independent entities remains a secret to us, we are still able to assert their existence and we can refer to them (Beebee 2006, 173). There is textual evidence for this reading. For instance, in EHU 8.4 (SBN 82, also EHU 7.8; SBN 63–64), Hume writes that “it is universally allowed, that matter, in all its operations, is actuated by a necessary force.” This piece of evidence suggests that Hume would think that a force necessitates all material operations in nature. However, in the end of this particular paragraph, and in the next paragraph, Hume explains what he means by necessity in this context. He asks how do we "form a just and precise idea of *necessity*." In the next paragraph, his answer is explicit:

> Our idea, therefore, of necessity and causation arises entirely from the uniformity, observable in the operations of nature; where similar objects are constantly conjoined together, and the mind is determined by custom to infer the one from the appearance of the other. These two circumstances form the whole of that necessity, which we ascribe to matter (EHU 8.5; SBN 82).

As Peter Millican (2009, 647–648) shows, the source of our idea of power or necessary connection is copied from a subjective impression, which is a feeling or "a reflexive awareness, of making customary inferences in response to observed constant conjuctions." Thus "causation is reduced to being a matter of regularity or constant conjunction." Hume remains agnostic on whether there is metaphysical necessity in nature. We feel that some natural operations are necessary because of customary, habitual, and instinctive reasons. Propositions concerning laws of nature are matters of fact—a point in which Hume is explicit (EHU 4.13; SBN 31, 7.25; SBN 73, fn. 16)—and only propositions concerning relations of ideas, namely the propositions of pure, non-applied, and non-factual mathematics, instantiate absolute necessity. Hume's copy principle and his understanding of causation as observed constant conjunction do not license us to infer that laws of nature are necessitated or grounded by mind-independent forces.

Specifics of Causation and the Status of Mechanism in Newton and Hume

Regarding the specifics of causation, there are three points in which Newton and Hume differ.[16] In the *Treatise* 1.3.15 (SBN 173–175), Hume's rules for judging causes and effects demand contiguity, as well as temporal succession. Both of these arguments are in tension with Newton's laws. First, the law of universal gravitation does not satisfy the contiguity criterion: the most distant particles of the universe attract each other. Second, gravity law and Newton's second law do not match with Hume's rule for temporal sequence: the exercise of force is simultaneous with acceleration. Newton thinks that there is simultaneous causation in nature, which Hume regards as an argument of *reductio ad absurdum* (Ryan 2003).[17] Third, Hume does not accept ultimate causes, as Newton (1999, 940–943) does in his theological considerations, for instance, in his argument for design in the General Scholium. According to Newton, motions of objects are governed by a causal chain. The proximate cause for a motion of an object is an impressed force or gravity. Gravity has a proximate cause. The ultimate, most remote cause for motions of objects is God (Ducheyne 2012, 22). Hume's rules of causation (especially rule 4), namely his insistence of observable constant conjunction between species of objects, do not license a reference to the original cause of the universe. Regarding ultimate causes, Hume is agnostic: we do not have any experience of an ultimate cause originating motions in the universe (see especially EHU 11.20; SBN 141, and EHU 11.30; SBN 147–48, and the *Dialogues*).

The main reason why Newton and Hume differ on specifics of causation is that the status of mechanism in their philosophies is different. Hume does certainly not, like the rationalist proponents of mechanical philosophy, such as Descartes and Leibniz, accept that we have an *a priori* insight into causal relations of the hidden microstructure of bodies (De Pierris 2006, 281). However, his conception of causation in the first Book to the *Treatise* indicates his tacit commitment to mechanism: natural effects are caused by contact between surfaces of bodies. Hume is uncomfortable with action at a distance, as he writes that

> tho' distant objects may sometimes seem productive of each other, they are commonly found upon examination to be link'd by a chain of causes, which are contiguous among themselves, and to the distant objects... (T 1.3.2.6; SBN 75)

Although Hume allows that contiguity is not always discovered in causal relations, for example, in the case of loadstone attraction (EHU 4.7; SBN 28), "we still presume it to exist." He thinks that "the relation of contiguity" is to be considered "as essential to that of causation" (T 1.3.2.6; SBN 75). As is well-known, Hume later abjures contiguity requirement in the first *Enquiry*. Yet his examples of causation in the first *Enquiry*, such as the famous billiard ball example (EHU 4.9; SBN 29), and his examples of the operations of clockworks, strings, pendulums, and wheels (EHU 8.13; SBN 87), indicate a mechanical understanding of causal relations between species of objects.

Newton (1999, 940) distances himself from mechanical philosophy. His dynamics is not purely mechanical. There are three types of forces in Newton: pressure, percussion, and centripetal force. The first two forces are mechanical, while the third is not. The centripetal force of gravity acts between masses, quantities of matter. A geometrical exposition for this attraction is provided by approximating the centers of masses of bodies (*Principia*, first Book, Definition 8). Newton encapsulates his non-mechanical position in the General

Scholium in asserting that gravitational force does not act "in proportion to the quantity of the *surfaces* of the particles on which it acts (as mechanical causes are wont to do) but in proportion to the quantity of *solid* matter." He is explicit about the fact that gravitational "motions do not have their origin in mechanical causes" (Newton 1999, 940, 943). In this sense, Hume's conception of causation is to be understood as a manifestation of pre-Newtonian mechanical philosophy, whereas Newton's conception of causation is dynamical.[18]

IV CONCLUSION

There are two main lines of interpretation of Hume's Newtonianism: the traditional, and the critical interpretation. In this article, I have insisted that it is not possible to reasonably support just one of these interpretation traditions. The traditional reading is right in emphasizing the constructive connection of Newton's natural philosophy to many of Hume's philosophical positions. Both Newton and Hume 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 Leibnizian principles of intelligibility or sufficient reason. The critical interpretation is also correct on several 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 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 ultimate, most remote cause for proximate causes, whereas Hume is agnostic with respect to ultimate 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.

As this article has shown, there are both Newtonian and non/anti-Newtonian elements in Hume. The traditional interpretation tradition is right in that Hume's philosophical project respects the experimentalist methodology of Newtonian natural philosophy and partially continues its legacy. However, some parts of Hume's philosophy are at odds with Newton's philosophy, as indicated by the critical tradition. In this sense, Hume is not a Newtonian in many cases, but relies more on to his science of man.[19]

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NOTES

[1] The traditional line of interpretation includes Nicholas Capaldi (1975), James Force (1987), Stephen Buckle (2004, 2011), Peter Millican (2007), Graciela De Pierris (2001, 2006, 2012), Charlotte Randall Brown (2012, 2014), Matias Slavov (2013), and William Edward Morris (2012, 2014). The critical interpretation tradition can be seen to include Larry Laudan (1981), Peter Jones (1984), Eric Schliesser (2009), Yoram Hazony (2009, 2014), Steffen Ducheyne (2009), Michael Barfoot (2010), and Miren Boehm (2013).

[2] On the distinction between experimental and speculative (or hypothetical) philosophy at the early modern period, see Anstey (2005).

[3] Belkind (2012) shows that Newton's argument for the law of universal gravitation requires at least four distinct arguments that lean on structural and background assumptions. Demonstrative induction is a process where an argument starts from an empirical premise (such as Kepler's area law), and an empirical conclusion (the gravitational force is centripetal) from this premise is deduced by applying the structural and the background assumptions.

[4] It should be noted that experiments in Hume's science of human nature differ from those in natural philosophy, as the former cannot do predictions: "Moral philosophy has, indeed, this peculiar disadvantage, which is not found in natural, that in collecting its experiments, it cannot make them purposely, with premeditation" (T Intro 10; SBN xviii–xix). See also Demeter (2012, 582).

[5] Hume is certainly aware of Newton's sympathies with some hypotheses, and of their provisional nature. In footnote 16 to EHU 7.25 (SBN 73), he refers to Newton as a "great philosopher" who "had recourse to an etherial active fluid to explain his universal attraction; though he was so cautious and modest as to allow, that it was a mere hypothesis, not to be insisted on, without more experiments."

[6] Hume's methodological sympathy to Newtonian philosophy is also made explicitly clear in EHU 1.14–1.15 (SBN 14–15, see also De Pierris' 2012, 158, fn. 4), and in the *History* (153, see also Demeter 2014, 179).

[7] The meaning of the word "experiment" in Hume is largely different from Newton's application of the term. Experimentation in scientific research, as in Newton's case, is usually understood as an idealization-involving activity where a target system is restricted and intervened on, and certain variables are manipulated (Walsh 2014, section 3.2). In Hume "experiments" do not refer to such activity. Rather, his application of the term is closer to "experience," as he defines it in T 1.3.6.2 (SBN 87).

[8] For a thorough analysis of the logic of Hume's "founded on" relation, see Millican (2002, section 10).

[9] About the distinction between truths and events in Leibniz's principle of sufficient reason, see Lin and Melamed (2010).

[10] Here my claim about Leibniz's standards of sufficient reason is confined to the context of his natural philosophy. Intelligibility according to the standards of sufficient reason is different from intelligibility according to the standards of mechanical philosophy. Mechanical reasons are not necessarily the only sufficient reasons.

[11] There are certainly intricate and important differences in Descartes' and Hume's argumentations concerning the connection between extension and body. But my specific point here is that Hume deviates from Newtonian natural philosophy as his philosophy of space can be understood to be closer to Cartesian natural philosophy.

[12] In his *Principles* (2.16) Descartes points out that "a vacuum or space in which there is absolutely no body is repugnant to reason." Likewise in the *Treatise* (1.2.4.2; SBN 39), Hume claims that "'tis impossible to conceive either a vacuum and extension without matter." However, in T 1.2.5 (SBN 53–65) Hume adds that it might be *possible* for us to acquire the idea of a vacuum. For a detailed analysis on Hume's position on vacuum, see Boehm (2012).

[13] For other instrumentalist interpretations of Hume on forces, see Millican (2002, 144–145, and 2007, 206).

[14] For this point, see Demeter (2014, 175).

[15] Note that I do not claim that Hume is an anti-realist about powers and of forces. I argue that his position is non-realist: he does not take an ontological stance about (in his view putative) entities that go beyond perceptions and constant conjunctions.

[16] Regarding the differences between Newton's and Hume's conceptions of causations, I rely on Schliesser's (2007) interpretation. It can be noted that Hume and Newton do, however, agree on repetition in causation (see Slavov 2013, 295). Hume argues that "the same cause always produces the same effect" (T 1.3.15.6; SBN 173). This argument is similar to Newton's rule 2 in Rules for the study of natural philosophy in the *Principia*: "Therefore, the causes assigned to natural effects of the same kind must be, so far as possible, the same" (Newton 1999, 795).

[17] It is interesting to note that Hume nowhere provides an analysis of Newton's third law of motion. This might be one reason for the tension between Hume's rules of causation and Newton's laws. Hume does not understand force as an interaction between members of an action/reaction pair. Rather, he takes forces to be causes that temporally precede their effects.

[18] For Newton's three conceptions of cause, see Janiak (2013b). Note that I do no claim that Newton excludes mechanical causes. Rather, Newton thinks that mechanical causes are not the only natural causes, whereas Hume's conception of causation is implicitly mechanistic.

[19] I wish to thank the following people who helped me with this article: Robert Callergård, for the weekly discussion we had while I was a visiting graduate student at the Department of Philosophy at the University of Stockholm; the anonymous reader of the journal, who made various valuable suggestions of improvement to the paper; the audience at a presentation given at the conference SCIENTIAE: Disciplines of Knowing in the Early Modern World, University of Toronto, May 29, 2015, and finally; Mikko Yrjönsuuri, Jani Hakkarainen, Vili Lähteenmäki, and Sara Heinämaa, as well as the participants of the philosophy PhD seminar at the University of Jyväskylä. My research has been supported by the Finnish Doctoral Programme of Philosophy, funded by the Academy of Finland together with the Ministry of Education and Culture.