On the Propriety of Physical Theories as a Basis for Their Semantics

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Outline

In theory, there's no difference between theory and practice. In practice, there is.

Yogi Berra

The Standard Conception

Carnap, *Introduction to Semantics* (1942, ch. B, §7, p. 22):

> *. . . to understand a sentence, to know what is asserted by it, is the same as to know under what conditions it would be true.*

for any view that founds semantic content on accuracy of prediction (truth, soundness, similarity, isomorphism. . .)

- predictive **accuracy** is a **necessary** condition for **semantic content**
- **failure** of predictive accuracy is a **sufficient** condition for **lack of semantic content**

THUS

A theory says what the world would be like if the theory were true of it, **and nothing more**.

But physical theory tells us far more about the world than that. A theory often tells us about the nature of physical systems it does not accurately represent in totality, cannot be true of.

Navier-Stokes Theory above the hydrodynamic scale

- in some states, equations of motion **fail before definitions** of pressure, temperature, *et al.*, begin to **break down**
- Navier-Stokes models **cannot be accurate**, but **still tell us much** about the state of the fluid (how to measure pressure, *e.g.*)
- standard semantics **rules out these models** because of their inaccuracy

this misses much semantic content

- when definition of quantities begin to break down, those models **not so much inaccurate** as **inappropriate**
- standard semantics: **no difference between inappropriateness and inaccuracy** in representation

but the **meanings** of "pressure", "temperature", *et al.*, **depend** on the fact that **their definitions break down** in those states, **not that** dynamical **predictions are inaccurate** well before that

No account of semantics founded on any notion grounded in accuracy can account for this distinction.

- All semantic notions of truth, soundness, similarity, isomorphism, and so on, are grounded in a theory's accuracy.
- Therefore, none of those notions can found a sufficiently rich semantics.

other problems with the semantic view

1. can't distinguish relations representing different kinds of quantities (interactive versus factitious)
2. can't distinguish necessary preconditions of applicability from predictions

The Problem with Truth

The Problem of Semantics

Kinematics and Dynamics

The Breakdown of Models

Propriety and Meaning

semantic content rests on sound articulation of experimental knowledge

Thus we must be able to construct **representations** of **actual observations** in theories

representations of **physical systems and experimental apparatus in relation to each other** as required by particular, actual experiments, **not just** representations of physical systems *simpliciter*, **in abstraction** from actual experiments

why we need to model actual experiments, not just systems

1. sometimes **observation "distorts"** the quantities measured, need model of instruments to correct (*e.g.*, stellar aberration)
2. to compute reasonable **values for imprecision and expected errors** in measurement, which depend on particular nature of instruments
3. if **theory is to guide experiment** in the construction of new tools for probing novel phenomena (Hertz's search for electromagnetic radiation)
4. if **experiment is to guide theory** in modeling practically constructed novel ways of coupling to systems (Hertz's search for electromagnetic radiation)

the fundamental problem: getting the laboratory into the theory

Howard Stein ("Was Carnap Entirely Wrong, after All?"):

> *. . . we have no language at all in which there are well-defined logical relations between a theoretical part that incorporates fundamental physics and any observational part at all—no framework for physics that includes observational terms, whether theory-laden or not. . . . I cannot think of any case in which one can honestly deduce what might honestly be called an observation. What can be done, rather, is to represent . . . "schematically," within the mathematical structure of a theoretically characterized situation, the position of a "schematic observer," and infer something about the observations such an observer would have.*

the pragmatics of the empirical application of theories

Howard Stein ("Was Carnap Entirely Wrong, after All?"):

> *Now, Carnap's scheme for philosophical analysis is admirably suited to just this situation. It is exactly the theories with a highly mathematical structure—the typical theories of physics—that lend themselves, ipso facto, to construction as Carnapian frameworks. The question of the empirical application of such a framework becomes a question of pragmatics. I do not know how, systematically, a general theory of such empirical application might be made; but at least I think the problem, in the neo-Carnapian form I have just outlined, finds a suitable locus and an intelligible formulation as a problem. . . .*

the pragmatics of the empirical application of theories

(Stein, cont.)

> *And I think it reasonably clear that* **to just the extent that we know in practice how to talk about the empirical application of specific physical theories, we can formulate what we know how to say in terms of the pragmatics of a Carnapian framework.**

The Program:

To found the semantics on comprehension of the actual pragmatics of theory application.

Propriety

Meaning accrues to the elements of a physical theory by virtue of the **propriety** of the theory for the production of sound schematic representations of physical systems

Propriety $\approx$ "the satisfaction of certain equations, the local kinematical constraints, by the values of the system's physical quantities"

propriety largely independent of, semantically prior to, accuracy

Propriety is:

- what a theory must have for it to yield **propositions whose truth-value can be** cogently **investigated**
- **not a fixation of truth conditions**, but rather the securing of the possibility to investigate **whether or how** truth-conditions **can be determined** in the first place

a theory does not possess even the capacity to be accurate or inaccurate if it does not represent phenomena with propriety

The Slogan

Meaning comes before truth.

Physical Quantities

dynamic those that can vary with time and place, while the system remains otherwise individually the same

kinematic those one assumes, for the sake of argument and investigation, remain constant as the system dynamically evolves, on pain of the system's alteration in species

Kinematical Constraints

fixed, unchanging, relations of constraint among possible values of quantities, **irrespective of state or environment**

local constrains a quantity attributable to a single state

global constrains a quantity not attributable to a single state

Equations Of Motion

determine temporal evolution of physical system, **basis for prediction**; their particular form **depends on particular state and interactions**

Example: Newton's Second Law

$$\dot{\mathbf{x}} = \mathbf{v} \qquad \textbf{versus} \qquad \dot{\mathbf{v}} = \mathbf{F}$$

theoretical status of kinematical constraints

Theories do not predict kinematical constraints; they demand them as preconditions for their applicability.

(if equations of motion fail, one may just have not taken all ambient forces into account)

local kinematical constraints are fundamental

Lots of different systems share identical equations of motion (SHOs); it is kinematical constraints that differentiate them.

- the cogency of the **representation of single states** is the necessary and sufficient condition for a **theory's being able to represent a system** as a system of its type
- satisfaction of the **local constraints guarantees** not only that all quantities are **well defined**
- but even more that they are quantities associated with **that kind of system**

Characteristic Scales

Every theory has a **characteristic scale** (spatial, temporal, energetic) past which **all quantities lose definition**.

- **different devices** measuring via same coupling **yield different results** depending on properties ignorable in good regimes
- at those scales, one **cannot formulate**, much more verify, **local kinematical constraints**

(Typically there is only one such scale—why is this?)

Navier-Stokes Theory

kinematic quantities bulk viscosity, shear viscosity, . . .

dynamic quantities mass fluid density, gross fluid velocity, distribution of shear-stress, . . .

kinematical constraints

1. symmetry of shear-stress tensor (local)
2. conservation of energy (local)
3. *etc.*

equations of motion Navier-Stokes equations

complete breakdown: symmetry of shear-stress tensor

- conditions under which shear-stress begins to lose symmetry are those where **different devices** coupling to molecular acceleration **yield different readings** (sensitivities below the characteristic scale)
- no quantity not manifesting behavior encoded in symmetry of shear-stress tensor can be **in the context of Navier-Stokes theory** shear-stress

Navier-Stokes can **give no guidance** in the construction of experimental tools for its unambiguous determination, and equations of motion **can't even be formulated**

partial breakdown: symmetry of shear-stress tensor

- as fluid approaches turbulence, equations of motion are **well formulated** but **predictively inaccurate**
- shear-stress remains symmetric—Navier-Stokes theory **still accurate for individual states**
- thus Navier-Stokes **can still guide experiment** in probing and characterizing the fluid

IF YOU'RE A TARSKIAN, NOTHING I JUST SAID MADE SENSE.

I hope it to be clear that it did make sense.

Other examples (for Q&A)

Newtonian gravitational theory anomalous precession of Mercury's perihelion

quantum theory the Ritz principle and the Lamb shift

general relativity small black holes and quantum effects

Regimes of Propriety and Adequacy

regime of impropriety not all local kinematical constraints are satisfied: theory's quantities not defined in the framework; individual states not defined; *a fortiori* the equations of motion cannot be formulated

regime of kinematical propriety all local kinematical constraints are satisfied: all quantities are well defined; individual states are well defind; some global kinematical constraints may not be satisfied; the equations of motion cannot be satisfied

regime of adequacy everything well defined and satisfied: a state of harmony and bliss in which systems and theories move together hand in hand with the equanimity of the blesséd gods

kinematical propriety and semantic content

a model in a framework's regime of kinematical propriety but not its regime of adequacy has **at least the semantic content** accruing to it in virtue of the fact that it is **an appropriate representation** of the system

predictive accuracy and semantic content

if the system crosses over into its **regime of adequacy**, the model gains **no semantic content independent** of that already having accrued to it **from its propriety**

for we must already know it is **that kind of system** to judge the prediction's accuracy in the first place

a virtue: insight into confirmation theory

- traditional confirmation theory: an observation that contradicts a theory disconfirms it
- but this is not always the epistemic situation!
- sometimes it serves only to demarcate a theory's regime of propriety

Tarskian semantics can't handle propriety

- kinematical constraints, as constant semantical content common to all models, not predicted but required by the theory, must be fixed as part of the initial interpretative stage, in which the designata of the elements of the syntax are given
- to fix the truth-values of actual propositions goes far beyond the scope of giving a standard Tarskian interpretation to a syntactical system

Aside: other problems with Tarski

Tarskian semantics, by construction, can't allow inter-model relations to contain or constrain a theory's semantic content—but the fact that an equation of motion has a well set initial-value formulation rests on such relations, and contributes much to the semantic content of a theory.

Meaning

We know the meaning of a model when we know the conditions under which it represents systems with kinematical propriety.

Relation to Truth

> To know the meaning of a theory is the same as to know under what conditions it is sensical to investigate the formulation of possible conditions of its truth, for this can be done only in so far as one already knows what systems the theory represents with propriety.

The Problem of Meaning, Again

Given a model in a framework, how does one determine its conditions of propriety?

> From a pragmatic point of view, to know those conditions is the same as to know the family of systems the model represents with propriety, which is to say, those systems the model, as a semantic element of the framework, designates.

This is the solution to our problem, stated in experimental terms.