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The nature of the physical and the meaning of physicalism

(La naturaleza de lo físico y el significado del fisicalismo)

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ABSTRACT: I provide an account of the physical appropriate to the task of the physicalist while remaining faithful to the usage of "physical" natural to physicists. Physicalism is the thesis that everything in the world is physical, or reducible to the physical. I presuppose that some version of this position is a live epistemic possibility. The physicalist is confronted with Hempel's dilemma: that physicalism is either false or contentless. The proposed account of the physical avoids both horns and generalizes a recent proposal by Vicente (2011). My account defines physicalism as the thesis that there are no objects that cannot be described by physical quantities. A dimensional account of physical quantities is given: quantities are determined by measurement procedures.

KEYWORDS: metaphysics, quantities, physicalism, mind, dimensions

RESUMEN: *Presento una caracterización de lo físico que resulta adecuada para el fisicalismo y se mantiene fiel al uso de "físico" entre los físicos. El fisicalismo es la tesis de que todo en el mundo es físico, o reducible a lo físico. Presupongo que alguna versión de esta postura es una posibilidad epistémica abierta. El fisicalista se enfrenta al dilema de Hempel: o bien el fisicalismo es falso o bien carece de contenido. Mi propuesta evita este dilema y generaliza una contribución reciente de Vicente (2011). Mi propuesta define el fisicalismo como la tesis de que no hay objetos que no puedan ser descritos por cantidades físicas. Se ofrece asimismo una caracterización dimensional de las cantidades físicas: son cantidades determinadas por procedimientos de medida.*

PALABRAS CLAVE: metafísica, cantidades, fisicalismo, mente, dimensiones

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1. Introduction

Physicalism is the thesis that everything in the world is physical. I presuppose that some version of this position is a live epistemic possibility. A challenge for physicalism is the difficulty of specifying "the physical" such that it is distinguished from "the mental" in a satisfactory manner. Hempel's dilemma provides an argument that the physical cannot be defined in terms of past scientific theories, which are false, or current scientific theories, which induction suggests are false. On the other hand "the physical" cannot be defined in terms of some postulated final theory, since that is so uninformative as to not exclude the mental, a necessary condition for an articulation of physicalism.

The purpose of this paper is to provide a criterion for some thing's being physical that avoids the horns of falsity and triviality. I also aim to draw this problem out of its native environment in the philosophy of mind and into the philosophy of physics. A definition of the physical must be extensionally adequate to the sorts of usages of "physical" natural to physicists.

First, in section 2, the puzzle facing the physicalist is described and two proposed solutions considered. The *via negativa* strategy is rejected on multiple grounds, particularly on the grounds that it begs the question against the monist and it fails to provide any *positive* conception of the physical, relying on a contrast with the mental. A recent, positive proposal by Vicente (2011) is considered but is found to lack the generality necessary for extensionally adequacy. My solution takes a more general view of the physical. The criterion established in section 3 is that a physical object is whatever can be described by a physical quantity. Section 4 then explicates the concept of a physical quantity in non-circular terms: physical quantities are properties with a particular dimensional structure, obeying certain invariance rules. Then, in section 5, I show how this criterion solves the motivating problem in the philosophy of mind: providing a statement of physicalism that does not fall to a trilemma of being false, trivial, or question-begging. Further tests of my criterion include the proper classification of non-fundamental, but physical objects, and purely mathematical objects. Two supposed problems are then addressed. The first is that my definition is circular, relying on some implicit understanding of "object" such that it is apt to quantitative description, i.e. that it is physical. Finally, in section 6, I attempt to flesh out the distinction between the physical and the mathematical by way of a provisional explanation of the quantitative nature of physics. This depends on making clear the relation between physical and mathematical *structure*. This clarification suggests a solution to the problem of mathematics' "unreasonable" effectiveness in physics.

As indicated above, my aim here is to develop a theoretical specification of physicalism. That is to say, the "reduction" to the physical with which I am concerned here is not of the sort that excludes metaphysical anti-reductivists.[1] This reduction need not imply a metaphysical reduction of the sort that would eliminate tables, chairs, molecules, and so on. What is important is that there is a *theoretical* reduction to the physical. Perhaps the physical book of the world includes non-fundamental entities; I leave the issue of whether a theoretical reduction implies a metaphysical reduction to future metaphysicians. Physicalism,

[1] Weakly emergent phenomena that appear in "non-reductive physicalism" (as described in Wilson, 2010) count as "reduced" in my sense.

as I take it here, is the position that there is a grand *unified* "theory of everything" of a certain sort, that is waiting to be discovered. I can make this more precise by using van Riel's (2022, p. 888) physicalism schema:

(Physicalism Schema) For every x there is some y, such that ($Fx \rightarrow [Rxy \wedge y \textit{ is physical}]$)

In the case of physicalism regarding the mental, x is the supposed mental entity and y is its physical basis or correlate. Reductionists might put in as R, "is identical to" or "is grounded in", while non-reductionists may hold the relevant relation to be "supervenes on". The F condition on x's being physical is a constraint on the physicalist ontology, van Riel suggests "is a concrete spatiotemporal object" or "is a property of a spatiotemporal object" as candidate properties for the schema. My proposal here is a version of the representationalist physicalism described by van Riel (and inspired by Hempel, 1969).[2] My proposal can be made to fit the schema in this way: every object has a description in terms of physical quantities. Much of the work to come is in unpacking a non-circular account of "physical quantity".

2. *A Puzzle Regarding Physicalism and Existent Responses*

Any partisan in a philosophical dispute is responsible for specifying their own position. It has long been noted in the philosophy of mind literature that the physicalist has a difficulty in pronouncing physicalism: Hempel's dilemma.[3] It is instructive to keep in mind the original context of this dilemma: Hempel's (1980) review of Goodman (1978), which defends an analogy between phenomenalism and physicalism,[4] Hempel puts Goodman's work in contact with the work of Neurath. A major difference between the two is that Goodman rejects Neurath's reduction of all empirical statements to a language of physics. Hempel extends the case against Neurath's reductionism by raising a problem for any such reductionist physicalism:

> I would add that the physicalistic claim that the language of physics can serve as a unitary language of science is inherently obscure: The language of *what* physics is meant? Surely not that of,

[2] A notable aspect of the representational physicalism that is developed by van Riel (2022) is that it is hyper-intensional. While I do not wish to say anything against this, nothing particular to my charaterization of physicalism hangs on it.

[3] Melnyk (1997) names the dilemma for Hempel. There is also a discussion of what is called Stoljar's dilemma. I will not discuss this explicitly, but, as the account of of physicalism to which it applies is theory bound, his dilemma *prima facie* does not apply to my account of the physical which is explicitly independent of actual physical theories. See Stoljar (2010) for the dilemma and Fiorese (2016) for a discussion of Stoljar's dilemma and a defense of the *via negativa* strategy in response (discussed below).

[4] "One of the most important themes in Goodman's book is that there is no privileged basis. Reducing sense data to physical objects or events is an admissible research program for Goodman. As research programs, there is nothing wrong with either physicalism or phenomenalism; as dogmatic monisms there is everything wrong with both of them... Goodman's assumption that physicalism and phenomenalism are *analogous* would be disputed by many philosophers." (Putnam, 1979, p. 603)

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> say, 18th century physics: for it contains terms like 'caloric fluid', whose use is governed by theoretical assumptions now thought false. Nor can the language of contemporary physics claim the role of unitary language, since it will no doubt undergo further changes too. (1980, pp. 194-195)

The resulting dilemma is this: either physicalism is false or else it is contentless. The first horn follows from the fact that past physical theories have been found to be false, so those theories cannot provide a basis for a successful physicalism. Neither can our current theories, which we have reason to believe are false, e.g. the pessimistic induction. The second horn follows from the pessimistic induction; we can only specify physicalism in a functionalist way: all there *is* is whatever the final, and so correct, physical theory commits to. This trivializes physicalism and fails to even exclude what we currently think of as canonical non-physical entities, like spirits, as they may show up in the final physical theory after all. This at least makes this specification of physicalism useless for us now—and physicalists likely do not want to postpone philosophy of mind to the arrival of the actual theory of everything.

In the face of this dilemma some have attempted to provide a characterization of the physical by contrasting it with the mental, in the theological fashion of *via negativa*.[5] Alternatively, Vicente's (2011) proposal, that physical objects obey conservation laws and have force-mediated interactions, is a positive characterization of the physical. As my interest is primarily in the nature of the physical *simpliciter* and not merely in the context of debate in the philosophy of mind, I will only briefly discuss the *via negativa* strategy and focus on Vicente's proposal which serves as a starting point for my own.[6]

In brief, the *via negativa* strategy holds as a necessary condition for physicality that an object is non-mental, perhaps particularly at the fundamental level.[7] Criticisms include that it fails to justify the causal closure argument for physicalism,[8] that it is question begging against the non-dualist,[9] and that it fails to account for other contrast classes for the physical (e.g. the chemical, the biological, the mathematical).

This last objection motivates both Vicente's account and my own. While Vicente raises the question of contrasting physics with other (broadly "materialist") sciences, I am

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5 There are other strategies, for surveys see Tiehen (2018) and Ney (2008a).

6 I also set aside views that attempt to recast physicalism as a stance or a methodology as opposed to a specific thesis (e.g. Dove, 2018; Ney, 2008b). I am sympathetic to such attempts and one might view my task here as complementary to them. In some sense, the physicalistic stance or approach to comprehending nature is prior to the content thereby entailed; my aim here is to explicate what the stable aim of physics has been since at least Galileo.

7 See Wilson (2006) for a formulation of the *via negativa* strategy as a fundamentality thesis.

8 See Judisch (2008). Dowell (2006) also criticizes this aspect of Wilson but retains the conception of physicalism as a fundamentality thesis.

9 I take this objection to be self-evident—a monist or idealist may very well *identify* the physical and the mental, so one ought not *define* the mental out of the physical. If you do not find this convincing evaluate my positive proposal as a competing explication. Conversely, there is a problem with specifying the mental without begging the question against its being reducible to the physical. Often, both in philosophy and outside of it, mental phenomena is described in terms of a theory that seems importantly proto-physical or pre-physical (in Vicente's sense). These descriptions involve forces or drives, discrete objects like ideas or thoughts, laws of association, etc. Consider that one of the most influential and incisive models of the mind, Freud's, was a prelude to a physicalist model (see Freud, 1954).

primarily motivated by the physicist's use of the, often evaluative, adjective "physical".[10] A physicist may describe string theory as "unphysical", complaining that it does not have testable empirical predictions, or they may describe apparent faster than light travel as unphysical and explain how the image of a laser on the moon contains no information, or they may describe some theory of quantum consciousness as unphysical as it has not been properly mathematized, or they may advise a student to ignore unphysical phenomena like mirror fermions when the student learns quantum field theory. A truly satisfactory account of the nature of the physical should give some license to these usages, as well as allow physicalism to be an open option in the philosophy of mind. This I think is the first and final reason to reject any version of the *via negativa* strategy.

Rather than characterizing the physical in terms of the ontological commitment of past, present, or future scientific theories, we must find a general characterization in terms of the *form* of physics—whatever is contemporaneously considered its matter. This avoids Hempel's dilemma altogether. For Vicente, the framework for any physical theory is specifiable in terms of force mediated changes in conserved quantities (energy, momentum, and charge).[11] Given conservation laws, physical changes can be brought about only by

> forces that conserve energy, momentum, and charge in all local interactions when the closed system considered is the whole universe (non-technically I shall call them 'conservative forces'). This is the constraint that conservation laws place on any force. (Vicente, 2011, p. 408)

Vicente's locality constraint is to account for models in general relativity in which spacetime itself can act as a energy sink or source. Though the formulation of "conserved in *all* local interactions when the closed system considered is the whole universe" is of questionable felicity, we can understand this as weakening his earlier characterization of the relevant interactions as only concerning bodies, and so bodies being the loci of "physical change", is reinterpreted so as to include spacetime itself. This caveat may very well be unnecessary, as the most common understanding of general relativity is a substantivalist one, meaning that spacetime *was already* a body in the relevant sense.[12]

That said, Vicente's response to this imagined worry raises a real worry that this characterization of the physical fails to be robust—a non-local quantum mechanics surely is an epistemic possibility, to say the least. On the other hand, non-local theories, like Newton's gravitation, have been viewed as essentially incomplete and unphysical, where "unphysical" has a mechanistic requirement built into it. Troubles about non-locality and nature of a "body" set aside, there is a more general problem with Vicente's characterization of the physical: it is not general enough with respect to a full consideration of theory space. The quantities specified have indeed been used quite generally in the historical development of physics, but they have not been used universally. One example of a force free theory is Galileo's theory of motion which was kinematic (he re-

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[10] I cannot discuss the other sciences here in depth, but I bite any bullet to the effect that I subsume the ontology of all of the natural sciences in the physical, see **§5.2**.

[11] To make this plausible even in the face of our current physics we must interpret "charge" broadly to include all possible intrinsic properties of matter, e.g. color, baryon number, etc.

[12] This is what makes the hole argument such a pickle.

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jected impetus theory);[13] another more "complete" physical theory is Cartan-style Newtonian gravity in which the gravitational interaction is embedded in the structure of spacetime, removing any notion of a gravitational *force*.[14] There was the debate regarding the nature of the *vis viva*, regarding whether the conserved quantity in dynamics was proportional to velocity or its square. Future theories may introduce a different set of conserved quantities, perhaps one based on the conservation of entropy or the some quantity proportional to the cube of the velocity. Whatever one thinks of this litany of examples, I think it is clear that the set of conserved quantities which Vicente bases his characterization of the physical upon need not be unique and need not be universal across physical theories. What is needed is a more generalized account of the nature of the physical, which does not assume any of the theory-laden concepts of physics—it must be literally *meta*physical. Such an account will meet our desiderata of avoiding both horns of Hempel's dilemma and capturing the theory neutral usage of "physical" we hear from the physicist.

3. *A Criterion of Physicality*

Prior to providing my account of the nature of the physical I want to define its role in a circle of concepts which allow a testing of its correctness. Two related concepts, which are in some sense dual to one another, are *physical significance* and *physical equivalence*. Both are used frequently, but only the latter has received a significant amount of recent attention.[15] The two are complements: A physically significant quantity is such that that changes in the value of that quantity violate any physical symmetry—any standard of physical equivalence—between two systems. For example, the famous bucket argument against Leibniz's relationalism regarding spacetime shows that acceleration is a physically significant quantity which violates the purported relationalist symmetry. This shows that rotations are physically significant phenomena.

As mentioned above, "physical" is used by the physicist in a number of distinct but related ways. What unifies the usages of "physical" is that a body, theory, quantity, or an element of any other category of phenomena is capable of creating some sort of measurable effect. Aristotle, who gave physics its name as the science of nature, describes the natural as those phenomena with a principle of motion and of stationariness. Motion being understood broadly as change with respect to qualities.[16] Though Aristotle may have rejected the methods of mathematics for the description of material, physical things, I will proceed with the conception of physics we have today, inherited from Galileo: physics is the study of nature under mathematical description.[17] The purpose of this historical interlude is to lend

[13] It appears to the author that Galileo's relationship to impetus theory is quite complicated, it is enough to say that some X or other *could* have developed a purely kinematic theory of motion. Apologies to Galileo scholars in the audience.

[14] See Knox (2011, 2014).

[15] A couple recent examples: Barrett & Halvorson (2016), North (2021).

[16] This is laid out in Book II of the *Physics,* see Aristotle (1984).

[17] Stillman Drake presents this distinction between Galileo and Aristotle in the introduction of Galilei (1638/1989). It seems to me Aristotle's philosophy of mathematics is much more complicated than

genealogical support to the main idea presented here, that physics is about distinguishing and describing the changing and the unchanging. This ought to seem like a natural generalization of Vicente's characterization of physics as concerned with the conservation of particular quantities and the changes mediated by forces. Without sacrificing this newfound generality, I can now present my proposal in more precise terms.

Physicalism is the thesis that there are no objects that cannot be described by physical quantities (or functions thereof). Here I've put physicalism in terms of a thesis about *objects*, I believe there may be equivalent descriptions in terms of properties or other metaphysical categories, but I will stay with the object-oriented form for simplicity. As I've defined physicalism—and therefore the physical—in terms of "physical quantities", clearly the burden is on me to provide a non-circular and non-trivial explication of "physical quantity". We can start with the model of a quantity we get from the representational theory of measurement:[18] A basic physical quantity kind is defined as a group of homomorphisms of mappings from objects to an ordering (usually some n-tuple of real numbers). The structure of the group determines the degree of determinancy in the ordering, distinguishing the familiar hierarchy of scales: ordinal, interval, ratio.[19] For example, mass would be a ratio scale where each pair of objects has a defined ratio of their mass magnitudes. Temperature[20] is only an interval scale, so only the difference in temperature between any two bodies is defined; it is meaningless to say one object has twice the temperature of the other.

Importantly, we must add that a *physical* quantity not only is defined by such group, but also by the dimension it is associated with. Many quantity types can share a group structure; most of the quantities considered in physics, e.g. mass and volume, share a ratio scale structure, and so they must be distinguished in a more fine-grained way.[21] The association of quantities with dimensions is done on the basis of *possible* measurement, whether in practice (e.g. temperature and thermometers) or merely conceptually (e.g. some yet unconfirmed intrinsic property of particles and its signature)—a quantity dimension is defined in terms of the set of all possible measurement procedures of that quantity type.[22] This condition guarantees the difference making quality I described as physical significance earlier: if a quantity is measurable, then it has some effect on the state of the world, meaning there are

this simple contrast would imply (see Mendell, 2019), and, further, Aristotle's physics is capable of being put in mathematical terms (Rovelli, 2015).

18 The locus classicus is Krantz, Suppes, Luce, & Tversky (1971-1990). Also significant is Stevens (1946) and, more recently, Wolff (2020).

19 I ignore the nominal scale which has very little structure as it is hardly "mathematical" in the sense relevant to physics, it only admits of categorical judgments and cannot be a ground for a dynamics.

20 Considering only temperature as defined by the Celsius and Fahrenheit scales. On the existence of an "absolute" scale of temperature I remain silent. See Chang & Yi (2005).

21 This supplies a ready objection to a naive extensionalist representational theory of measurement. Consider a world in which all objects have the same density. In such a world the homomorphisms associated with mass and volume would be indistinguishable, however it seems that they ought to be distinguished (they figure differently in the laws, etc.). Therefore an extensionalist mapping to the reals in insufficient to define a quantity. See Tal (2021) for further criticism of certain interpretations of the representational theory of measurement.

22 This may remind one of the operationalism of Bridgman (1927). This is intentional. I cannot here defend a form of "sophisticated" operationalism (but see: Chang, 2017, 2019; Feest, 2005; Vessonen, 2021a, 2021b, Jalloh 2022).

some states that its measured value excludes. The quantity's value must distinguish some possibility from others; this is a necessary, but not sufficient, condition on a quantity's being measurable. Absolute velocity is thought of as an unphysical quantity precisely because it is unmeasurable,[23] since there is no absolute space of the sort that Newton grounded absolute velocities in.[24] Beyond the basic quantity types, derived quantities can be defined as functions of those basic quantities, and so they inherit the property of being "physical".

Dimensional systems in which there is a set of basic quantity dimensions and all other dimensions are derived or defined in terms of them is referred to as an "absolute" or "complete" dimensional system. For any such complete dimensional system there is a corresponding class of "coherent" unit systems in which the units of the derived quantities are defined in terms of the units of the basic quantities sans numerical coefficients—this allows for the laws to be expressed in a way invariant of changes in the basic (or "fundamental") units.[25] Ultimately, the notion of a complete dimensional system is more fundamental than that of a coherent system of units; however, a coherent system of units implies a complete dimensional system and so may be used as a terminological substitute when units are of higher salience.[26]

The analysis of "physical" as it stands thus far can be broken into three stages:[27]

(i) A physical object is any object that can be described by some set of physical quantities;[28]
(ii) A basic physical quantity is a group structure of mappings from objects to numerical representations, with each group structure being distinguished by their degree of determinancy and the physical dimension they are associated with;
(iii) Physical dimensions are specified by characteristic operations on objects that correspond to the algebraic operations available to the groups structure (e.g. ad-

[23] See Roberts (2008).

[24] This raises a noteworthy fact, which is that what quantities are in fact physical is an empirical matter. So it is an empirical matter whether utility or degree of pain is physical. This makes it clear then that, insofar as we take phenomena like this to be real, that it is an empirical matter whether or not physicalism is *true*.

[25] Note that this unit invariance condition does not correspond to any conservation law of the usual kind. This symmetry holds even if no quantities are conserved in dynamical processes.

[26] Terminology is not totally standardized. Buckingham (1914) used "complete" to refer to an equation that was expressed in terms of such a dimensional system and met a unit invariance condition. "Absolute" often has a special connotation of referring to a purely mechanical dimensional system, where electromagnetic dimensions are reducible products of powers to mass, length, and time (see Mitchell, 2017 on the Maxwellian context for the development of the dimensional calculus). For more on the significance of coherent unit systems and a general introduction to dimensional systems see Sterrett (2021).

[27] I here want to acknowledge similarity with the methodological criterion put forth by Paolini Paoletti (2017). I believe my account gives a fuller picture of the methodology of physics and this discussion is free of any seriously "metaphysical" (mereological or substantival) criteria (see also Markosian, 2000).

[28] I should note that this excludes possibilia from being physical, one cannot measure the mass of a possible horse. That is not to say that there are not possible physical objects, however. There are no physical possible objects.

> dition). Consider the operation of addition in the group structure which represents mass, this operation takes two elements of the mass group and maps them onto another element. Usually the corresponding operation on objects is the comparison of two objects with a single object, usually a standard weight, on a scale.[29]

The nature of a physical quantity, as presented, makes no reference to the mental (so it is not question begging) and it is theory neutral, without being contentless. The account avoids Hempel's dilemma by giving an abstract account of the physical which proves more general than Vicente's proposal. While I remain here neutral to the question of whether physicalism is *true*, my criterion of physicality still has to show that it does not succumb to circularity.

4. The Circularity Objection: What is a Physical Quantity?

There remains a circularity worry: I've snuck in a substantive notion of "physical" into my understanding of the measurements that constitute the basic quantity dimensions. The mathematization of phenomena is not exclusive to the physical, psychologists and social scientists alike have done this for decades (e.g. welfare, GDP, intelligence). In order to exclude such phenomena I have made it necessary that the mathematization is on the basis of basic quantity dimensions, like those given by SI. Then there is a new dilemma:

(1) If the basic quantity of e.g. length is defined in terms of operations like coincidence observations, I've committed myself to a preferred basis for physical theory. I've assumed some measurement operations are *physical* and others aren't.
(2) Otherwise, I've simply stipulated that the basic quantity dimensions are those of the SI and have failed to provide a properly general account (e.g. time may fail to be a basic quantity dimension in a theory of quantum gravity).

I cancel any implicature that my view is committed to the basic quantity dimensions of the SI being the *actual* basic quantity dimensions. My view only requires that the physical has some such basic quantities, meaning that there is a complete dimensional system—identifying the set of the basic dimensions is a matter for empirical investigation.

If I've avoided the stipulative view, (2), which falls victim to the falsity horn of Hempel's dilemma, I am left to avoid the vacuity horn apt to fell (1) in the absence of any further specification. My constraint on the set of the (theory dependent) basic quantity dimensions is not vacuous but bottoms out in empirical significance. Basic quantity dimensions correspond to a formal scale structure and a set of characteristic measurement operations. No particular set of measurement operations is fixed *a priori*; a necessary condition is that the characteristic measurement operations are "absolutely significant" (Bridgman, 1922/1931, pp. 18-22). Such operations yield measurements of relative magnitudes that are invariant under changes fundamental units (e.g. feet to meters). Delineating the condi-

[29] More serious axiomatic models of the group structure of quantities and their dimensions can be found in de Boer (1995), and Raposo (2018, 2019) and their references. Most important to philosophers may be Ellis' (1964) account of dimensions as classes of similar scales.

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tions of such an invariance is a fundamental issue for the philosophy of measurement and I will not settle it here. However, it suffices to say that the absolute significance of the basic measurement operations constitutes their objectivity and observational invariance—the structure of a coherent system of units (i.e. a complete dimensional system) guarantees that this absolute significance propagates up to measurements associated with derivative quantity dimensions.[30] We can understand the requirement of a coherent system of units for physical quantities as a constraint on the forms of the laws, a constraint that current day psychology has yet to meet (see §5.1). Given this explication of "physical quantity" a quantitative account of the physical can be given that avoids the apparent circularity of my earlier (equivalent) formulation:

> (A Quantitative Criterion of Physicality) An object is physical if and only if there exists some lawful description of it in terms of a set of dimensional quantities which are part of a dimensional system such that the basic quantity dimensions are associated with absolutely significant measurement operations.

This restatement of my criterion for the physical ought to make clear that physical objects bear quantitative properties that link them to the laws and to empirical observation. This makes the truth of physicalism an empirical question: Is the world such that there is a complete quantitative description of it?

5. *The Object Objection and the Meaning of Physicalism*

I've been at pains to ensure that my definition of the physical does not end up being in any way trivial or question begging. One may object that in my multi-step procedure I've allowed in a Trojan horse by the name of "object". I define *physical objects* as objects describable by physical (measurable) quantities. I then define quantities as group structures of maps from *objects* to mathematical structure, particularly the reals,[31] which have associated, absolutely significant measurement operations. The question then is: What are my criteria for being an *object in general*? It is clear that if this only includes physical objects my definition becomes trivial and uninformative. Instead, I can be completely ecumenical and have a Carnapian principle of tolerance: whatever is quantified over in some language or context counts as an object. Physicalism is then that for any such object, it has a counterpart in the domain of the language of physics which is describable by physical quantities. The test of my criterion of physicality, then, will be if it gets the right results (of inclusion or exclusion) in a number of cases—i.e. extensional adequacy. I discuss three notable cases below: the putatively mental, the non-fundamental, and the mathematical. My categorization will

[30] This is Bridgman's lemma, see Bridgman (1922/1931) and Berberan-Santos & Pogliani (1999) for proofs. Philosophical discussion of the role of the lemma in dimensional analysis can be found in Jalloh (2023).

[31] I am here adopting the choice of the reals as a wellworn *convention*; It may be that the physical facts do not have the same fineness of grain or precision. See Miller (2021) and Bennett & Miller (2023) for arguments that the structure of the reals may outstrip the physical facts and that this structure is used as a matter of convention, as opposed to a matter of joint-carving.

be tested by contemporary intuitions; physicalism is a thesis that has yet to be shown to be true and its meaning ought to reflect that. Classes of entities which are not yet describable by physical quantities are set for the current day physicalist as a *task*. If physicalism turns out to be true, then the exclusionary verdicts will change, either due to the elimination of the (now) excluded entities from our ontology or due to their successful physical analysis.

5.1. (Provisionally) Excluding the Mental

With regards to mental objects, for example Cartesian souls or intrinsic qualia, a satisfactory definition of the physical will leave it open whether or not they are physical objects. What needs to be excluded, is an *a priori* closing of the door.[32] If, in the course of investigation, such objects are found to describable by physical quantities, the physicalist thesis will be found to be true. The great majority of psychological phenomena do not yet yield of mathematical description. Even contemporary quantitative methods in psychology do not measure psychological phenomena in themselves but the (in a broad sense, behavioural) signs of such phenomena. The problem here is that there is no *law* to bridge the gap between the psychological experience and the behavioural data, we only have the inductive base of our own introspection and an inference by analogy to other minds. This is not meant to be an argument to the effect that a reduction is impossible or that such laws are not forthcoming, though my account leaves the (epistemic) possibility of an impossibility proof open. Indeed, there have been attempts to generalize or "reverse" dimensional analysis so as to include mental phenomena, like sensation, into a physical dimensional system.[33] If my formulation of physicalism developed here, in terms of dimensional quantities, is convincing, this research program in psychophysics should be a priority for all physicalists.

5.2. Including the Non-Fundamental

My quantitative account of the physical ought to include those non-fundamental entities which can be provided descriptions in terms of physical quantities. While this may read like a Nagelian reductionist thesis, the physical description need not supplant "higher" descriptions of chemical, biological, or manifest objects either by a reduction of sentences about them to physical sentences or by a reduction of concepts of the relevant special domain of discourse to physical concepts.[34] While a Nagelian reduction, with bridge principles connecting the concepts or sentences of the special domain to the physical, certainly would qualify these sorts of objects as physical, I include the other extreme, a Bohrian complementarity, as providing a model for including the non-fundamental in the class of the physical. Under complementarity, each higher domain of entities may have their own "native" description but they *also* each have a description in terms of physical quantities. In

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[32] I hesitatingly endorse a version of Moore's open question argument against any *a priori* form of physicalism. A somewhat weaker commitment would be that we are excluding any physicalism that holds that, as things stand, the reduction of the mental to the physical is clear and distinct. The hard problem is *hard*.

[33] Optimists include Luce (1959, 1990) and Marinov (2004, 2005); pessimists include Laming (1997).

[34] See Hempel (1969) for a discussion of the prospects of and the problems with such approaches.

this way my criterion of physicalism can be of use to the non-reductionist physicalist and the reductionist physicalist alike.

One special class of non-fundamental entities may serve to show how, in general, a quantitative physicalism can include apparently problematic non-fundamental objects: privational entities. Privational entities include holes, shadows, and omissions. Such privational objects are taken to be problematic for physicalist accounts of causation (most notably Dowe, 2000), so it will serve to strengthen the general case for my account of physicalism to see how such entities prove not be problematic under a quantitative physicalism.[35]

There is a quite developed and sophisticated metaphysical tradition of holding privational objects to be real.[36] I'll take this as given, since if such objects are for some other reason eliminated from our ontology they can serve as no challenge to the physicalist, on my quantitative conception or any other conception. The problem for physicalist conceptions of causation is that these privational objects seem to violate the basic conditions set for physical, causal processes, making them unamenable to physical analysis. For example, "pseudo-processes" like the movement of shadows or of light images can apparently break the physical laws, e.g. travel faster than the speed of light.

From at least Rothman (1960), such "pseudo-processes" were thought to be unproblematic on the basis that they are not causal or physical processes, with common criteria of exclusion being that such processes are non-continuous, do not involve the exchange of conserved processes, cannot be used to signal or otherwise transfer information, and so on.[37] Insofar as such conditions are merely constraints on the relativity principle and not physicality in general, this a perfectly acceptable response for the physicalist. However, this leads to the unfortunate result that not all physical things obey the physical laws, so I must find a condition within my account of the physical that excludes such privational objects if and only if they break the laws, but in a manner which does not assume what those laws *are*.

Let's reconsider my earlier condition of "absolute significance" on physical quantities from §4. There I explicated this condition in the manner of Bridgman: absolute significance is unit invariance. However, consideration of the violations of the light postulate by privational objects leads us to generalize the specification. Absolutely significant quantities are quantities that are observer independent, including both the unit system of the observer and their reference frame. On this somewhat broader explication of absolute significance, we find that privational objects which yield of a observer independent, and therefore, law-abiding, quantitative description may be counted as physical, while those which do not have an observe independent quantitative description are not counted as physical. This will generally include objects like shadows, while excluding things like their motions—an intuitively satisfying result. Further, while the conditions of observer independence will be constrained by the laws, they are epistemically accessible independent of knowledge of the laws—hence, this does not sneak in an undesirable theory-dependence which reopens the problem of Hempel's dilemma.

[35] See Dowe (2004) and Schaffer (2004) for a debate on whether omissions can be casual relata.

[36] See Casati & Varzi (1995) and Sorensen (2008) for comprehensive accounts of privational object metaphysics.

[37] See Dowe (2000) and Maudlin (2011) for some of these accounts and for references to more of the literature.

5.3. Excluding the Mathematical

One final test of extensional adequacy should provide my criterion of physicality with some plausibility. In the absence of a satisfactory physicalist account of the mathematical, it is incumbent upon quantity physicalism to exclude mathematical entities, like numbers. However, one may worry that my criterion does precisely the opposite of that: numbers are exactly the sorts of things that have quantitative structure, by the above definition of "quantitative". This worry is misplaced. Important to my definition above is that a physical object is an object describable by a set of *measurable quantities*. There are two points to make here. First is that even if mathematical objects were to be understood describable by quantities or as quantities in their own right, it is self-evident that we cannot *measure* them. Whether a homomorphism maps, for example, 2 to 4 or 2 to the set of reals between 0 and 0.2 makes no *observable* difference. These mathematical structures are identical in the relevant sense and any distinctions to be drawn are in no way physically significant. These "quantities" have no corresponding dimension associated with a set of absolutely significant measurement operations and are therefore excluded from the domain of physical quantities.

This exclusion raises another worry: physicists talk of "dimensionless quantites", like the fine-structure constant, α, all the time. It is a reductio of any account of quantity that it excludes such important quantities as α. The response is that such *physical* dimensionless quantities are necessarily composite; they have definitions in terms of aspects of a physical systems which can be described by relations between dimensional quantities. For instance, in Sommerfeld's initial use of α, it was an abbreviation of the factor $2\pi e^2 / c\, h$ or $e^2 / c\hbar$, defined in terms of a ratio between the unit of electric charge, the speed of light, and Planck's constant. In different contexts α is given different definitions, most notably as a spectroscopic quantity, which gave it its name as the fine-structure constant.[38] What makes dimensionless constants of interest is that they often unify several physical definitions, showing a link between disparate physical models or systems. What matters for my point here is simply that for any *physical* dimensionless quantity, there will only be such definitions in terms of dimensional quantities such that some measurement operations can be used to distinguish it from other such dimensionless quantities. This means that dimensionless quantities meet a measurability criterion that dimensionless numbers do not.

6. *Explaining the Quantitative Nature of the Physical*

In closing, I want to again address the role of the mathematical in my account of the physical. One might object to my criterion that it relies too much on a mathematical conception of physics. The worry would be that by specifying the physical as those objects which can be described with some physical quantity, I am falling into a version of Benacerraf's (1973) problem. Either I endorse some sort of Platonism and face the epistemological challenge of how we come to know some physical quantity has some structure or else be faced with some intractable version of the problem of universals because my account would be forced into some real connection of the physical with the mathematical, precluding any nominal-

[38] See Kragh (2003) on the conceptual development of the fine-structure constant.

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ist, physicalist reduction of mathematics. Let me be clear: I will not solve the problem of universals, nor will I defend or disarm Platonism here. Rather I want to consider how one might think my criterion commits the physicist to mathematical objects and will show that physical quantities are not their merely mathematical counterparts (whatever they may be). This will in part solve a different perennial problem, though I hope it is less audacious to do so: the unreasonable effectiveness of mathematics.

In 1959, Eugene Wigner raised the question of how it is that mathematical descriptions of physical laws have been so successful: He describes the situation thus:

> The miracle of the appropriateness of the language of mathematics for the formulation of the laws of physics is a wonderful gift we neither understand nor deserve. (Wigner, 1979, p. 237)

My aim here is to distinguish the physical from the mathematical and in doing so, I believe light will be shed on how it is that mathematics proves to be an effective language for describing the physical. There are two ways in which one may worry that my account of the physical requires commitment to mathematical objects: (1) a commitment to ideal mathematical structures which do not occur in the physical world but which explain physical phenomena; (2) a commitment to the existence of dimensionless quantities. (1) and (2) are in a way the same problem, or at least they have the same solution, so my focus will be on (1), while (2), insofar as it is distinct from (1), has already been fundamentally addressed in the previous section.

The primary issue, then, is how to account for the fundamental strategy of physics since at least Galileo: the use of idealized models. In the discovery and development of physical laws, with their simple forms and mathematical exactitude, we describe situations involving frictionless planes, extensionless points, and rigid bodies. Following Islami's (2017) Wignerian proposal for solving the problem of explaining the applicability of mathematics to physics,[39] my approach will rely on invariance principles. It is the invariances of physical phenomena under particular transformations that licenses the use of mathematical descriptions of their structure via natural law. This is part of what Wigner refers to this as "reversal of a trend". Where invariance principles were once derived from the laws of motion, it is now the invariance principles from which we derive the laws of nature and "test their validity".[40]

Now the fact that mathematical laws apply to idealized models is no mystery. The models are nothing more than their mathematical description, e.g. a circle is nothing but the collection of points equidistant from some center, or some equivalent description thereof (e.g. in terms of algebra). It is that these models can correctly or approximately describe real physical phenomena that is mysterious. Recall my specification of a physical object: a physical object is any object that can be described by some measurable physical quantities. These physical quantities, in turn, are group structures of mappings to mathematical structure from some operationally defined relations among bodies. The mapping between the physical structure and the mathematical structure is what legitimates the use of math-

[39] If she is right, this is also Wigner's own approach. See also Islami & Wiltsche (2020) for a phenomenological spin on the symmetry principle approach to the applicability problem.

[40] From "Invariance in Physical Theory" in Wigner (1979). Similar ideas can be found throughout the volume.

ematical descriptions—in the most basic case, numbers. The relationship between the two structures is a homomorphism, meaning that the mapping is preserved under certain symmetry transformations. That idealized models and the physical phenomena these models describe share symmetry transformations justifies the inference from application of mathematical laws to models to predictions of the behavior of the phenomena.[41] For example, that the mass is invariant under transformations of change of place justifies the use of a simple quantity description that in no place depends on location—by contrast *weight* does not have this symmetry, and so we must figure in the relative location factor r^{-2} that describes the lawful dependence of weight on relative location (with respect to other massive bodies).[42]

The question I began with then recurs, why is there not a unique relation of homomorphism rather than a group of them between the mathematical and physical structures? Are we not committed to these "physical" structures really being mathematical abstractions to begin with? Are these two structures not really *identical*? The answer to all these questions lies in the fact the mappings between the physical structures and the mathematical structures *are* many. This is a substantive fact of what these mappings correspond to in physical practice: measurement.

The centrality of measurement has already been indicated and a full account of the way in which measurement grounds the use of physical dimensions would take us far afield. The important thing for my purposes here is that the measurement procedures which distinguish quantities from one another have enough structure to delineate quantity dimensions, e.g. length, mass, duration, charge. Once these dimensions are in place, it is no mystery that their correspondence to mathematical structures are one-many; this is just the conventionality of units, a well accepted aspect of physical theory. This is only an account of how basic physical quantities relate to their mathematical representations. The significance being that we ultimately measure quantities in terms of numerical ratios of unit quantities when we wish to compare theory with experiment. Here I simply put this forward as conjecture: all complex mathematical representations of physical phenomena are grounded in the representation functions (from physical relations to mathematical structures) of basic quantity dimensions. I believe this easy enough to see in the case of physical equations which juxtapose the various relevant quantity dimensions in an algebraic manner.

7. Conclusion

I have provided a proposal for a definition of "the physical" which meets the desiderata of making physicalism coherent and viable. I have also provided a positive conception of the physical agreeable to the physicist, with the necessary degree of theoretical agnosticism to

41 This compares well with the Wignerian solution: "What *symmetries* made it possible for the laws to be formulated based on events, is what precisely makes it possible for them to be formulated mathematically." (Islami, 2017, p. 4859)

42 It is this recognition of invariances that allows for the separation of initial conditions from the laws, the initial conditions being what vary under the symmetry transformations. See Islami (2017, pp. 4851-4855) for an exposition of Wigner's argument.

avoid Hempel's dilemma. The physical is the measurable and the quantifiable. The relation of the physical to the mental is to be determined empirically, though currently there is no successful reduction of the latter to the former. Doubtless further work is needed to understand the ontological category of the physical and more generally how distinctions in "ways of being" are to captured by philosophical analysis.

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