The Mind-Body Problem and Conservation Laws: The Growth of Physical Understanding?

J. Brian Pitts
Faculty of Philosophy and Trinity College
University of Cambridge

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Abstract

The success of science, especially physics, is often invoked as contrasting with the degeneration of world-views involving immaterial persons. A popular question from the 17th century to the 21st is how human minds/souls could interact with bodies in light of physical conservation laws. Leibniz invented this objection and wielded it to motivate his novel non-interactionist dualism, pre-established harmony.

A historical treatment of how this objection has been made over the centuries *vis-a-vis* the growth of knowledge of physics and logical persuasiveness is desirable. Given the massive amount of material, selectivity is necessary. This paper covers the period until Euler. While physics has of course advanced subsequently, most of these advances are either irrelevant or perhaps even harmful to Leibniz's objection (except General Relativity). Many of the most important advances, such as the connection between symmetries and conservation laws (known to Lagrange in the early 19th century), were in any case unknown to philosophers. The 18th century debate involved leading figures in an era when physics and philosophy were less separated. Thus the 18th century debate, normatively construed, is instructive for today.

Keywords: vis viva, conservation laws, mind-body problem, Euler, Cartesianism

1 Introduction

This paper explores the early history of an argument, due originally to Leibniz, that the conservation of momentum and energy (or its ancestor *vis viva*) poses an objection to mental causation construed as the influence of a mental substance or mental properties on the physical, presumably the brain or body of the mind in question. This paper adds an historical angle to the more normative considerations of the previous articles in the series. The first paper [Pitts, 2019a] considered the logic of the objection, especially noticing aspects of physics between the mid-19th century (roughly the level typically employed in the philosophy of mind literature) and the 1910s, when local field theories became standard and the symmetry-conservation law link was fully understood due to the work of Emmy Noether. This paper found that such mental causation indeed causes energy and momentum not to be conserved, *pace* many dualist efforts or claims to respect conservation during the last century, and this result follows clearly from Noether's converse of her first theorem. Noether's first theorem says that symmetries imply conservation laws, so the converse is that conservation laws imply symmetries [Noether, 1918], or contrapositively, non-symmetries imply non-conservation. The symmetries of time- and space-translation invariance fail because the mind acts in certain places and times and not others, or more generally does not act in the same way at every point in space-time. However, the claim that conservation holds in the brain is obviously equivalent to a denial of the type of mental causation in question. Thus the erstwhile argument reduces to question-begging or an incredulous stare. That the argument is question-begging has been claimed occasionally in the last century or so [Ducasse, 1960, Averill and Keating, 1981, Larmer, 1986, Plantinga, 2007]. The frequency with which such a claim was made in the 18th century is part of the topic of this current paper and turns to be higher than one might have thought. This view has been called the "conditionality" response, because it takes conservation laws to hold conditional on the absence of non-physical influence. A companion paper explored the "varying constants" proposal by E. J. Lowe and showed how it does in fact violate the conservation laws, contrary to Lowe's claims [Cucu and Pitts, 2019].

Another paper [Pitts, 2019b] considers the question of whether Einstein's General Relativity, a quite innovative theory in may respects and the locus of a century-long controversy about gravitational energy and consequently the existence of physically meaningful conservation laws. A few authors have had the insight to apply General Relativity to the question of mental causation and energy causation; they invoked a standard gloss that General Relativity lacks physically meaningful conservation laws and concluded that General Relativity therefore facilitates such mental causation. This paper, however, reaches the opposite conclusion by way of novel calculations that are free of the interpretive controversy involving gravitational energy: General Relativity makes such mental causation harder, impossible in the simplest case but perhaps not in all cases, and the seriousness of the difficulty depends on background world-view issues such as theism *vs.* atheism. The theism-dualism link is of course not unprecedented [Bunge, 1980, Taliaferro, 1994, McGinn, 1999, Larmer, 1999, Foster, 2001, Meixner, 2004, Plantinga, 2007].

This paper attempts a *normative* exploration of the history of the issue from the late 1600s until sufficiently late that useful lessons can be learned for today. That turns out to be the mid-late 18th century, the time of Euler. A comprehensive treatment of the issue could fill a book; telling the reminder of the 320+-year story would fill another book. (To that end, good leads are available [Heidelberger, 2004, van Strien, 2015].) In the 19th and 20th centuries, the increasing gap between philosophy and what we would now call physics (including analytical mechanics) makes careful exploration of how philosophers either used or responded to the energy conservation objection to interactionism less rewarding, for much the same kind of reason that Ladyman *et al.* have warned against the philosophy of A-level chemistry as the accidental result of insufficiently informed attempts at the philosophy of physics [Ladyman et al., 2007, p. 24]. Such a normative history of the 19th and 20th centuries should still be written, but it would tend to undermine the presumption that contemporary philosophical opinion that claims to respect science actually succeeds in doing so.

Even a history up to Euler cannot be comprehensive, at least not within the scope of an article. The mind-body problem was extremely important in the 18th century Germany [Watkins, 1995b], involving many of the leading minds in philosophy and even some of the best in natural philosophy/physics. Serious discussions occurred in French, German and Latin, languages which, though not neglected here, have gotten less attention (due to the author's limitations) than have works written in or translated into English. Nonetheless a sufficiently stable picture has emerged. What this work offers is not a comprehensive picture that enters into the minds of the time and stays there, but rather a survey informed by a thorough understanding of the relevant physics (of the modern day but also with an eye to its historical development), which makes possible a normative perspective. This normative perspective is especially useful in that the position that will be singled out as (nearly) *correct* is one that many today think is (and quite a few in the 18th century thought was) in tension with physics: that interactionists should simply admit that the conservation laws fail in the context of mental causation. Indeed in the modern philosophy of mind literature, the claim that such mental causation indeed implies non-conservation *and* that this is no serious objection has been considered a bridge too far for almost everyone but the heartiest of religious *a priori* metaphysicians. Be that as it may, that this position follows from understanding the physics (especially Noether's first theorem and its converse) is argued by the previous papers in the series [Pitts, 2019a, Cucu and Pitts, 2019].[1]

This paper argues a complementary theme, namely, that the rejection of Leibniz's argument was the position of not only of some excellent philosophers, but also probably the position of the very best physicists, including Newton and Euler, more than a match scientifically for Leibniz, Wolff, and Bilfinger, the most physically astute proponents of the conservation objection. The normative and historical threads have a certain coherence: if the physics and logic show that Leibniz's argument doesn't work, then good physicists who were not hostile to broadly Cartesian mental causation should have noticed, whereas if world-class physicists were unimpressed by Leibniz's argument in the 18th century, then it is not surprising that contemporary physics should cast doubt on the argument. These complementary claims might appeal differentially to different audiences. It is also noteworthy that interactionist dualist E. J. Lowe thought that the conditionality view was unexemplified in the 17th and 18th centuries [Lowe, 2003]; evidently even those with incentive to know this history might not be familiar with it.

Readers with a bent toward the history of science will notice the forthright normative stance taken, a stance perhaps in tension with the anti-Whiggish customs [Butterfield, 1965] of recent decades in that field. Several things might be said in response. First, it is admittedly not very interesting to evaluate past actors in terms of knowledge that they could not have had, but that is not done (or not usually done) here. Second, the history of science might best be served by a plurality of aims. One aim that some people have is ascertaining the growth of knowledge (in the philosophical sense involving truth and justification, or some reasonable approximations thereof). One of the main reasons that the history of science seems so worthwhile to so many people—*c.f.* the history of witchcraft or parapsychology—is the apparent tendency of science to produce justified true claims about the world (or some

[1] Another accessible introduction to conservation laws and symmetries for both particle and field physics is by Manton and Sutcliffe [Manton and Sutcliffe, 2004].

reasonable approximation thereof). A methodological stance in the history of science that prevents recognition of the apparent quality of science that makes the history of science seem important is not obviously healthy. The aim of ascertaining the growth of knowledge achievable in certain instances, though not others. Historians of mathematics, for example, seem not to be reluctant to say that someone proved this, or that that result was false, *etc.* Correctness in mathematics is more demonstrable than in say, religious liberty (one of Herbert Butterfield's key examples in identifying and critiquing the "Whig interpretation of history"). The conservation argument from Leibniz is to a large degree mathematical, so it is not unreasonable that some of the demonstrable character of mathematics might be inherited. Third, the dominance of anti-Whiggish views in the history of science has been challenged recently by Hasok Chang [Chang, 2009, Chang, 2012]. I believe that this paper's methodology would not transgress Chang's broadened approach to the history of science. Fourth, whereas Whiggish history is written from the supposedly enlightened perspective of the present, the project at hand exposes a deep tension between presently widely held views in one community (philosophy) about physics and the actual content of mathematical theorems presently known in another community (physics). There is no single contemporary perspective against which the past could be judged. Fifth, one often sees hints that early modernists' own judgments about which views were scientifically reasonable color their treatments of this objection. These judgments do not always coincide with those of experts in the relevant physics, as will appear below. Thus it is appropriate that the latter judgments also play some role in the interest of balance.

2 Conservation and Mental Causation: Descartes and Leibniz

As is well known, Descartes held that there is a conservation of the total quantity of motion in the world. This constancy he motivated by appeal to divine immutability. Descartes also held that the soul acts on the body, in particular on part of the brain. Given how Descartes is now used as a poster child for unscientific *a priori* metaphysics, it is worth recalling how scientifically progressive Descartes's views were in moving away from scholasticism, eliminating Aristotle's vegetative and animal souls [James, 2000], and embracing the mechanical philosophy. Descartes's views on mental causation and his claimed constancy of motion appear to be consistent, but unfortunately Descartes's physics was incorrect. The question arises, therefore, what would or should Descartes have said if he could have survived into the later 17th century and benefitted from the improved understanding of physics, especially the conservation of momentum.

At least according to Leibniz, Descartes held that the soul could change the direction but not the speed of matter, and therefore the soul's influence was compatible with Descartes's law of the conservation of motion (volume · speed). Leibniz seems to have been rather fond of this argument, judging by how often he made it [Leibniz, 1997, Leibniz, 1969, Leibniz, 1981, Leibniz, 1985] [Leibniz and Latta, 1898, paragraph 80, pp. 263, 264] [Mason and Parkinson, 1967, pp. 117, 118] [Schmaltz, 2008, §4.3.3]. Leibniz could therefore present Descartes's system as empirically falsified by the progress in understanding conservation laws (especially due to Huygens, Wallis and Wren [Hugens, 1669, Wallis, 1668, Wren, 1668]) made after Descartes's day. Here is how Leibniz expressed the matter in the *Theodicy*:

> 61. Moreover, two important truths on this subject have been discovered since M. Descartes' day. The first is that the quantity of absolute force which is in fact conserved is different from the quantity of movement, as I have demonstrated elsewhere. The second discovery is that the same direction is still conserved in all bodies together that are assumed as interacting, in whatever way they come into collision. If this rule had been known to M. Descartes, he would have taken the direction of bodies to be as independent of the soul as their force; and I believe that that would have led direct to the Hypothesis of Pre-established Harmony, whither these same rules have led me. For apart from the fact that the physical influence of one of these substances on the other is inexplicable, I recognized that without a complete derangement of the laws of Nature the soul could not act physically upon the body. [Leibniz, 1985, p. 156].

The first conservation law here asserted is that of *vis viva*, mv^2, the ancestor of (two times) kinetic energy, not speed $|v|$ as Descartes had held. The second discovery is that of the conservation momentum $\vec{p} = m\vec{v}$. Leibniz is quite correct that these conservation laws would not hold if souls acted on bodies, although whether the result would be a "complete derangement" or a justified and small deviation is worth considering.

There is, however, a controversy about whether Descartes actually held the view attributed to him by Leibniz. In particular, Descartes apparently never actually said what Leibniz ascribes to him [Remnant, 1979, Garber, 1983, Woolhouse, 1986]. Moreover, sometimes he seemed to deny it [Garber, 1983]. So did Descartes expect conservation to apply even with influence on bodies from souls? According to Dan Garber,

> [t]he overwhelming impression that one gets from the texts is that Descartes just was not very concerned about reconciling his interactionism with his conservation law. ... [T]here is reason to believe that Descartes may never have been committed to the position that his conservation law holds universally and may have allowed for the possibility that animate bodies lie outside the scope of the laws that govern inanimate nature. [Garber, 1983]

Garber quotes Descartes and intersperses commentary:

> "Therefore, *except for changes [in quantity of motion] which evident experience or divine revelation render certain*, and which we perceive or believe to happen without any change in the Creator, we ought not to suppose that there are any other changes in His works, lest from that we can argue for an inconstancy in Him." Here Descartes clearly admits that there *can* be violations of the conservation law, circumstances in which motion is added or taken away. The reference to divine revelation suggests that some such violations might arise from miracles. But Descartes also makes reference to violations that "evident experience ... renders certain." An obvious suggestion as to what Descartes has in mind here is the ability that the human mind has to set the human body in motion, which, as he told Arnauld, "is shown to us every day by the *most* certain and *most* evident experience." This natural reading is confirmed a few pages later in the *Principia*, where Descartes is discussing his third law of motion, a law explicitly governed by the conservation law, in which Descartes sets out the general features of his account of impact. Descartes writes: "And all of the particular causes of the changes which happen to bodies are contained in this third

> law, *at least insofar as they are corporeal*; for we are not inquiring into whether or how human or angelic minds have the force [*vis*] to move bodies.. . . " [Garber, 1983, emphasis Garber's, footnotes suppressed]

Such a reading of Descartes is not confined to Remnant and Garber among recent writers. According to Woolhouse, "... there is reason to think that the real explanation [for Descartes' apparently never worrying whether the action of mind on body involved contravention of his own law of conservation of motion] is that the law was never meant to cover all changes of motion of bodies, but only changes of motion of a body caused by the motion of another body." [Woolhouse, 1986] Schmaltz thinks Descartes would have let conservation fail for minds if asked, but probably shouldn't have on systematic grounds [Schmaltz, 2008, §4.3.3]. While the view that Leibniz ascribes to Descartes might well not have been Descartes' view (though some have continued to defend the ascription [McLaughlin, 1993]), and perhaps shouldn't have been Descartes' view, the view at least was held among some Cartesians and apparently was widely discussed [Woolhouse, 1986] [Schmaltz, 2008, pp. 172, 173].

I have nothing to contribute to this historical discussion, but I recall it because it shows that Descartes himself might well have had the view that conservation should not be expected to hold in the context of mental causation. In that case, Descartes is the first proponent of the "conditionality" view that conservation holds conditionally upon the absence of non-physical influence, and a quite distinguished one (in both philosophy and physics) at that.

3 Conservation among Newtonians: Conditionality?

There seems to have been a tendency among those regarded as Newtonians to have regarded the conservation laws as applicable (only) in the absence of mental influence. This section will consider first some key British Newtonians and then some figures often described as Newtonian on the Continent.

3.1 Isaac Newton, John Locke, and Samuel Clarke

There is not necessarily a unified position on all matters between Newton and Clarke, but they agreed at least in maintaining a strong view of mental causation with mind influencing body and *vice versa*. An important reason why is that the Newtonian tradition of forces could include mental forces [McGuire, 1968]. Newton's drafts for the *Opticks* showed his belief in mental causation: "Seeing therefore the variety of motion (wch we see) in the world is always decreasing, there is a necessity of conserving & recruiting it by active principles; such as are (the power of life & Will by which animals move their bodies with great & lasting force;)" [McGuire, 1968, pp. 169, 170, bracketed and cancelled]. Again Newton writes:

> We find in o^{r}selves a power of moving our bodies by o^r thoughts (but the laws of this power we do not know) & see y^e same power in other living creatures but how this is done & by what laws we do not know. And by this instance & that of gravity it appears that there are other laws of motion (unknown to us) than those wch arise from Vis inertiae (unknown to us) wch is enough to justify & encourage our search after them. [McGuire, 1968, p. 171, quoting a draft of Newton's *Opticks*].

Newton in fact quite frequently affirmed strong views of mental causation [Dempsey, 2006]. His view is perhaps better described as a dual-aspect monism, not substance dualism [Dempsey, 2006], or perhaps the question is premature [Stein, 2016]. But whether it is mental substance interacting with physical substance, or mental properties interacting with physical properties, or something else, there is a strong emphasis on mind-body interaction. While the Newtonians denied the conservation of *vis viva* (energy) within physics anyway, for Newton mental force evidently was an additional reason to deny that conservation law.

John Locke, an older non-technical sympathizer of Newton's, likewise took mental causation to be clearly real in experience, however little we might be able to understand it:

> Another *Idea* we have of Body, is the power of *communication of Motion by impulse*; and of our Souls, the power of *exciting of Motion by Thought*. These *Ideas*, the one of Body, the other of our Minds, every days experience clearly furnishes us with: But

> if here again we enquire how this is done, we *are equally in the dark*. For in the communication of Motion by impulse, wherein as much Motion is lost to one Body, as is got to the other, which is the ordinariest case, we can have no other conception, but of the passing of Motion out of one Body into another; which, I think, is as obscure and unconceivable, as how our Minds move or stop our Bodies by Thought; which every moment we find they do. [Locke, 1975, Book II, Ch. 23, §28] [Stein, 2016, p. 344]

Locke indeed finds the situation with mental causation perhaps clearer than that of physical causation, as well as extremely well attested by experience. It is thus clear what Locke *should* say about conservation laws in the context of mental causation, whether or not he addressed the question.

Clarke, the leading early 18th century British philosopher (Locke having died in 1704), Newton's stand-in in the Leibniz-Clarke debate, and frequent writer on topics such as God and the soul, seems to have been at least implicitly committed to the same view as Newton regarding the conservation objection. Clarke affirmed libertarian free will—the soul can make event A or event B happen, without the choice's being predetermined by the past or anything else [Clarke and Vailati, 1998]. It would be exceedingly difficult to reconcile libertarian freedom with the conservation laws, even omitting the *vis viva* conservation law that Clarke rejected [Clarke, 1727, Rey, 2018]. Clarke also took immaterial souls to be spatially located and to occupy a finite rather than point volume [Vailati, 1993, Zimmerman, 2007]; Newton held an analogous view about minds [Stein, 2016]. Whatever the merits of such views for understanding the mind itself, at least they avoid throwing up another large barrier to mind-body interaction.

Thus the Newtonian view clearly affirms strong mental causation and is at least implicitly committed to the conditionality view, that the conservation laws hold in the absence of mental causation but presumably not when the soul or mind is acting on the body. To the conservation objection against mental causation such persons in effect reply, "of course conservation does not hold in the context of mental causation; so what?"

In response one might reply that the Newtonians were mistaken on an important point and that this mistake deprives their position of contemporary interest. This was the era of the great *vis viva* controversy over the proper definition of force [Hankins, 1965, Laudan, 1968, Iltis, 1970, Iltis, 1971, Gale, Jr., 1973, Heimann, 1977, Papineau, 1977, Terrall, 2004, Smith, 2006].

The Newtonians were wrong to think that they had to deny the conservation of *vis viva*. *Vis viva* or some recognizable descendent is in fact conserved, as became clear in the 19th century with the first law of thermodynamics, the conservation of energy.

While these points are all correct, they hardly render every part of the Newtonian viewpoint obsolete or of merely historical interest. That is because already in the 17th or 18th century it should have been clear that momentum conservation was also involved (as Leibniz himself already said), the Newtonians affirmed the conservation of momentum in ordinary physical contexts, and the non-conservation of momentum would occur due to the soul's influence on the body. One should notice a contrast between mental force and gravity, which Newton mentioned together. Gravity, an active force, still satisfies conservation of momentum due to the 3rd law of motion, that of action-reaction. The 3rd law and the 2nd law together imply the conservation of momentum. But at least if one has Newton's strong view of mental causation, there is no reason even to suspect that the 3rd law of motion, the action-reaction principle, applies to the soul. So it seems plausible that Newton would have allowed that the soul violates momentum conservation. It wouldn't even make sense to suppose that the body exerts an equal and opposite force on the soul, so clearly there is no applicable Newtonian third law of motion to imply the conservation of momentum. (Admittedly it would be helpful to have more smoking guns on this point—places where Newtonians explicitly let the conservation of momentum fail.) However, it is difficult to imagine the best physicists in the world in their eras, Newton and (as will appear below) Euler, not making such an obvious inference. The interactionist position clearly implied the falsehood of the conservation of momentum, a principle that they otherwise accepted within physics. Hence they seem to have been committed to letting momentum conservation fail in the context of mental causation. Thus they should have been equally unconcerned if they were to learn, as 19th century people did, that *vis viva*/energy is also conserved in physical contexts. Thus one may take the Newtonian viewpoint seriously in most respects, even granting that *vis viva* or its descendent is in fact a conserved quantity in ordinary physical contexts. In short, it seems that Newton was at least implicitly committed to the view that conservation laws are conditional, and his failure to embrace the conservation of *vis viva* does nothing to undermine the interest of his views regarding whether conservations undermine mental causation.

3.2 Willem 's Gravesande: Conditionality?

An important early proponent of Newtonian natural philosophy (both mathematical and experimental) on the continent was Willem 's Gravesande. In the highly partisan environment of the *vis viva* controversy, 's Gravesande's work on collisions found *vis viva* more appropriate than momentum; this apostasy led to controversy with the more doctrinaire Newtonian, Clarke [Clarke, 1727, Costabel, 1964, Rey, 2018]. From a later perspective 's Gravesande presents a welcome example of someone accepting what is good from both sides and arriving at the truth.

Clearly he remained closer to the Newtonian view on mental causation than the Leibnizian one, being unmoved by Leibniz's argument. More specifically, 's Gravesande affirmed mind-to-body causation, which he described as outside our knowledge, right at the start (pp. 1, 2 of volume 1):

> DEFINITION 3.
> *Natural Phænomena, are all Situations, and Motions, of natural Bodies, not immediately depending upon the Action of an intelligent Being, and which may be observed by our Senses.*
> We don't exclude those Motions out of the Number of natural Phænomena, which are made in our Body by the Will : In these we must distinguish what depends upon the Will, from that which is to be attributed to another Cause. There is Motion made in a determinate Manner, and at certain Times, which ought to be ascribed to the Determination of the Will, and does not relate to Natural Philosophy : But the Motions proceeding from the Action of the Muscles, whose Action depends upon some other Motion, are these natural Phænomena ; but the Motion arising from the immediate Action of the Mind, and which is entirely unknown to us, is not a natural Phæenomenon. ['s Gravesande, 1742, pp. 1, 2]

Thus physiology is natural, but the mind's action the body, though real, is not part of natural philosophy and, presumably, not subject to physical laws. While this statement sounds clearly interactionist, there are indications that at times he left open the door to occasionalism [van Besouw, 2019]. Either way, spirit acts on matter and conservation laws would presumably not hold. Such views strongly suggest that 's Gravesande held, or was implicitly committed to, the conditionality view: conservation laws simply do not apply in the context of mental causation.

Given the example of Clarke's libertarianism, it is noteworthy that 's Gravesande was a determinist, not merely a theological determinist such as one might expect in traditional Dutch Reformed theology, but also a determinist regarding inference from past to future [van Besouw, 2019]. This must have been a partly psychological, as opposed to purely physical, determinism. Hence determinists will not necessarily have been of a Leibniz-Wolff stripe regarding the philosophy of mind.

3.3 Madame du Châtelet

Madame du Châtelet played an important role in bringing Newtonian ideas to France. She also wrestled with the conservation issue in relation to the mind [Rey, 2017] and seems at least to have entertained seriously the idea that conservation did not apply in the context of mental causation.

> In her correspondence with Maupertuis she exhibited great concern for the implications of the conservation of living force for free will. Stating early in 1738 that she had read much on the subject of *forces vives*, she asked whether the freedom of living beings to create motion must not be a violation of conservation. 'I believe myself free', she wrote, 'and I do not know whether the same quantity of force in the universe does not destroy freedom'. In the commencement of motion, she reasoned, is it not true that a force is produced which hitherto did not exist? If we do not have the power to produce motion, then there is no free will. But if there is free will then it is absolutely necessary that the will can initiate motion. [Iltis, 1977, footnotes suppressed]

4 Conservation of Force in Leibnizians

4.1 Christian Wolff

While Leibniz's repeated advocacy of the conservation objection might have had some effect, Christian Wolff's use of the same argument appeared in a work, *Vernünfftige Gedancken von Gott, der Welt und der Seele des Menschen, auch allen Dingen überhaupt* in 1719-20, which drew more than two dozen critical responses by 1725 [Watkins, 1995b]. Watkins gives some indication just how popular pre-established harmony became in Germany (while occasionalism had considerable influence in France):

> The main tenet of Physical Influx is that causation occurs between substances. [footnote suppressed] That is, the changes of state in a finite substance that would naturally *appear* to be caused by other finite substances [footnote suppressed] *are* caused by these other substances. While this tenet may appear self-evident today, at times during the late seventeenth and early eighteenth centuries it was the minority view. [Watkins, 1995b]

Wolff's advocacy of pre-established harmony thus had a considerable influence. The difficulty of making metaphysical sense out of physical influx was an important argument. Another influential argument, one more relevant for present purposes, was the argument from the conservation of force including *vis viva*. In Wolff's view, interactionism (physical influx) "seems to be contrary to the order of nature because of the doctrine of the conservation of forces." [Blackwell, 1961]. Unsurprisingly, his view is similar to Leibniz's on this issue. Wolff's philosophy was full of what he took to be demonstrations. While he preferred pre-established harmony, he did not demonstrate it [Blackwell, 1961, Corr, 1974]. Let us encounter Wolff's objection in his own words from the later work *Psychologia Rationalis*. A marginal summary reads: *"Influxus physici cum conservatione virium vivarum pugna."* The main text begins: *"Si anima in corpus & corpus in animam physice influit ; in toto universo non semper conservatur eadem virium vivarum quantitas."* [Wolff, 1734, vol. III §578, emphasis in the original] Wolff's claim that soul-to-body causation is inconsistent with conservation is of course correct as far as it goes: in the whole universe the quantity of living force does not remain the same if souls and bodies act on each other. Whether body-to-soul causation conflicts with conservation is not so obvious, but soul-to-body conservation does and it is difficult to see how to have one without the other.

A key question, at least for those not attracted to the Leibniz-Wolff metaphysical program, is how to show that this consequence is absurd. (Presumably today's and even 19th and 20th century proponents of this objection are not Wolffians.) The ease with which more Newtonian authors, including first-rate physicists and philosophers, maintained physical influx suggests that showing the absurdity of non-conservation of *vis viva* without Leibnizian or Wolffian metaphysics was not all that easy. This paper aims to survey the growth of physical knowledge, not the trajectory of metaphysical opinion, so distinctively Leibnizian/Wolffian metaphysical reasons, besides being unconvincing to many in the 18th century and nearly everyone today, are also irrelevant to the task at hand.

4.2 Georg Bernhard Bilfinger

Bilfinger's *De harmonia animi et corporis humani, maxime praestabilita, ex mente illustris Leibnitii, commentatio hypothetica* is a classic defense of preestablished harmony [Bilfinger, 1723]. He deploys the conservation of *vis viva* objection to physical influx [Bilfinger, 1723, III, pp. 27-29, §32, §33, §34]. Watkins reports that "Bilfinger rejects Physical Influx for many of the standard reasons (it seems to violate the law of the conservation of motion. . .)" [Watkins, 1998, p. 144].

Joachim Kintrup gives us more of these reasons:

> BILFINGER widerlegt den Influxus physicus damit, daß er unvereinbar mit den Naturgesetzen ist. Wenn man diese Argumente zusammenfaßt, so sind die Grundsätze, gegen die der Influxus physicus verstößt, folgende:
>
> a Der Satz vom zureichenden Grunde, Ursache und Wirkung entsprechen sich vollkommen.
>
> b Die Größe der Kraft ist konstant.
>
> c Der Trägheitssatz oder das Gleichförmigkeitsges.
>
> d Das Wechselwirkungsgesetz (actio = reactio).
>
> e Es besteht keine Proportionalität zwischen heterogenen Dingen.
>
> BILFINGER kann sich außerdem das vermittelnde Medium zwischen Leib und Seele nicht vorstellen, und es wurde bisher nach seiner Ansicht auch nirgends gefunden.
>
> Auch heute noch sprechen gegen den Influxus physicus die Naturgesetze, so als wichtigstes Argument das Gesetz von der Erhaltung der Energie. [Kintrup, 1974, p. 48]

It is worthwhile to comment on some of these objections. The first, the principle of sufficient reason, is certainly to be expected of a follower of Leibniz and Wolff, but it is a principle both controversial and metaphysical. Furthermore, one can imagine a proponent of physical influx embracing the principle. Clarke claims to accept the principle [Alexander, 1956], though his allowing God's will to be the sufficient reason and allowing God and humans libertarian freedom make this claim not very convincing, or at any rate not the same principle that Leibniz envisages. It is easy to imagine, however, a proponent of physical influx with a compatibilist view of divine and human freedom. Indeed 's Gravesande is a good candidate [van Besouw, 2019]. Such a person would be able to embrace the principle of sufficient reason while affirming interactionism.

Regarding the conservation laws, one should distinguish between conservation as an objection to soul-to-body causation and conservation as an objection to body-to-soul causation. Regarding the former, the Leibnizians are certainly correct that soul-to-body causation would cause conservation of energy and momentum not to hold. But it would help to work harder to show why this consequence is unacceptable. Rhetoric such as a "complete derangement of the laws of nature" [Leibniz, 1985, p. 156] seems both exaggerated and potentially question-begging. Regarding potential question-begging, one of the issues at stake is whether the usual laws of nature should be expected to hold when such a radically different and yet antecedently plausible phenomenon as mental causation, one that also varies over time and from place to place, is in view. Hence to expect conservation to hold anyway appears to be merely a denial of soul-to-body causation, which would make a rather tendentious premise in an argument against soul-to-body causation. Regarding total derangement, one might argue that minds' influences are both slight and localized in brains and hence not a very serious derangement. With the rise of local conservation laws in continuous physics (of which Euler gave the first example [Euler, 1757], with the program complete finally in the 1910s with field theories of gravity [Born, 1914, Nordström, 1914, Einstein, 1914, Kastrup, 1987, Pitts, 2016]), one could further respond that conservation laws hold point-by-point rather than globally in the absence of soul-to-body causation, so conservation will still hold point-by-point everywhere and always except for the rather small spatio-temporal regions in which souls act—a region of vanishing proportion to the universe. Hence Leibniz, Wolff and Bilfinger are right that soul-to-body causation is incompatible with conservation laws, but they haven't done enough to convince those of different metaphysical persuasions why the latter group shouldn't simply bite the bullet. Considering that the Leibnizians are on the offensive dialectically, and that soul-to-body causation is at least *prima facie* one of the most well-confirmed empirical facts available to the human race, they have a duty not to beg the question. So this objection is not powerful.

Bilfinger also takes conservation as a reason to doubt *body-to-soul* causation [Kintrup, 1974, pp. 22, 47] [Bilfinger, 1723, p. 28 §32]. While he elsewhere he of course (correctly) criticizes Descartes's quantity of motion in favor of Leibniz's *vis viva*, the point applies equally well: if body-to-soul conservation changes the amount of Cartesian motion in the world, it changes the amount of Leibnizian *vis viva* also. One thing that seems unclear is whether body-to-soul influence really must change such quantities as motion, *vis viva*, energy, momentum, or the like. (The conditionality response implies that failure of conservation here might not be unacceptable if it occurs.) Even if one takes body-to-soul causation literally, while it is unclear how physical objects might affect immaterial substances (in the vicinity of a Princess Elisabeth or Gassendi metaphysical objection to Descartes), it still isn't altogether clear why, if somehow this is possible, it should cost physical objects any *vis viva*, momentum, or motion. It also isn't clear why body-to-soul causation has to be taken so literally. If I stub my toe on a rock, perhaps my soul 'scans' the part of my brain connected to my foot, detects damage, and hence feels pain, without any metaphysical causal juice flowing from my foot to my soul. (Lewisian counterfactual dependence might do the job nicely.) While scanning sounds anachronistic for the 1720s, the extramission theory of vision goes back to the ancient Greeks and provides a possible conceptual precedent. Watkins discusses in detail what 18th century interactionists actually did say in defense of their position [Watkins, 1995a, Watkins, 1998].

Continuing with the objections that Kintrup isolates in Bilfinger, I suggest that the principle of inertia doesn't seem to have any clear relevance to the question of interactionism. Newton's first and second laws of motion are quite compatible with interactionism. Newton's third law is certainly relevant, though the form of relevance is contested. Bilfinger evidently finds it disagreeable that the third law (action-reaction) cannot apply to soul-body interaction. On the other hand, it is hard to see why someone not committed to Leibnizian metaphysics would even entertain the idea that the third law would apply to soul-body interaction. Mind-body interaction is motivated, after all, on daily experience, not on devising a theory of the mind on the model of the body. When I stub my toe and feel pain (apparent body-to-mind causation) or decide to raise my arm and it goes up (apparent mind-to-body causation), the idea of an equal and opposite reaction is entirely absent. It is not difficult to notice that the failure of the third law will lead to the non-conservation of momentum. But such a result seems like an acceptable consequence: the effect, if real, is small, localized, and confined to out-of-the-way places, namely brains. Nowadays one could add, in light of local field theories, that such momentum non-conservation occurs only in brains, while momentum is conserved point-by-point everywhere else in the universe, so only a small part of a presumably infinite universe suffers slight non-conservation in some out-of-the-way places. Such a result is hardly the death of science. That is especially true if strong views of mental causation are perhaps required for doing science, as has been argued [Swinburne, 2019].

The lack of proportion between soul and body does seem to pose some genuine questions. In particular, it seems to follow that there is no built-in exchange rate between pleasures, pains, willings, *etc.* on the one hand, and Joules of work or the like on the other. One cannot know *a priori* how much energy one imparts to a ball as a result of undertaking to throw a ball, or how much pain one will feel in stubbing one's toe at a particular speed. This lack of proportion will have consequences for anyone attempting to engineer an interacting soul-body composite being: many choices will need to be made. Descartes may have had lack of proportion in mind here:

> A sword strikes our body and cuts it; but the ensuing pain is completely different from the local motion of the sword or of the body that is cut [Descartes, 1985, Principles of Philosophy IV.197, 321; p. 284]

The distinction between primary and secondary qualities [Allen, 2008] attests to the lack of proportion between the mental and the physical. Locke indeed explicitly portrays the divine engineer as having made certain choices:

> Let us suppose at present, that the different Motions and Figures, Bulk, and Number of such Particles, affecting the several Organs of our Senses, produce in us those different Sensations, which we have from the Colours and Smells of Bodies, *v.g.* that a Violet, by the impulse of such insensible particles of matter of peculiar figures, and bulks, and in different degrees and modifications of their Motions, causes the *Ideas* of the blue Colour, and sweet

> Scent of that Flower to be produced in our Minds. It being no more impossible, to conceive, that God should annex such *Ideas* to such Motions, with which they have no similitude; than that he should annex the *Idea* of Pain to the motion of a piece of Steel dividing our Flesh, with which that *Idea* hath no resemblance. [Locke, 1975, II.viii.13 lines 23-35, pp. 136-137]

Thus the relation can only be that God has established the connections.[2] If God has done this by engineering human and any other soul-body composite beings with the appropriate causal powers, then such a view will be an interactionist view, not an occasionalist one. Doubtless an omnipotent God is up to the task of making the engineering choices required to effect a more or less arbitrary trade-off between mental and physical events. A related question is whether the soul 'know what it is doing' in order to do it—must it know how to excite a certain part of the brain in a certain way, in order to make my arm go up? While it is clear that an ordinary human agent does not consciously know how to act on the brain in order to raise his or her arm, perhaps the divine engineer solved that problem and hid it behind a more user-friendly interface. Thus it seems that interactionists did not need to solve these problems, and they aren't problems in any serious sense given the theism that was common property in the 1720s.

In short, if one imagines oneself into the mind-set of an early 18th century Newtonian like Clarke, some of the Leibnizian arguments made by Bilfinger pick out true and interesting consequences of interactionism, but few provide much if any reason to deny interactionism. In particular, the more strictly physical arguments provided little or no reason to deny interactionism, and the same holds today. On the other hand, the theistic background of the discussion clearly is also clear, so parts of the discussion are not immediately applicable today or else show why interactionist dualism is not more attractive to non-theists. Needless to say, an enormous difference exists regarding the understanding of the brain between now and 300-odd years ago, so *a posteriori* our situation might be very different indeed—but that is a very different argument.

[2]The pre-critical Kant held a perhaps stronger view, that interactions between any substances was only possible *via* God's plan. [Laywine, 1994, pp. 37, 38, 42] [Watkins, 1995b]

5 Pietists & Wolffians for Physical Influx

As Watkins's title "From Pre-established Harmony to Physical Influx: Leibniz's Reception in Eighteenth Century Germany" [Watkins, 1998] indicates, Leibniz's views came to be very influential for some time, but later came to be widely rejected.

5.1 Andreas Rüdiger, Pietist Physician

An important early player criticizing pre-established harmony during its era of dominance was Andreas Rüdiger in 1727 [Rüdiger, 1727, Watkins, 1998, Lorini, 2016]. Rüdiger was a physician (hence better qualified than most to discuss the mind and the brain) and a Pietist.

> In response to Leibniz's and Wolff's other main criticism of Physical Influx, namely that it violates the law of the conservation of motion, Rüdiger remarks that these laws describe only part of nature, namely its mechanical part, and do not describe the other forces of nature ... such as vegetative and animal forces. ... Similarly, the soul and the body are not subject to this law of nature, "for the body and the soul do not move like machines". ... [Watkins, 1998, p. 163].

Rüdiger's response appears to reject Cartesian mechanism in favor of a form of vitalism and hence seems logically stronger than necessary to address Leibniz's objection. But as a physician Rüdiger was surely entitled to reject Cartesian mechanism if it did not strike him as biologically adequate. More relevant for present purposes is that he accepts the conditionality response to the conservation objection: conservation holds in the absence of external force, but not in its presence, such as where and when minds act.

5.2 Johann Christoph Gottsched, Wolffian

Gottsched, though a Wolffian, rejected the Wolffian doctrine of pre-established harmony. He seems to be a very early example of a phenomenon that one sometimes still (or again) sees [Hart, 1988], namely, ascribing energy to the mind in more or less the same sense as physical energy. Gottsched considered

> ... whether Physical Influx violates this [conservation of motive force mv^2]. In justifying his negative answer, he uses an example of a taut bow.... Thus, Gottsched can argue by analogy that according to Physical Influx the soul can add motion to the universe or the motion of a body can cause an idea in the soul (possibly diminishing the amount of motion in the universe) without violating the 'corrected' law of conservation.... an interesting reply to one of the most important objections raised against Physical Influx... [and] on the basis of Leibnizian principles [Watkins, 1998].

In my opinion this response is less interesting than Watkins finds it, because it makes no mathematical sense unless one is prepared to ascribe mathematical properties to the mind, which seems itself highly implausible. What intensity of will to throw a bill trades off against a $1kg$ mass moving at $1m/s$? Whereas any interactionist will presumably need to say that a certain amount of mental effort produces a certain physical effect (for a given soul), interactionists such as Gottsched who claim that the conservation laws hold even given mental causation need for there to be some precise quantitative trade-off such that the total of mental effort-equivalent plus physical *vis viva* remains precisely constant, making the mental and physical commensurable. While formally claiming to uphold conservation and hence accord with natural sciences has a superficial pro-scientific flavor, this appearance is illusory.

5.3 Martin Knutzen, Wolffian-Pietist

Martin Knutzen does not easily fit the Wolffian *vs.* Pietist dichotomy. While he is sometimes called a Wolffian, he was an orthodox Christian (not just professedly like Wolff [Saine, 1987]). Such classification, fortunately, is not crucial, so I solve the problem through hyphenation. Nowadays Knutzen is remembered primarily as a teacher of Kant. His attempt to defend physical influx on Wolffian grounds is striking, though it has been criticized [van Biema, 1908]. More relevant for present purposes is his treatment of the conservation objection.[3]

> Knutzen's main response to the objection that Physical Influx violates the law of the conservation of motion is to deny that

[3] Wolff's oldest philosophical opponent, G. P. Müller, already in 1722 had denied that conservation law held in the context of mind-body action. [Erdmann, 1876, p. 68]

> the law holds for mind-body interaction. He notes that the law has been proven only for elastic bodies, not for inelastic bodies, much less for the mind and the body. . . . Knutzen even provides a reason why this law should not hold for the mind. Since Leibniz derives the law of the conservation of motion from the law of inertia . . . and . . . the law of inertia does not hold for the mind. . . , there is no reason for the conservation law to hold for the mind. [Watkins, 1998, pp. 178, 179]

Thus Knutzen adopts the conditionality response, which was typical of Pietists, and which suggests a more sound understanding of physics than Gottsched displayed.

5.4 Christian August Crusius, Pietist

Crusius was another orthodox Christian who defended physical influx quite influentially. He is sometimes called a Pietist, but not of the sort that persecuted Wolff. Again Watkins can be our guide:

> The third objection Crusius considers is the traditional objection raised against both Occasionalism and Physical Influx (by Leibniz and Wolff), namely that Physical Influx would violate both the law of the conservation of motive forces and the law of the conservation of motion. Crusius's full reply is novel; he "bites the bullet" and rejects as impossible these particular laws of motion, noting that if they were true, the absurd results would follow that minds could not cause any motion and, as [Johann Peter] Reusch had noted earlier, that matter would not be able to fulfill the purpose for which God intended them [*sic*], namely to be a means for rational and free beings. [Watkins, 1998, pp. 193, 194]

Crusius's response is thus a version of the conditionality reply. Such a reply does not seem altogether novel in the larger debate if arguably Descartes, Newton, Clarke, and 's Gravesande had held it outside Germany, besides the German authors discussed above. It is, however, the response that proponents of physical influx *ought* to have made.

6 Leonhard Euler, Interactionist

Leonhard Euler's defense of interactionism, though not as systematic as one might wish a view on the mind-body problem to be, was a potent and widely read force against pre-established harmony and for interactionism [Calinger, 1976]. Euler was, of course, not primarily a philosopher. He was one of the greatest mathematicians of all time and perhaps the most prolific; his fundamental contributions to mechanics, fluids, optics, and acoustics make it natural to call him a physicist also (even if the term is anachronistic) [Calinger, 2007].

> EULER (1707–1783) was the dominating theoretical physicist of the eighteenth century. While his work is undervalued in the usual vague, historical books and attributions, the short factual history in the old *Handbuch der Physik* lists twice as many specific discoveries for EULER as for any other one physicist, earlier or later, and even at that most of his work is omitted. [Truesdell, 1960, p. 17]

The Euler-Lagrange equations in analytical mechanics have become crucial in physics. Euler's ground-breaking work on continuous media included reformulating conservation laws in general to describe place-by-place conservation, not just global conservation (for the world as a whole) [Euler, 1757]. He also write down partial differential equations for fluids without viscosity, the Euler fluid equations, which described conservation of mass and conservation of momentum. He planned a treatise on fluids based on the principle of living force until he yielded to a similar plan of Daniel Bernoulli [Darrigol and Frisch, 2008]. The law of the conservation of angular momentum owes much to Euler [Truesdell, 1964]. It is difficult to overstate Euler's contributions in mathematics and physics [Truesdell, 1972]. Though willing to use *vis viva* where it was useful, Euler reckoned that its conservation isn't generically true [Euler, 1746, Calinger, 2016]. Euler's status as the best physicist in the middle of the 18th century made his views both influential and probably as correct as any views available at the time.

As an orthodox Christian and occasionally an apologist [Euler, 1840, Euler, 1965, Arana, 1994, Breidert, 2007, Knobloch, 2010, Drozdek, 2010, Knobloch, 2018], Euler did have things to say about spirit-matter interaction. He was a staunch interactionist dualist and opponent of pre-established harmony [Euler, 1926] [Euler, 1840, I Letts. 79-115, II Letts.

1-17] and of monads [Broman, 2012]. In line with some contemporaneous scientific claims, he took the soul to act on the corpus callosum [Euler, 1840, I, Lett. 94]. He defended the Bible and the existence of evil spirits both in the *Letters to a Princess of Germany* [Euler, 1840, I Lett. 111] and in his earlier defense of the Bible against freethinkers [Euler, 1965, Knobloch, 2010]. He took the laws of mechanics to be so certain that a metaphysics of nature must be answerable to mechanics, not *vice versa* [Breidert, 2007, Calinger, 1976, Stan, 2012] as the more traditional Wolffian claim held [Euler, 1750]. Euler's reliance on the principle of inertia (lack of self-moving ability in mechanics) in application to fundamental metaphysical reality could be questioned by Wolffians, blunting his attack on pre-established harmony [Laywine, 1994, pp. 29, 30, 50]. But that is relevant only to Euler's *offensive* project against pre-established harmony; his defensive posture against the Leibniz-Wolff conservation attack on physical influx is unaffected. Euler "was very careful to exempt the object of rational psychology—the human soul—from the laws of motion." [Laywine, 1994, p. 50]

What did Euler have to say about the conservation objection to interactionism? Unfortunately no smoking gun where he explicitly addressed the question is known to me or, more significantly, to Martin Mattmüller of the Euler project. So what follows is my own opinion of what Euler probably thought. Euler obviously knew *all* and *discovered/invented* a fair amount of the relevant physics. Euler was too good a physicist to think interactionism and conservation were compatible. Neglecting gravity, Euler's equations implied *local* momentum conservation, with 3 equations per spatial point [Euler, 1757], not 3 for the whole universe. Given Euler's robust view of mental causation, including libertarian freedom, it seems undeniable that Euler would have held Newton's 3rd law likely to fail in mind-body interaction and thus would have simply accepted momentum non-conservation in line with the conditionality response. In any case Euler cannot have failed to encounter the conservation objection and evidently was quite unmoved by it, so his mere example as an interactionist, a critic of pre-established harmony, and the best physicist in the world presumably had some effect, whether or not he addressed the objection explicitly. While Euler's views on the conservation of *vis viva* seem ambivalent, the same answer would work perfectly well in case of full acceptance of that conservation law as well.

7 Later 18th Century: Interactionism Reascendant

In the later 18th century there was a return to broadly Cartesian interactionism (physical influx) [Watkins, 1995b]. (This included the pre-critical Kant.) Joseph Priestly mentioned this fact with disapproval:

> Neither of these hypotheses [occasionalism or pre-established harmony] having given lasting satisfaction, the defenders of the modern doctrine of immateriality have generally contented themselves with supposing that there is some *unknown real influence* between the soul and the body, but that the connection is a mystery to us. And this is not the first absurdity, and impossibility, that has found a convenient shelter under that term. [Priestly, 1777, p. 64]

Earlier Priestly speaks of his own views as having previously been standard for his day:

> Like the generality of christians [*sic*] in the present age, I had always taken it for granted, that man had a soul distinct from his body, though with many modern divines, I supposed it to be incapable of exerting any of its faculties, independently upon the body ; and I believed this soul to be a substance so intirely distinct from, matter, as to have no property in common with it. Of this several traces may be found in my *Institutes of Natural and Revealed Religion*, and probably in some of my other writings. [Priestly, 1777, p. xi]

Why for present purposes is the 18th century, especially 18th century Germany, so interesting? There are a number of factors. First, there was less of a split between philosophy and physics (natural philosophy) in that era, so that many or most people who were experts in one of them would be at least interested in and tolerably informed about the other. Second, the debate over theories of the relation of the mind and the body was extremely important in early 18th century Germany [Watkins, 1995b]. Thus the participants in the debate were both numerous and in many cases distinguished. Third, contemporary analytic philosophy of mind is very poorly informed about this history, despite the continued use of Leibniz's argument. Indeed analytic philosophy of mind rarely recalls much of anything between Leibniz's *Monadology* and the 1910s, such as the fact that interactionism fought back from being at times a minority view in France and Germany to regain dominant status. Indeed E. J. Lowe thought conditionality response was unexemplified in 17th-18th centuries [Lowe, 2003]. But as has appeared above, the view was held by (perhaps) Descartes, (likely) Newton and Clarke, Rüdiger, Knutzen, Crusius, and (likely) Euler, among others. This is an extremely powerful team. Indeed when interactionism fought back from minority status at times to become the majority view once more, the bulk of the authors involved seem to have held to the conditionality response. Fourth, the philosophy of mind literature also has not advanced much in its grasp of *relevant* physics. While the 19th century saw the revival of the conservation of *vis viva*/energy, and this revival seems to have been the *occasion* for a revival of Leibniz's objection, it is difficult to find a *justification* for the revival of the objection. The problem is that there was never any doubt in physics about the conservation of momentum; if it was reasonable to make an exception to the conservation of momentum due to mental causation, then it was no less reasonable to make an exception to the conservation of energy as well. Thus the 18th century (especially German) debate covered most relevant issues about as well as, or better than, the subsequent discussions did or have.

The fact that physical influx recovered as the dominant view in the later 18th century indicates that the conservation objection ceased to be regarded as decisive. To what degree this shift reflects the rejection of Leibniz's conservation of *vis viva* in ordinary physics (apart from the mind-body problem) would repay further study. This was the era of theories of caloric, the heat fluid, a theory that obviously had to perish before the conservation of *vis viva* could reappear as the first law of thermodynamics. If the Leibnizian conservation objection ceased to have much force simply because of the rejection of the conservation of *vis viva*, then this shift shows how poorly the physics was understood by those writing on the philosophy of mind. That is because physical influx was also contrary to the conservation of momentum, a conservation law older than, no less fundamental than and, during the 18th and early 19th centuries, more secure than the conservation of *vis viva*/energy. But if on the other hand there was an increased recognition that the hypothesis of physical influx simply deprived one of any reason to think that the conservation of momentum was (exactly) true (especially in the brain), then the rejection of the conservation objection would seem to represent an improved understanding of the basis for conservation and hence an instance of the growth of physical knowledge. Such a form of growth of scientific knowledge of course tends to conflict with the idea that the objection itself manifests growth in physical knowledge.

Analogous questions apply to the 19th century when, following the revival of the conservation of *vis viva*/energy and its coronation as the first law of thermodynamics, the conservation objection to interactionism resurfaced. Insofar as the argument went like this: (Energy is conserved, interactionism entails non-conservation of energy, therefore interactionism is false), this revived objection does not represent a growth in physical knowledge. It might, of course, represent a sincere but ill-informed effort to submit to physics without understanding it. But if one strips away that mistake, what remains is a growth of materialist philosophy or perhaps some other doctrines hostile to spirit-matter interaction.

In the 19th century, one must distinguish between the understanding of mathematicians doing analytical mechanics and the understanding of philosophers (and even some physicists!). Mathematicians had the roots of an understanding that energy/*vis viva* is conserved assuming the uniformity of nature in time [Lagrange, 1997, pp. 233, 234] [Lagrange, 1811, p. 318] and momentum is conserved assuming the uniformity of nature across space [Hamilton, 1834, Jacobi, 1996]. Such derivations from variational principles in physics became widely accepted in physics (not just mathematics) during the 1910s-20s. In that same era, Noether's synthesis of derivations from symmetries to conservation laws and a converse theorem appeared [Noether, 1918, Brading, 2001, Brown and Holland, 2004, Kosmann-Schwarzbach, 2011]: symmetry $\leftrightarrow$ conservation. This work consolidated progress in the relation between local field theories of gravity (such as Nordström's and Einstein's) and conservation laws, removing the last example of action-at-a-distance, gravity, and making *local* conservation laws the norm. Perhaps ironically, in those same decades quantum physics arose and showed that 'classical' physics, based on variational principles, is not the last word. Quantum physics, however, either tells basically the same story about symmetries and conservation laws—witness how quantum field theory books frequently start with Noether's theorem—or perhaps is slightly *looser* regarding conservation. Thus while a great deal in physics has happened since Euler's day, a fair amount of which is permanent progress, little or none of it tends to strengthen the conservation objection, and some of that progress might even undermine the objection. That is despite the fact that the later 19th century witnessed a revival of Leibniz's objection among philosophers—a revival which partly reflects the growth of naturalistic research programs (such as Helmholtz's) and partly reflects philosophers' efforts to respect physics while treating conservation laws as a black box based on authority rather than as inferences from symmetries. Thus the revival of Leibniz's objection is certainly professionally excusable, but it owes rather little to the growth of scientific knowledge.

The converse symmetry-conservation (Noether's first theorem's converse), if anything, weakens the conservation objection because it becomes all the clearer that the objector needs and yet lacks a reason to think that conservation holds that has some claim on the interactionist. Now symmetry (the uniformity of nature, that is the denial of interactionism) and conservation are logically equivalent. The conditionality response is what the interactionist *ought* to say, though it does not work so well regarding General Relativity [Pitts, 2019b]. Empirical studies of the brain, on the other hand, certainly do have a claim on the interactionist's acceptance. Such studies are, however, a quite different argument from Leibniz's, and probably are not best framed in terms of conservation laws anyway.

It is worthwhile to recall some perspective from Jeremy Butterfield:

> This argument [from conservation laws against interactionism] is flawed, for two reasons. The first reason is obvious: who knows how small, or in some other way hard to measure, these energy gains or losses in brains might be? Agreed, this reason is weak: clearly, the onus is on the interactionist to argue that they could be small, and indeed are likely to be small. But the second reason is more interesting, and returns us to the danger of assuming that physics is cumulative. Namely, the principle of the conservation of energy is not sacrosanct. The principle was formulated only in the mid-nineteenth century; and although no violations have been established hitherto, it has been seriously questioned on several occasions. It was questioned twice at the inception of quantum theory (namely, the Bohr-Kramers-Slater theory, and the discovery of the neutrino). And, furthermore, it is not obeyed by a current relevant proposal ... [spontaneous collapse] for solving quantum theory's measurement problem.
>
> In short, physicalists need to be wary of bad reasons to think physicalism is true, arising from naivety about physics. [Butterfield, 1997, pp. 146, 147]

What is involved in respecting science? Is it believing one's secondary school chemistry textbook, or believing Noether's first theorem and its converse [Ladyman et al., 2007, p. 24]? The latter is of course more difficult because it requires encountering much more advanced material. One should also distinguish among the sciences: physics doesn't have much of anything positive to say about Leibniz's objection (though General Relativity novelly implies a related objection that isn't so obviously question-begging [Pitts, 2019b]), but neuroscience, which studies the relevant system (the brain), can provide good reasons to doubt interactionism, and has made considerable progress in that regard. Such progress is thus entirely *a posteriori* and empirical. Perhaps neuroscience is finally providing the justification for which physics has long been unjustifiably invoked.

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